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Gastrointestinal Surgery

Management of Complex Perioperative Complications

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We dedicate this book to our families and our colleagues, who consistently give us the inspiration to seek new knowledge. We also dedicate this book to patients everywhere who entrust us with their care.

Foreword

Every surgeon who operates has complications. The surgeon who says he never has a complication, does not operate. It is a matter of the law of averages. Virtually every surgical procedure that is performed has a certain incidence of complications. It can be as low as 1%, after an inguinal hernia repair, or as high as 45 or 50% after a pancreaticoduodenectomy. If enough of a surgical procedure is performed, a complication will result. Every experienced surgeon is aware of the statement "good judgment comes from experience, and experience comes from bad judgment." As the busy surgeon gains experience, he or she will make mistakes that will add to their experience, and result in better judgment the next time that situation is encountered.

It has been shown for many complex operative procedures in recent years that larger volume leads to better outcomes. Part of the reason is that larger volume leads to more complications, which leads to more experience, which leads to better results. The high-volume surgeon gains better knowledge of the anatomy of the procedure, understands the complications that can occur, and learns to intervene earlier, all of which lead to better management.

The list of authors in this text entitled *Gastrointestinal Surgery: Management of Complex Perioperative Complications* reads like a who's who in surgery. The fact that these superb, experienced surgeons are willing to participate in this text demonstrates that these high-volume surgeons realize that complications are inevitable, and that their high volume has lead them to manage these complications earlier. In turn, the authors are able to provide many excellent suggestions on how to intervene to manage them. It is a textbook that I predict will be imminently successful, and one that every surgeon who performs complex gastrointestinal surgeries should have in their possession. I commend the authors/editors on putting together this outstanding text.

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Preface

It's fine to celebrates success but it is more important to heed the lessons of failure.

—Bill Gates

Surgery is a wonderful profession that allows us the privilege to care for patients. As surgeons we constantly strive for technical excellence in the hopes of achieving flawless results, an uneventful postoperative course, and overall exceptional healthcare outcomes. While often associated with the celebration of many "successes," surgery also is a humbling profession punctuated by intermittent failures. Although postoperative morbidity represents one type of "failure," complications can be viewed as an opportunity to learn, grow, and identify means to improve the treatment of future patients. While some surgeons may be inclined to avoid discussing their complications, those who choose to talk, teach, and discuss their experiences, share an enormous gift. These surgeons help the clinical community find better ways to care for patients—whether it be through prevention, detection, or treatment of difficult clinical problems.

This book aims to equip clinicians who perform complex gastrointestinal surgery with the knowledge and tools to identify, manage, and hopefully avoid some of the more difficult and challenging perioperative clinical scenarios. Topics include a broad spectrum of complex gastrointestinal surgery, including upper gastrointestinal (GI), hepatopancreaticobiliary, and colorectal procedures. The book benefits from a wide range of leading surgical experts who have contributed their clinical knowledge. These "masters of surgery" not only discuss the literature on the management of complications following complex gastrointestinal surgery, but perhaps more importantly, provide their vast personal experience on how to navigate difficult intra- and postoperative clinical situations. We hope to have captured the collective "lessons learned" from these experts in their respective fields.

Ultimately, it is our hope that the knowledge found in this book will provide all busy GI surgeons with practical and relevant information regarding how to better avoid, recognize, and treat complications. It is only in sharing our failures that we can better ensure the success of future patients.

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Part I
Esophageal Surgery

Tracheo-Esophageal Fistula

1

Douglas J. Mathisen and Ashok Muniappan

Overview

A benign acquired tracheoesophageal fistula (TEF) most commonly develops after prolonged intubation, esophageal surgery, or laryngeal surgery [1]. The complication may not be immediately apparent, and a delay in diagnosis is associated with significant morbidity and the risk of mortality. Given the relatively low incidence of this complication, most surgeons have little or no experience managing TEF, which makes choosing amongst the disparate therapies difficult. In recent decades, definitive management of TEF has been described, which requires surgical division of the fistula, repair of the airway and esophageal defects, and not infrequently resection and reconstruction of the airway [2, 3]. The primary goals of management are elimination of airway soilage by esophageal contents, restoration of swallowing and oral alimentation, and freedom from airway appliances such as a tracheostomy.

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Etiology

Postintubation tracheoesophageal fistula (PITEF) develops as a consequence of pressure induced ischemic necrosis of the membranous wall of the trachea and the adjacent esophagus. Historically, high-pressure and low-volume endotracheal cuffs frequently caused tracheal stenosis and occasionally TEF. Although modern low-pressure high-volume cuffs are less prone to causing such injury, over-inflation of a cuff and prolonged intubation occasionally induces a TEF. An over-inflated cuff pressing against an indwelling nasogastric tube also predisposes to the fistula development. In the most contemporary reports on surgical management of TEF, PITEF accounts for 40–70 % of patients [1, 4].

TEF is a relatively rare complication following esophagectomy. While the exact incidence of postesophagectomy TEF (PETEF) is unknown, several reports (Table 1.1) focusing on this complication found its incidence to be between 0.1 and 3 % [5–11]. PETEF arises exclusively after esophageal reconstruction in the posterior mediastinum, and may occur with either a cervical or intra-thoracic anastomosis. The pathogenesis of PETEF is variable, but most commonly is related to anastomotic leakage leading to erosion into the trachea or bronchus. Traumatic disruption or ischemia due to devascularization of the tracheobronchial tree during esophagectomy, which occurs in about 1 % of cases, may also predispose to TEF [7]. An aggressive and radical lymphadenectomy as well as prior radiotherapy

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Table 1.1 Incidence of postesophagectomy tracheoesophageal fistula

Author (reference)	Country	Incidence	Percentage
Iannettoni [6]	USA	1/856	0.12
Bartels [7]	Germany	4/501	0.80
Buskens [5]	Netherlands	1/383	0.26
Maruyama [8]	Japan	2/305	0.66
Yasuda [9]	Japan	9/603	1.49
Schweigert [10]	Germany	7/222	3.15
Kuwabara [11]	Japan	9/475	1.89
	Total	33/3345	0.99

contribute to airway ischemia [8]. While gastric conduit ischemia and necrosis most commonly leads to mediastinal sepsis, it may also promote formation of a TEF. A late presentation of PETEF may be due to an ulcer in the gastric conduit or staple line erosion into the airway, and may occur decades after esophagectomy [12, 13].

Clinical Presentation

There are a number of signs and symptoms of TEF which are related to the size, location, and stage of the TEF. Early and small fistulas may simply present with cough after oral ingestion, also known as Ono's sign. Persistent airway soilage typically leads to pneumonia, and signs of sepsis and respiratory insufficiency follow. In PETEF developing after an anastomotic leak, there may be accompanying mediastinal sepsis, and patients are usually critically ill with multiorgan dysfunction.

If a TEF develops in a mechanically ventilated patient, there is usually a sudden increase in airway secretions, which represents contamination with saliva or gastric contents. It may be difficult to maintain a seal with the endotracheal tube's cuff, and in extreme cases, ventilation may become impossible if the tip of the tube migrates into the fistula. Positive pressure ventilation may lead to air leakage into the esophagus or gastric conduit and leads to abdominal distention or air escaping the pharynx.

Diagnosis

A chest x-ray may find a dilated esophagus or gastric conduit secondary to air leakage through the TEF. Computed tomography (CT) delineates the fistula with good detail in large or giant TEFs, which are defined as a fistula involving the entire width of the membranous wall. The CT may also identify anastomotic or conduit disruption after esophagectomy and also accurately reveals mediastinal and pleural collections.

Contrast esophagography has a role in milder presentations of TEF, when patients are able to participate in a swallow study. Water soluble contrast agents are strictly avoided as they can severely exacerbate pulmonary injury. Barium is typically used, and contrast outlining the trachea or bronchus is seen. An experienced radiologist is able to localize the level of fistula with respect to the airway and the esophagus (or neo-esophagus).

Endoscopic inspection of the tracheobronchial tree and esophagus further elucidate the location and nature of the fistula. While a small fistula may be difficult to appreciate in the folded mucosa of the esophagus or gastric conduit at esophagoscopy, it is usually apparent at bronchoscopy. In mechanically ventilated patients, the orotracheal or tracheostomy tube may need to be withdrawn to reveal the fistula. Esophagoscopy is useful to assess the integrity of an esophagogastric anastomosis and viability of a gastric conduit in patients with PETEF.

Management

Effective management of TEF requires a combination of conservative, endoscopic, and operative measures. The therapies chosen are predicated on the patient's presentation and condition.

Conservative Management

When a patient presents early after a small TEF develops, the only complaint may be a cough with oral ingestion. Even before the diagnosis is confirmed, the patient is made strict nil per os. The patient is instructed to stay upright at all times, which minimizes reflux and ensures drainage of the gastric conduit in patients presenting after esophagectomy. When there are signs of tracheobronchitis or early pneumonia there is a low threshold to start empiric antibiotic therapy.

A more severe presentation of TEF is the patient with advanced pneumonia and frank respiratory failure. Mechanical ventilation is unavoidable in this situation. It is important to position endotracheal tubes with the cuff inflated beyond the location of the tracheal fistula, if possible. Bronchoscopic guidance of ortracheal and tracheostomy tubes is invaluable in these circumstances. Imprecise positioning can lead to exacerbation of the fistula, if the balloon is inflated adjacent to or within the fistula. When initially intubating the patient with a TEF, it is best to guide the tracheal tube over a bronchoscope, in order to avoid intubation of the fistula, a life-threatening event if it is not recognized immediately.

Even with the cuff positioned and inflated beyond the TEF, airway contamination is possible. Appropriate measures to decompress the stomach or gastric conduit are indicated to prevent ongoing soilage across the fistula. An aggressive pulmonary toilet with bronchoscopy and appropriate antibiotic therapy are the mainstays of treating pneumonia after the development of TEF. Weaning from positive pressure ventilation remains a priority and greatly facilitates the medical and surgical management of patients with TEF, as emphasized in the section on operative techniques.

Especially in the mechanically ventilated patient with a TEF, there is early consideration of jejunostomy tube placement to provide adequate enteral nutrition. A gastrostomy may also be considered to prevent reflux of gastric contents into the TEF.

There are a few reports of spontaneous closure of TEF with conservative management alone [14]. Only early and the tiniest of fistulas are expected to heal without operative management. These patients presumably had fistula tracts that had not already epithelialized, and ongoing drainage across the fistula was minimal. The fistula tracts that spontaneously close are usually long and likely lead into pulmonary parenchyma rather than the trachea or main-stem bronchus. Such patients are not ill, and a trial of conservative management is reasonable, as long as patients are closely observed for deterioration. In the vast majority of patients presenting with clinically significant TEFs, conservative management is expected to fail in the long-term.

Endoscopic Management

An increasing experience with esophageal and airway stents has led to their application in the management of anastomotic leaks and TEF. Exclusion of the fistula by covered stents may partially or completely control exchange of air and fluid across the fistula. There are isolated reports of acquired TEFs resolving after stenting [10]. As with the patients that had TEFs resolve with conservative management alone, stents are likely associated with fistula closure only when the TEF is extremely small and the tract is still not epithelialized, which is most commonly not the case. More typical of expected outcomes are the experiences of Blackmon et al., who placed stents to control the TEF in four patients with two patients succumbing to their TEF related medical problems and two reported to have control of the fistula without evidence of healing [15]. Even more concerning are the outcomes of Eleftheriadis et al., who used stents in 12 patients with TEF, observed nine deaths, and had 3 patients who

went on to definitive operative management, as the TEF persisted after the stent placement [16].

Esophageal stents may actually potentiate the TEF-associated pathology. In one report, giant TEFs were induced by esophageal stents placed for a benign stricture or esophageal perforation [17]. The radial force of self-expanding esophageal stents has the potential to enlarge the TEF or exclude abscesses that would normally drain back into the esophagus. Another concern is that stenting does not address mediastinal sepsis that may accompany anastomotic disruptions or gastric conduit necrosis. Persistent mediastinal contamination and inflammation not only leads to TEF, but may also result in aortoesophageal fistula, which is almost uniformly fatal. One report, in which a silicone airway stent controlled a PETEF, describes a patient who eventually succumbed to hemorrhage that appeared suspicious for aortogastric fistula [18]. A further concern with airway stenting is that it induces inflammation and granulation. This may extend the length of airway injury, which complicates or precludes definitive operative repair. A technical difficulty with esophageal stent deployment for the PETEF is that there is only a limited esophageal length to accommodate the stent after a cervical anastomosis. Additionally, the anastomosis, conduit, and esophagus are relatively capacious relative to the stent's diameter, and stent migration and poor sealing of the fistula are common.

There is very little role for esophageal or airway stenting to control the benign TEF. Conservative measures such as careful positioning of an endotracheal tube's cuff, gastric decompression, and jejunal feeding are sufficient to allow a patient to recover from complications of a TEF prior to operative repair. Moreover, in patients with evidence of conduit necrosis and significant mediastinal or pleural contamination after an esophagectomy, stenting is absolutely contraindicated, and is expected to fail quite quickly. In contradistinction, esophageal stenting is the standard of care for the management of malignant TEF, and is quite effective in controlling the TEF during the short life-expectancy of such patients [19].

An alternative endoscopic strategy that is sometimes promoted is fistula control with glue or endoscopically applied clips. This strategy is most effective in pediatric cases of benign TEF, where fistulas are typically pinpoint and there is minimal associated pathology in the esophagus, airway, and mediastinum. Fistula closure is achieved by deepithelializing the fistula tract and sealing the defect with glue or clips [20]. Efficacy in adult cases of TEF is anecdotal and there is no reliable data to suggest that there is a role for endoscopically applied clips or glue in the management of acquired TEF, such as those that occur postesophagectomy.

Operative Management

Operative repair of an acquired TEF is indicated in all patients with a reasonable life expectancy. This includes patients who have undergone complete resection of esophageal cancer and develop PETEF. The patient is weaned from mechanical ventilation, as tracheal repairs should ideally not be exposed to positive pressure ventilation. Aggressive pulmonary toilet, appropriate antibiotic therapy, and reliable enteral nutrition are essential for the patient's recovery. This may require tracheostomy and feeding tube placement if the patient does not quickly improve after presentation. The operative techniques are selected based upon the location and size of the TEF as well as the associated pathology (e.g., conduit necrosis).

Postesophagectomy TEF

PETEF occurs primarily after an anastomotic leak or gastric conduit necrosis. Patients are quite ill from pulmonary, mediastinal, and pleural contamination. Early operative intervention is typically necessary in these patients. Fistulas are predominantly located in the distal half of the trachea or proximal main-stem bronchus, but may be located more proximally if the anastomosis was constructed close to the cricopharyngeus. Preoperative endoscopy localizes the TEF and guides the surgeon as to whether the fistula may

be approached with a low cervical collar incision or by thoracotomy. Endoscopy also establishes whether or not the conduit is ischemic. Flexible and rigid bronchoscopy determine whether there is any tracheal stenosis and to measure the distance of the fistula from the larynx and carina.

When conduit necrosis or major anastomotic dehiscence results in a TEF several days after an esophagectomy, and patients are critically ill, the appropriate operation is trans-thoracic takedown of the anastomosis. Nonviable stomach is resected, and the remainder is returned to the abdomen. The tracheal or bronchial defect is repaired primarily with interrupted vicryl suture, which minimizes airway granulation. The defect is buttressed with robust vascularized tissue, such as an intercostal muscle flap. The proximal esophagus is used to construct an esophagostomy, preserving as much esophagus as possible to facilitate future reconstruction. Thorough irrigation and drainage of the mediastinum and pleura, including decortication of the lung, is essential.

A TEF that occurs months to years after an esophagectomy is quite different in terms of presentation and pathology. There is minimal or no mediastinal inflammation and contamination. The conduit is viable and the anastomosis may be completely healed and intact. A more measured approach to operative repair may be taken and the patient's condition is optimized with simple conservative measures. It is important to determine whether or not there is tracheal stenosis in addition to the TEF, as this will dictate whether or not a simple fistula division is all that is required or if a tracheal resection and reconstruction is necessary to address a significant stricture. All but the lowest supracarinal TEFs may be approached via a low cervical collar incision (Fig. 1.1). In TEF patients with a small fistula and normal trachea, the fistula is approached from the side, through the cervical incision (Fig. 1.2). The recurrent nerve on the side the fistula is approached from is at great risk, and care should be taken to avoid retractor injury or inadvertent division. Once the fistula is isolated and divided, the trachea is repaired with interrupted absorbable vicryl sutures. The esophageal or gastric conduit defect is repaired with a two-layered closure whenever possible. The inner layer is an interrupted inverted silk closure. A second outer layer is constructed with interrupted silk sutures approximating esophageal muscle or gastric serosa. A pedicled strap muscle is sutured in place to buttress and isolate the esophageal and tracheal suture lines, which otherwise would lie next to each other and predispose to fistula recurrence. When there is a relatively large defect in the membranous wall of the trachea and there is a concern of airway narrowing with primary repair, a small amount of esophageal wall may be left behind on the tracheal aspect of the fistula to augment the amount of tissue available to reconstruct the membranous wall. There is little concern about narrowing the lumen of the esophagus with this maneuver, as long as the residual lumen easily accommodates a nasogastric tube. Patients are extubated in the operating room whenever possible. A contrast esophagogram is performed after 7 days to ensure healing before starting oral alimentation.

Postintubation TEF

Postintubation TEF also exhibit circumferential tracheal damage and stenosis induced by cuff injury or granulation and scar from the tracheotomy. Operative repair requires not just division and repair of the TEF, but also resection and reconstruction of the diseased segment of the trachea. While the airway reconstruction adds to the complexity of the operation, the fistula repair is actually facilitated by the airway resection, which allows direct approach and repair of the fistula, as opposed to the approach from the side.

The operation is performed through a low cervical collar incision (Fig. 1.1). The diseased segment of the trachea is circumferentially dissected, taking care to dissect close to the airway to avoid injury to the recurrent nerves. Division of the airway requires cross-field ventilation of the distal airway and is performed with close collaboration of the anesthesiologist (Fig. 1.3a). The diseased airway is resected, taking care not to remove trachea before determining that a tension-free repair is feasible. The esophageal defect is closed over a nasogastric tube using a two-layer closure as described above (Fig. 1.3b). The tracheal reconstruction is performed using an interrupted vicryl

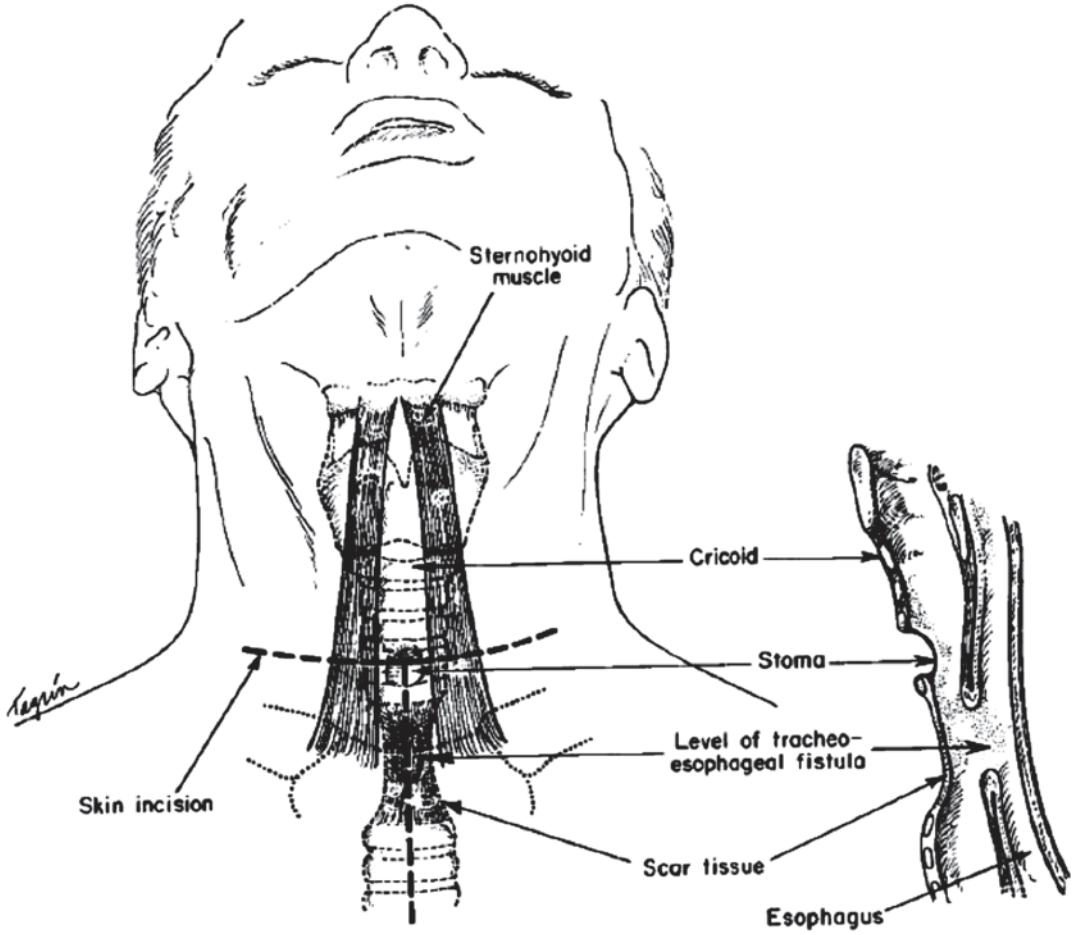

Fig. 1.1 Surgical approach for tracheoesophageal fistula (*TEF*). A low-collar incision permits access to all but the lowest TEFs. Occasionally, a vertical midline extension to the sternal angle enhances access to the mediastinal trachea, necessary for the repair of lower TEFs. (With permission from [2] © Elsevier)

suture technique (Fig. 1.3d), using the principles we have described previously [2].

Separation of the tracheal and esophageal suture lines is accomplished with a pedicled strap muscle (Fig. 1.3c). The anterior aspect of the tracheal anastomosis is also covered with another strap muscle or thyroid isthmus. Prolonged mechanical ventilation is avoided after a tracheal anastomosis, and patients are normally extubated in the operating room. If a tracheostomy is necessary, it is placed at least two rings caudal to the anastomosis. In some instances, the length of tracheal stenosis exceeds the limits of how much trachea may be safely resected. In these cases, the division and repair of the fistula is still warranted, and the remaining airway stenosis is managed with a T-tube placed through a tracheotomy.

Bronchoesophageal Fistula

Most reports describing the management of TEF lump together fistulas to the trachea and the mainstem bronchus. There are, however, some differences between TEF and bronchoesophageal fistulas (BEF) that should be highlighted. BEFs are typically smaller than true TEFs, and small fistulas may be easily missed at esophagoscopy or bronchoscopy. A high index of suspicion and an expert contrast esophagogram are often nec-

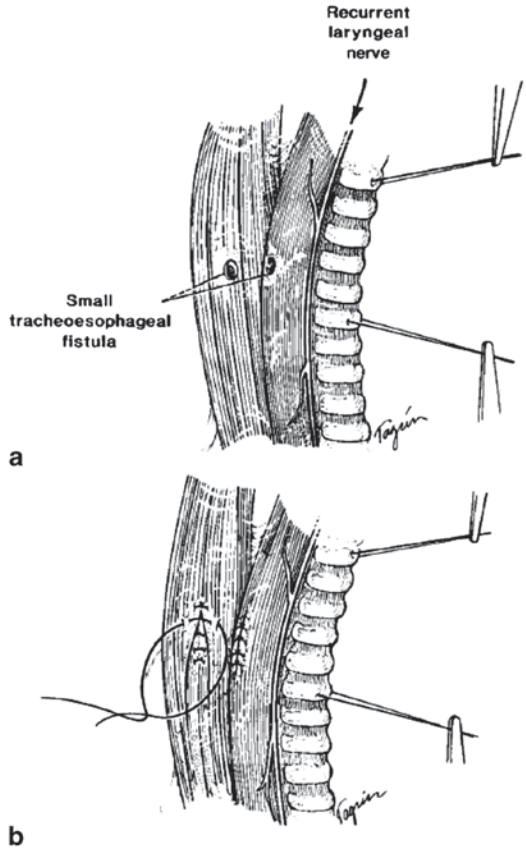

Fig. 1.2 **a** Lateral approach of a small tracheoesophageal fistula (*TEF*) without tracheal stenosis. **b** Primary repair of esophageal and tracheal membranous wall defects without tracheal resection. (With permission from [2] © Elsevier)

essary to establish the diagnosis. As with TEF, BEF are best managed by surgical division of the fistula and repair of the airway and esophageal defects. A right thoracotomy is the primary incision used to approach fistulas to either the proximal right or left main-stem bronchus. Resection of the bronchus or lung is almost never necessary, and the goal should be to preserve all functioning pulmonary tissue. The intercostal muscle flap is the most robust and versatile tissue for buttressing the esophageal and bronchial repairs.

Prevention of Tracheoesophageal Fistula

It is remarkable that there is about a 30-fold difference in the incidence of PETEF (0.1–3 %) in several large series of esophagectomies (Table 1.1). While there are certainly patient variables such as preoperative chemoradiotherapy and malnutrition that contribute to the development of TEF, there are also just as certainly operative variables as well. It is easy to see that minimizing the rate of postesophagectomy anastomotic leaks should also minimize the risk of the TEF development. The author is troubled by the tolerance of anastomotic leak rates greater than 5 %, when it is feasible to virtually eliminate the incidence of anas-

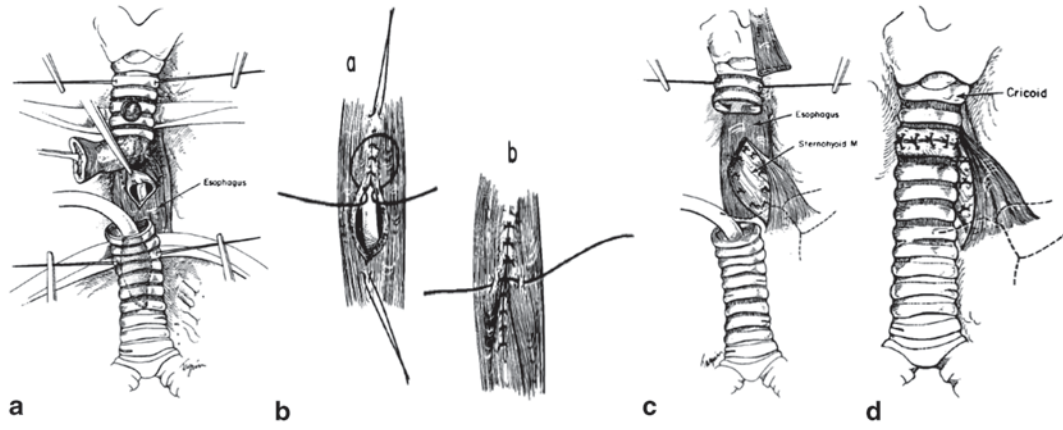

Fig. 1.3 Surgical management of postintubation tracheoesophageal fistula (*TEF*). **a** Exposure of TEF after the division of the trachea distal to fistula. Distal trachea is intubated for cross-field ventilation. **b** Two-layer closure of esophageal defect. The first layer is an inverted interrupted suture closure, and the second layer is a simple interrupted layer to bring the muscle together. **c** Strap-muscle reinforcement of the esophageal repair, which buttresses the closure and separates it from the tracheal anastomotic suture line. **d** Primary reconstruction of trachea with an interrupted anastomotic suture technique. (With permission from [2] © Elsevier)

tomotic leaks [21, 22]. Attention to anastomotic technique and consideration of buttressing anastomoses with omentum or muscle may mitigate anastomotic leaks and reduce the risk of TEF.

Aggressive nodal dissection and traumatic injury to the airway also predispose to the TEF formation after an esophagectomy. The incidence of airway injury during a transhiatal esophagectomy is as high as 1%, although it is certainly much lower at centers who practice this technique extensively [6]. If the surgeon cannot safely perform a transhiatal dissection in every instance, the patient is better served by a technique that incorporates transthoracic or video assisted thoracic surgery (VATS) techniques that allow safe dissection of the esophagus from the airway.

Delayed TEFs after esophagectomy may arise many years after the original operation. They typically arise due to perforated ulcers in the gastric conduit, or erosion of the staple line used to construct the gastric conduit. While the development of an ulcer is unlikely to be preventable, staple line erosion can be mitigated by over-sewing the staple lines. This step is often omitted in minimally invasive esophagectomy, as it is relatively inconvenient to perform and extends the operative time. In patients undergoing esophagectomy for benign disease or early stage esophageal cancer and for whom life-expectancy is long, oversewing the gastric staple line is advisable.

Outcomes

Development of PETEF is associated with significant risk of mortality, in the range of 20–30% in most published series [9]. Patients may succumb either to respiratory failure or multiorgan dysfunction. The greatest risk of mortality is in patients with PETEF and gastric conduit necrosis. Patients with chronic or subacute TEFs do much better and aggressive treatment is warranted to ensure complete recovery in the majority of patients.

Conservative nonoperative management of PETEFs is reported to be successful in scattered reports. When described, the fistulas are usually pinpoint in size and patients are otherwise well. Conservative management is normally abandoned when the fistula fails to close in 4–6 weeks [5]. Conservative management alone is insufficient for most patients with PETEF.

Endoscopic management of PETEF is also reported to succeed in scattered reports. One such report claimed successful closure of PETEF in four patients undergoing stent placement [10]. A closer examination of their results reveals that two patients died with the stent left in place. The two other patients who had successful healing of the TEF had esophageal stents placed for anastomotic leaks, and the size and location of the fistula was not precisely defined. Of the seven patients with PETEF, only two survived. We are of the opinion that stents and endoscopic application of glue and clips only delay definitive treatment. Moreover, we are wary of stent induced complications such as pressure induced necrosis of the airway and gastric conduit as well as possible aorto-enteric fistula.

The most reliable approach to the management of TEF is operative, using the principles outlined above. A cervical approach, and occasionally a cervico-mediastinal approach where a partial upper sternotomy is also performed, is suitable for 90% of operative repairs of TEF, in our experience [1]. About three-fourths of our patients required tracheal resection and reconstruction, while the remainder simply underwent membranous wall repair after fistula division. All four PETEF patients underwent primary repair without tracheal resection in our series. Patients undergoing surgical management of TEFs have mortality rates of about 3%. Successful closure of the fistula is expected in approximately 90% of patients, and the majority of patients resume oral alimentation and breathe without a tracheal appliance.

Conclusion

Although the incidence of PETEF is relatively low, the significant morbidity and mortality associated with this condition dictate that this complication is avoided by minimizing the risk of anastomotic leaks and taking care to preserve the

vasculature of the airway and the gastric conduit. If a TEF occurs, there is a step-wise and ordered approach to the management that encompasses conservative, endoscopic, and operative measures. An individualized approach to TEF management that takes into consideration the size and location of the TEF as well as the condition of the gastric conduit will ensure the best outcomes.

Five Key Points to Avoid Complications

1. Minimize airway ischemia by preserving bronchial vasculature during nodal dissection.
2. Avoid prolonged nasogastric tube placement in the setting of an inflated tracheal cuff.
3. Avoid inadvertent tracheobronchial trauma when mobilizing esophagus.
4. Ensure gastric conduit is well perfused prior to anastomosis.
5. Consider buttressing anastomosis routinely or when there is a concern about anastomotic healing. Consider over-sewing gastric staple-line.

Five Key Points to Diagnose or Manage Complications Intra or Postoperatively

1. Diagnosis of small TEFs requires a high index of suspicion as well as radiographic and endoscopic examination to confirm.
2. Bronchoscopic guided placement of endotracheal or tracheostomy tubes is critical in patients requiring mechanical ventilation.
3. Wean patients from mechanical ventilation prior to operative repair of TEF.
4. Avoid routine stenting of the esophagus or airway for management of PETEF.
5. Separate tracheal and esophageal suture lines with pedicled muscle, after the division of the TEF.

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Esophageal Strictures Refractory to Endoscopic Dilatation

2

Shawn S. Groth, David D. Odell and James D. Luketich

Introduction

Esophageal stricture is a common issue faced by clinicians who care for patients with foregut disorders. Generally, strictures can be effectively managed using endoscopic techniques such as dilation. Improved control of the primary pathology, in most cases gastroesophageal reflux disease (GERD), is also typically effective in limiting recurrence of a stricture after therapy. However, while many strictures are effectively managed with simple dilatation, a minority remain refractory to treatment, posing a particularly difficult challenge to both the patient and the physician. We define such a "refractory" esophageal stricture if one or more of the following criteria are met: (1) failure to achieve an adequate luminal diameter to allow intake of solid food without dysphagia despite up to four repeat dilatations at 2-week intervals or (2) stricture which requires surgical intervention at any point. While such strictures can be challenging to manage, a thoughtful and systematic approach can allow the restoration of good swallowing function for the patient.

Etiology of Esophageal Strictures

Esophageal strictures form as the result of injury to the esophageal wall with the subsequent development of scar tissue and secondary tissue contraction. The vast majority of the time, stricture formation is associated with long-standing GERD and may be seen in combination with a primary motor disorder of the esophagus. However, approximately 20–30% of cases are unrelated to GERD. These strictures may be associated with surgical anastomoses (such as following esophagectomy), scar formation after antireflux surgery, caustic ingestion, prior radiation treatment, or malignancy.

Typical esophageal strictures are characterized by a cicatricial, anatomic narrowing of the esophagus, which we define as either simple or complex strictures. Simple strictures are short (<2 cm) and focal, straight, and can be traversed with an adult endoscope prior to dilatation. In contrast, complex strictures are long (>2 cm), irregular, angulated or difficult to traverse with an endoscope [1].

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Treatment

There are a variety of nonsurgical and surgical treatment options for esophageal strictures. The choice of approach depends upon the etiology and complexity of the stricture and the response to prior treatment. First-line therapy for esophageal strictures is endoscopic dilation, with serial intervention often required. More aggressive surgical therapy is typically reserved for those patients who fail an endoscopic management strategy.

Treatment of Benign Esophageal Strictures

With the exception of congenital strictures, the pathogenesis of all benign esophageal strictures is transmural cellular injury; the inflammation that ensues leads to collagen deposition and fibrosis and ultimately causes a cicatricial narrowing of the lumen. Consequently, treatment strategies for benign strictures are designed to (1) establish patency of the esophageal lumen, (2) disrupt and displace the fibrotic tissue of strictures to restore a satisfactory diameter of the lumen, (3) minimize or prevent reorganization of the fibrotic tissue (and hence recurrence of) the stricture, and (4) minimize or prevent ongoing cellular injury.

Nonsurgical Options

Endoscopic Dilatation

Esophageal dilation has been performed for nearly 400 years. It was first described in the seventeenth century when a sponge was affixed to a piece of carved whalebone and used to dilate a patient with achalasia [2]. Alexis Boyer performed the first bougienage (as it is performed today) in 1801 to dilate an upper esophageal stricture [3]. Since then, a number of materials have been utilized to construct bougies. The word "bougie" is derived from a town in Algeria (Boujiyah) that was a medieval center for wax candle trade; the original bougies were made of wax and cloth [3].

There are two broad categories of dilators: bougie dilators (i.e., Maloney, Savory-Gilliard®, and American Dilation System® dilators) and balloon dilators. Bougie and balloon dilators have slightly different mechanisms of action. Bougie dilators exert both longitudinal and radial force. In contrast, balloon dilators exert only radial force. Based on data from randomized controlled trials, there is no proven difference between either system with regard to safety and efficacy [4, 5]. Consequently, the choice of dilator is usually simply based on the endoscopist's preference, though there are certain situations where one dilator system may be preferable [6].

In general, we prefer to dilate strictures using Savory dilators over a guidewire under real-time fluoroscopic guidance. However, this approach does not work well for complex, distal, angulated strictures (e.g., a complex distal anastomotic stricture after colonic interposition) due to the inability to pass the relatively rigid tip of a bougie dilator beyond such strictures. In these situations, balloon dilators are a better option since they can be guided and deployed across an angulated strictured segment. Before classifying a stricture as "refractory," it is important to assure that it was properly treated.

In general, our goal is to dilate esophageal strictures to a level that allows patients to tolerate a regular diet without dysphagia. As a general, safe guide to dilating strictures, the "rule of threes" is useful to minimize the risk of perforation. The rule states that once moderate resistance is encountered when passing serial dilators at three French intervals, no more than three serial dilatations should be performed in a single session (beginning with the dilator that was associated with moderate resistance). We also perform regular interval repeat endoscopies when performing multiple repeat dilatations in a single setting to assure that it is safe to proceed with further dilatation. A superficial or moderate thickness mucosal tear (due to disruption of fibrosis) is indicative of an "adequate" dilatation and serves as our stopping point. A low threshold should be adopted to obtain a postprocedure barium esophagram prior to discharge if a full

thickness tear cannot be ruled out on completion endoscopy.

Patients with tight strictures who have near-complete obliteration of their esophageal lumen should be approached cautiously. These strictures can function as a one-way valve. Consequently, if excessive endoscopic insufflation is used, massive gastric distension can ensue and, in extreme circumstances, may result in gastric necrosis. For such strictures, we recommend cautious endoscopic insufflation and passing a guidewire under both endoscopic and real-time fluoroscopic guidance prior to antegrade dilatation.

For patients who continue to have dysphagia after dilation, we perform a repeat endoscopy and dilation in 2 weeks to allow the mucosal tear sufficient time to heal yet reintervene before the stricture can fully reorganize. Some patients (especially those with anastomotic or caustic strictures) require an aggressive schedule of multiple repeat dilatations at 2-week intervals.

Stricture recurrence is common. The likelihood needing a single recurrence is 40–80 % [7–10]. For patients who have a single recurrence, up to 90 % develop another recurrence [9]. For motivated, select patients who require frequent dilatations, self-dilatation is well-tolerated, effective strategy [11, 12]. Alternatively, for strictures that fail to respond to simple bougie or balloon dilatation, adjunctive endoscopic measures may be considered.

Steroid Injection

Because benign esophageal strictures result from the production of fibrous tissue and collagen deposition, endoscopic intralesional injection of steroids has been utilized as an adjunct to dilatation for refractory strictures. The mechanism of action of intralesional steroids in the reduction of fibrosis is poorly understood but may involve inhibition of fibrogenic cytokines (i.e., IL-1, TNFα and TGF-β), reduction in procollagen and fibronectin synthesis, and reduction in the synthesis of collagenase inhibitors (i.e., α2-macroglobin) [1, 13].

There are a number of small observational studies that suggest a possible benefit for treating refractory benign esophageal strictures from various causes. These studies demonstrated an improvement in dysphagia [14, 15], an increase in the symptom-free interval between dilatations [16, 17], an increase in the maximal diameter achieved on subsequent dilatations [17, 18], and a decrease in the need for subsequent dilatations [14].

There is little randomized data on the use of intralesional steroid injection. One randomized trial compared steroid injection (0.5 cc/quadrant of triamcinolone [40 mg/cc]) plus balloon dilatation ($n=15$) versus sham injection and balloon dilatation ($n=15$) for patients with peptic strictures who continued to have at least weekly dysphagia. For patients who underwent steroid injection, there was a statistically significant reduction ($p=0.02$) in the need for repeat dilatation (13 %) as compared with the control group (60 %). There was also a significant increase ($p=0.01$) in the interval between dilatation [19]. Another (smaller) randomized trial reported similar results [20].

Esophageal Stenting

Esophageal stents maintain patency of the esophageal lumen by exerting radial force on the stricture. Due to the risk of granulation tissue in-growth and over-growth and the resultant risk of obstruction and difficulty removing the stent, we do not use self-expanding metal stents. Self-expanding plastic stents, however, are a potential option for middle and distal esophageal strictures. One systematic review pooled the results for 130 patients (from 10 studies) with benign esophageal strictures that were treated with self-expanding metal stents. Dilatation-free remission was achieved in 52 % of patients [21]. That study also highlighted one of the major limitations of plastic stents—high migration rates (approximately 25 %) [21]. Consequently, reintervention for stent migration is common. Migration into stomach is easily managed (by stent removal and [if needed] replacement); migration into the duodenum can be dangerous. Given the limitations of metal and plastic stents, biodegradable stents are an interesting development [22]. However, further investigation is needed to define their role in the treatment of benign esophageal strictures.

Self-expanding plastic stents are a temporary treatment strategy. If used, repeat endoscopy should be performed at 2-week intervals to assess the need ongoing stenting. If still needed, the stent should be removed (preferably through an overtube) and replaced. We primarily use self-expanding plastic stents for patients with benign middle and distal esophageal strictures that sustain a perforation during dilatation. For refractory strictures near the cricopharyngeus, we prefer silicone salivary bypass (Montgomery) stents due to the risk of proximal migration, globus sensation, and tracheal compression (and resultant risk of airway compromise or tracheoesophageal fistula) from the radial expansile forces associated with self-expanding plastic stents [23, 24]. Covered, flexible stents that exert a low degree of radial force (e.g., Ultraflex stents) are an alternative to Montgomery stents.

Rendez-Vous Procedure

Some patients develop complete loss of the patency of the esophageal lumen from a variety of benign and malignant disorders. Standard antegrade dilatation can be dangerous in such patients. For these patients, combined antegrade and retrograde dilatation (a "rendez-vous procedure") is a safe, useful technique that restores patency of the lumen in 80–100 % of patients [25–30].

We perform the procedure under general anesthesia. A standard adult (9.8 mm) flexible endoscope is advanced antegrade down the esophagus under direct vision to the level of the obstruction. If a gastrostomy tube was previously placed, the gastrostomy tube is removed and a pediatric (5.5 mm) flexible endoscope is advanced retrograde up the esophagus to the distal aspect of the occlusion. Alternatively, if a gastrostomy tube is not in place, we perform a mini-laparotomy and place one. The orientation of the lumen is determined using a combination of endoscopy and fluoroscopy. Next, the lumen is punctured retrograde using a guidewire, brought out through the mouth, and used for antegrade dilation.

Incisional Therapy

As an alternative to repeat dilatations, some endoscopists have explored the use of incisional therapy. These techniques use electrocautery with [31] or without dilatation [32], electrocautery combined with argon plasma beam coagulation [33], needle-knife techniques [34], or endoscopic scissors [35]. However, based on data from a randomized trial, there is no significant difference in the success rate of incisional therapy as compared with Savary bougienage [36]. Consequently, we prefer dilatation to incisional therapy.

Surgical Options

Antireflux Surgery for Peptic Strictures

First-line treatment for peptic strictures is esophageal dilatation and use of proton pump inhibitors (PPIs). However, a significant number of patients with peptic strictures fail conservative (first-line) treatment of peptic strictures, evidenced by failure of their esophagitis to heal, inability to achieve symptom relief (or development of worsening symptoms), and the need for repeat dilatations. In fact, 30–40 % of patients with peptic strictures need repeat dilatations within a year of their initial dilatation [37–39]. Peptic strictures are a complication of GERD. For GERD patients who fail maximal medical therapy, laparoscopic antireflux surgery is a time-proven, safe, and effective treatment with low associated morbidity and mortality [40, 41]. Consequently, for patients with peptic strictures who are otherwise appropriate surgical candidates and who fail a trial of dilatation and PPI therapy, antireflux surgery should be offered.

To date, there are no randomized trials comparing maximal medial therapy with laparoscopic antireflux surgery. One retrospective study compared a group of 42 patients treated with antireflux surgery with a control group of 78 patients treated medically (with H2 blockers and bougienage) over a 3-year period and found that patients treated surgically required fewer dilatations [42]. Furthermore, there are single institutional series that have demonstrated that laparoscopic antireflux surgery is safe and effective in appropriately selected patients with peptic strictures that have failed to respond to conservative therapy. It

results in improvement in both dysphagia scores and quality-of-life measures while reducing the need for dilatations [43, 44].

Special consideration needs to be given to patients with peptic strictures who undergo esophagectomy. Peptic strictures are the result of transmural inflammation which can cause esophageal dysmotility (in approximately 20% of patients) and the resultant need for a partial fundoplication [43]. Transmural inflammation can also cause esophageal foreshortening. If inadequate intraabdominal esophagus is present at the completion of the lower mediastinal dissection, a Collis gastroplasty should be performed.

Esophagectomy

Some patients with benign esophageal strictures from failed prior fundoplications [45, 46], use of synthetic mesh to repair a hiatal hernia [47], and corrosive injuries that fail to respond to dilatation [48–50] are best served by esophagectomy, which can be performed with a morality rate under 1% [51]. We prefer to use a tubularized gastric conduit for esophageal replacement, and use a colonic conduit when the stomach is not usable.

As an alternative to esophagectomy, some investigators have described the esophagoplasty with myocutaneous flaps [52], a vascularized colonic patch [53], and extracellular matrix scaffolds [54]. However, patch esophagoplasty is prone to anastomotic leak, graft necrosis, and donor site complications. Consequently, we prefer standard esophagectomy and reconstruction techniques.

Finally, some have advocated bypass (rather than esophagectomy) for corrosive esophageal injuries due to a perceived increased risk of bleeding, tracheobronchial injury, and recurrent laryngeal nerve injury secondary to dense periesophageal adhesions [55]. However, based on retrospective studies, there is no significant difference in morbidity or mortality between bypass and esophagectomy [48, 56]. Furthermore, there is a 3–13% chance of developing cancer within the bypassed esophagus (which is not accessible for routine endoscopic examination) [55, 56]. Consequently, we do not perform an esophageal bypass.

Malignant Esophageal Strictures

Endoscopic Treatment

Dilatation

Though it may require repeat intervention, simple dilatation is an effective method to treat dysphagia secondary to malignant esophageal strictures, especially when external beam radiation therapy with or without chemotherapy is planned.

Stent Placement

Esophageal stent placement provides rapid relief of dysphagia and is the most commonly used modality to palliate dsyphagia secondary to malignant esophageal strictures. A variety of esophageal stents are available, which differ in their design, length, diameter and flexibility as well as the amount of radial force they exert. We do not use uncovered metal stents due to the risk of tumor and granulation tissue in-growth, which results in a partial obstruction and recurrent dysphagia. Most of the available self-expanding metal stents in the United States are made of nitinol and are available in partially covered (i.e., Ultraflex stent [Boston Scientific, Natick, MA]) and fully covered designs (i.e., Alimaxx-E stent [Merit Medical Systems, South Jordan, UT] and Niti-S stent [TaeWoong Medical, Seoul, Korea]). Some stents are available in both partially and fully covered designs (i.e., Wallflex stent [Boston Scientific] and Evolution stent [Cook Medical, Bloomington, IN]).

A limitation of partially covered self-expanding metal stents is recurrent dysphagia (in approximately 30% of patients) due to stent migration, tumor in-growth, granulation tissue in-growth, or food impaction [57]. Fully covered stents are more resistant to tumor or granulation tissue in-growth (and hence are easier to remove) but are more prone to stent migration. Both partial and fully covered stents are equally effective. There is no evidence in the literature to suggest that one particular stent offers optimal outcomes.

As an alternative to covered metal stents, the Polyflex stent (Boston Scientific, Natick, MA) is a fully covered plastic stent that is made of silicone and is encapsulated with a polyester mono-

filament braid. Given its success in the treatment of benign strictures, its role in the treatment of malignant strictures has been explored. As compared with self-expanding metal stents, it provides comparable relief of dysphagia. However, it is associated with a higher rate of complications (migration, hemorrhage, and tumor over growth) [58]. In our study, we noted a 63 % migration rate of Polyflex stents [59].

Stenting across the gastroesophageal junction (GEJ) poses a particular problem—reflux. Consequently, all patients with GEJ stents should be placed on proton pump inhibitors. With the rising incidence of esophageal adenocarcinoma, malignant strictures in the distal esophagus and GEJ and their attendant stent-related complications will likely continue to increase [22]. To minimize reflux, stents with an antireflux valve have been developed and have produced mixed results in the literature [60, 61].

Laser Therapy

Neodymium yttrium-aluminum-garnet (Nd:YAG) laser is best suited for exophytic tumors that are less than 6 cm and located in the mid-esophagus. Nd:YAG lasers should not be used for circumferential tumors because it can cause stricture formation. Multiple treatments (at 4–6-week intervals) are usually required to achieve palliation [62]

Photodynamic therapy (PDT) involves administering light (at a 620 or 630 nm wavelength) endoscopically to patients who are given a photosensitizer (e.g., Photofrin [Axcan Pharma, Quebec, Canada]) 48 h before treatment. It has 5–6 mm of tissue penetration. In our series of 215 patients, PDT was 85 % effective in improving dysphagia and 93 % effective in controlling bleeding [63]. It is also effective at treating tumor in-growth of previously placed stents [64].

As compared with self-expanding metal stents, laser therapy provides similar improvement in dysphagia. However, laser therapy is expensive, requires repeat intervention, is not widely available, and has higher rates of perforation, fistula formation, and stricturing [65]. PDT is also associated with photosensitivity for 4–6 weeks.

Brachytherapy

Brachytherapy is a safe and effective treatment option that involves the administration of a radiation source (e.g., Iridium-192) down the esophagus over a guidewire. The highest rates of palliation are achieved when 7.5–20 Gy is administered in 1–3 fractions [62, 66]. As compared with stent placement, brachytherapy provides slower (but longer lasting) relief of dysphagia, has a lower complication rate, and results in improved quality of life [67]. Brachytherapy is best suited for patients who do not require immediate relief of dysphagia and will survive long enough to benefit from it (> 3 months) [68].

Chemotherapy and Radiation Therapy

As compared to esophageal stents and other endoluminal therapies, there is no evidence that chemotherapy and radiation therapy (alone or in combination) provides better palliation of dysphagia [65]. As such, patients with dysphagia secondary to a malignant esophageal stricture who are undergoing chemotherapy and/or radiation therapy should also be treated with endoluminal therapy (i.e., dilatation or stent placement).

Surgical Treatment

Esophagectomy (as part of a multimodal approach) is the treatment of choice for localized esophageal cancer. Consequently, esophagectomy is a treatment option for malignant strictures in medically fit patients with localized disease if an R0 resection can be achieved with an acceptable risk of morbidity and mortality.

The 5-year survival rate for patients with stage IV esophageal cancer is less than 5 % [69]. Given the success of endoscopic palliation and the morbidity, mortality, and negative immediate impact on quality-of-life, esophagectomy (or bypass) is rarely indicated for palliation of malignant dysphagia. In select patients, esophagectomy is an option for those patients who fail endoscopic palliation of dysphagia, bleeding, or tracheoesophageal fistulas [62].

Conclusion

The management of esophageal stricture poses a significant clinical challenge. First-line therapy involves careful endoscopic characterization of the lesion and a trial of therapeutic bougienage in nearly all cases. More aggressive interventions should be reserved for patients who do not respond to dilatation or the presence of malignancy or other primary motility disorders of the esophagus (i.e., achalasia) which may respond well to primary surgical therapy. Novel techniques such as submucosal steroid injection for benign lesions or intraluminal photodynamic therapy or Nd-Yag laser debridement for malignancy should be reserved for use in selected patients by practitioners with specific experience with the techniques. Self-expanding metal stents may afford excellent palliation for malignant stricture, but may have issues related to migration and erosion and frequent surveillance may be needed. Further, a commensurate increase in reflux should be anticipated when stents are used in the palliation of foregut strictures.

Surgical management of refractory stricture is the treatment of choice in the setting of a localized esophageal cancer for which a complete resection is felt to be feasible. For patients with advanced malignancy, endoscopic palliation may provide a reasonable option with limited morbidity. An aggressive surgical approach may also be warranted in situations where the stricture is the result of an anatomic abnormality created as a result of prior antireflux surgery. Careful operative planning and intraoperative evaluation are crucial. For all lesions, a thorough understanding of the underlying pathology is paramount in determining the appropriate treatment course.

Key Points for Avoiding Postsurgical Esophageal Strictures

1. For patients who undergo an esophageal anastomosis:
   a. Construct an appropriately sized, tension-free anastomosis
   b. Minimize risk factors for esophageal anastomotic strictures (e.g., ischemia and anastomotic leak)
2. For patients who undergo fundoplication and repair of a hiatal hernia:
   a. Avoid iatrogenic constriction (constructing a tight wrap and closing the hiatus tightly)
   b. Avoid use of a synthetic mesh to close the hiatus
3. Use proton pump inhibitors for patients at risk for ongoing mucosal injury

Key Points for Managing Esophageal Strictures

1. Endoscopic dilatation is the first-line treatment of esophageal strictures. Surgery should be reserved for failure of maximal nonoperative therapy.
2. Serial dilatations at 1–2-week intervals may be needed to maximize the potential of dilatation and to achieve a satisfactory outcome
3. Stenting is a temporary treatment option, especially for benign strictures.
4. For patients with complete loss of the patency of the esophageal lumen, a rendez-vous procedure is an excellent option
5. Always have a backup plan if the first choice of treatment fails or results in a complication.

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Esophageal Anastomotic Leak

3

Onkar V. Khullar and Seth D. Force

Introduction

As the incidence of esophageal cancer continues to rise, increasing numbers of esophagectomies will be performed. Esophagectomy, with or without neoadjuvant therapy, continues to provide the best possibility for cure for early stage cancer. Despite improvements in surgical technique and perioperative care, morbidity after esophagectomy continues to be common [1, 2]. Anastomotic leak, in particular, remains a major source of morbidity and mortality after esophagectomy and continues to be one of the most feared complications. Early identification and treatment remain paramount in order to avoid long-term complications and death.

Regardless of surgical approach for resection including minimally invasive techniques, leak rates remain a common topic of surgical research. Several large case series and database analyses have been published looking at a variety of anastomotic techniques, reporting leak rates ranging from 5 to 20% (Table 3.1). Unfortunately, complications from anastomotic leaks can be considerable with mortality rates ranging from 30 to 40% [3, 4]. Perioperative outcomes, length of stay, long-term morbidity, and anastomotic strictures have all been shown to be worse after conduit leak [5]. Leak rates and the resultant severity of illness vary based on the source of the neoesophageal conduit and location of the anastomosis. Stomach, colon, and jejunum are the most commonly used conduits with anastomoses either in the neck or in the chest. The most frequently used conduit is the stomach given its extensive blood supply, anatomic convenience, relatively short distance to the anastomotic site, and the need for only a single anastomosis. Regardless of the choice of conduit, possible sites of leak include the proximal and (in the case of colon and jejunum) distal anastomoses, staple lines along the conduit (in the case of tubularized stomach), and necrosis/ischemia of the conduit itself. Treatment of a leak is perhaps best managed by avoiding one. Therefore, any discussion of leaks must begin with discussion of risk factors for their development.

Risk Factors for Anastomotic Leak

Risk factors for leaks are best considered when divided into technical and patient specific causes. Technical risk factors are perhaps the most easily modified and harken back to the basic tenets of any surgical anastomosis—minimizing tension while maintaining perfusion. First and foremost is careful preparation of the neoesophageal conduit and avoidance of conduit ischemia. Prevalence of conduit ischemia may be as high as 10% [6]. Meticulous surgical technique in preservation of vascular supply of the conduit is vital to prevent conduit ischemia, and a major risk factor for leak is reflected in the surgical maxim "Pink in the belly, pink in the neck or chest." Therefore, maintaining adequate arterial blood supply through

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Table 3.1 Selected published esophageal anastomotic leak rates

Authors	Publication year	Surgical approach	N	Leak rate(%)
Cervical anastomosis				
Heitmiller et al. [17]	1999	[a]	262	0.8
Swanson et al. [42]	2001	Three field	342	8
Walther et al. [12]	2003	Three field	41	2.4
Luketich et al. [43]	2003	MIE	222	11.7
Orringer et al. [44]	2007	Transhiatal	944	9
Klink et al. [45]	2012	Transhiatal	36	31
Kassis et al. [5]	2013	Transhiatal	1050	11.6
		Three field	519	14.3
		MIE	168	10.1
Price et al. [46]	2013	[a]	163	21
Intrathoracicanastomosis				
Visbal et al. [47]	2001	Ivor-Lewis	220	0.9
Walther et al. [12]	2003	Ivor-Lewis	42	0
Crestanello et al. [4]	2005	Ivor-Lewis	761	6.3
Ott et al. [48]	2009	Ivor-Lewis	240	8.3
Klink et al. [45]	2012	Ivor-Lewis	36	11
Kassis et al. [5]	2013	Ivor-Lewis	1174	9.3
		Thoracoabdominal	105	5.7
		MIE	280	10.7
Price et al. [46]	2013	[b]	269	5.9

MIE minimally invasive esophagectomy
[a] Includes both transhiatal and three-field approaches
[b] Includes Ivor-Lewis, MIE, and thoracoabdominal approaches

preservation, in the case of gastric conduits, of the right gastroepiploic, and if possible the right gastric artery, is of paramount importance. To accomplish this, the greater omentum is separated from the stomach beginning high on the greater curve where the right gastroepiploic terminates. The omentum should then be divided proximally to the left crus, dividing the short gastric vessels. Distally, the omentum should be separated carefully while palpating the gastroepiploic artery to ensure it is not inadvertently injured.

Of equal importance, though often less emphasized, is preservation of venous drainage through careful dissection and preservation of the pars flaccida. The gastrohepatic ligament should be divided at its filmy attachments up toward the hiatus. The left gastric vein is identified and divided close to its origin, as is the left gastric artery. All adjacent lymph nodes and venous drainage along the lesser curve should be swept toward the stomach. Once ready to divide the stomach, the lesser curve should be divided at the level of the second vascular arcade, thereby preserving some of the venous drainage. The stomach should continue to be divided toward the gastric fundus while progressively stretching the stomach cephalad and straightening the gastric tube. Upon completion of the conduit, the stomach should be carefully inspected while still in the abdomen to ensure that it remains pink and perfused and to confirm a palpable pulse in the right gastroepiploic artery.

Key points in regard to minimizing tension on the anastomosis include adequate mobilization and careful tubularization of the stomach in order to create a conduit of sufficient length. Kocherizing the duodenum and division of any adhesions to the pancreas in the lesser sac will allow for a complete mobilization of the stomach. Additionally, division of the left gastric and short gastric arteries will further increase intraabdominal mobilization and length. Finally, tubularizing the stomach along the greater curvature will help create a straight conduit of sufficient length to reach the anastomosis while allowing for adequate drainage of the conduit. A conduit which

is too wide will not have enough length and will not empty well predisposing to a leak. However, a narrow conduit (3 cm in width) is predisposed to increased ischemia at the gastric tip, likely due to the removal of collateral blood supply. Previous studies have shown the ideal conduit width to be 4–5 cm both in open and minimally invasive esophagectomy [7–9].

In the rare case in which stomach is unavailable, most commonly due to prior gastric surgery, colon or jejunum can be used as possible conduits. While both of these methods provide possible alternatives to stomach, they carry the disadvantages of two additional anastomoses and the risk of an intraabdominal leak. Use of colon interposition, while uncommon, has been studied in several retrospective series with equivalent, if not slightly lower, leak rates when compared with the stomach [6, 10]. Both right and left colon with inclusion of the transverse colon can be used, though our preference is the left as it provides a better size match to the esophagus. Use of the colon often necessitates a preoperative colonoscopy to rule out colonic pathology and a CT angiogram to evaluate the colonic vessels, including the patency of the marginal artery. The blood supply to the left colon conduit will depend on the ascending branches of the left and middle colic arteries with a patent intervening marginal artery. Pulsation in all colonic arteries should be confirmed at the time of laparotomy. Mobilization of the peritoneal reflection from the splenic flexure down to the rectosigmoid junction is necessary in order to minimize tension. A 1- to 2-cm rim of mesocolon on the conduit should be maintained in order to preserve collateral blood supply.

Jejunum, on the other hand, lacks the risk of diverticular or malignant disease progression. Short segment jejunal interposition can be completed with relative ease when only a segment of distal esophagus needs reconstruction. When longer reconstruction is required, the use of a super-charged jejunum is necessary for added length though it requires the greater complexity of two microvascular anastomoses in addition to three enteric anastomoses. Recent data from the MD Anderson Cancer Center reported a leak rate of 32 % when utilizing this method [11].

Technical approaches to the esophageal-conduit anastomosis beyond the choice of conduit have been extensively studied as a possible risk factor of leak. Both the location and method of anastomosis have been looked at with prospective and retrospective studies. As previously mentioned, possible anastomotic locations are intrathoracic, as with Ivor-Lewis and thoracoabdominal esophagectomy, and cervical, as with transhiatal and McKeown three-hole esophagectomy techniques. A selection of studies reporting anastomotic leaks is shown in Table 3.1. Four randomized controlled trials have been conducted examining cervical vs. thoracic location [12–15]. A meta-analyses conducted by Markar et al. examining these studies ultimately concluded that leaks were significantly more common in the cervical group (13.64 %) than in the thoracic group (2.96 %) [16]. There continues to be a considerable variability in reported leak rates, however, with two studies reporting cervical leak rates less than 3 % [12, 17]. Given the additional length of conduit necessary to reach the neck, it is reasonable to assume that this increased leak rate is a result of increased tension and perhaps compromised blood flow at the conduit tip and possible decreased venous outflow due to conduit compression by the thoracic outlet. Nevertheless, it should be remembered that intrathoracic anastomotic leaks can be associated with considerable mortality and pulmonary complications, as opposed to a cervical anastomotic leak, which typically will present as a local wound infection requiring drainage only.

There has been considerable debate and study over the use of hand-sewn vs. partially stapled vs. circular-stapled anastomosis and their associated leak and stricture rates. Several prospective, randomized studies have been completed examining this with mixed results. Two separate meta-analyses analyzing 12 randomized, controlled studies have concluded no difference in leak rates between these methods (though stricturing does appear to be more common with the use of circular stapling) [16, 18]. Our practice, regardless of intrathoracic or cervical location, is to use a

Table 3.2 Risk factors for anastomotic leak

Technical factors	Patient-specific characteristics
1. Cervical anastomosis	1. Age
2. Tension	2. Diabetes mellitus
3. Excessive intraoperative blood loss	3. Steroid use
4. Prolonged operation	4. Congestive heart failure
5. Compromised blood supply/venous drainage	5. Hypertension
	6. Renal insufficiency
	7. Poor nutritional status

modified Collard technique, creating a partially stapled anastomosis where the posterior wall is created with a linear cutting stapler, and the anterior hood is closed using a single- or two-layer hand-sewn technique.

The other major technical factor often cited as a risk factor for anastomotic leaks has been the use of neoadjuvant chemoradiation therapy. It is logical to think anastomotic leak may be more common in this group as a result of radiation changes to the neoesophageal conduit, remaining native esophagus, and operative field. Conversely, the landmark CROSS trial, a randomized trial comparing patients undergoing esophagectomy with or without neoadjuvant chemoradiotherapy, found no significant difference in rates of anastomotic leakage [19]. A meta-analysis published in 2014 including 23 studies found no difference in rates of postoperative morbidity, including leakage rates [20]. Finally, several studies have examined the volume–outcome relationship for esophagectomy and have shown reduced postoperative mortality at high-volume centers [21]. However, very little work has been done examining the relationship between volume and postoperative complications, including anastomotic leaks, and will need further study.

In addition to these technical considerations, several patient-specific characteristics have been identified as risk factors for both anastomotic leak as well as overall morbidity after esophagectomy and are shown in Table 3.2. A multi-institutional Veterans Administration study identified the most important risk factors for morbidity after esophagectomy to be COPD, diminished functional health, advanced age, albumin less than 3.5 g/dL, alkaline phosphatase greater than 125 U/L, creatinine greater than 1.2 mg/dL, and prothrombin time of greater than 12 s [22]. Perhaps the most important risk factors for breakdown of the anastomoses are those that have a direct effect on tissue healing, namely diabetes, malnutrition, and steroid use. The use of epidural anesthesia has been found to be associated with decreased leak rates in one retrospective study [23], and several other studies have suggested diminished blood flow in the anastomotic end of a gastric tube after the administration of thoracic epidural bupivacaine [24, 25]. These seemingly dichotomous findings will need to be further examined in future studies before any definitive conclusion can be made.

Presentation and Identification of a Leak

Clinical presentation of anastomotic leaks can be quite variable and can range from asymptomatic to severe sepsis. The severity of presentation is largely secondary to the size and location of the leak. Urschel et al. proposed a frequently cited four-category classification in 1995: clinically silent leak, early fulminant leak, clinically apparent thoracic leak, and clinically apparent cervical leak [26]. This classification system provides a convenient framework to discuss the presentation and identification of post-esophagectomy anastomotic leaks.

Clinically silent leaks are those found on imaging studies alone. Routine gastrografin/barium esophagram is often pursued one week after esophagectomy by many surgeons, ourselves included. These imaging studies will occasionally show extraluminal extravasation of contrast material into a contained collection (Fig. 3.1). Other methods of detection include careful physical examination, chest radiograph showing new right pleural effusions in transthoracic esophagectomy, and CT scan. These leaks are typically the result of a small defect in the anastomosis itself. As a result, patients with clinically silent leaks will often remain asymptomatic, or only have subtle clinical findings missed at first glance, such as

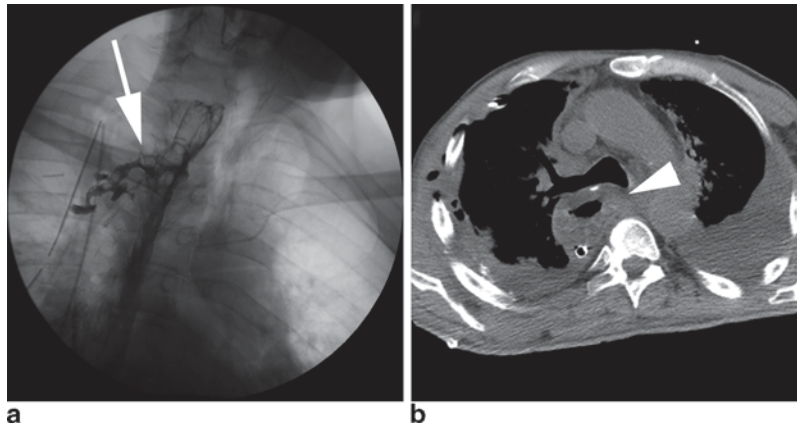

Fig.3.1 Commonly used imaging studies to evaluate for an anastomotic leak include contrast esophagram (**a**) and CT scans (**b**). Esophagrams may show contrast extravasation freely into the chest or into a contained leak (*arrow*). CT scans may have a number of findings including worsening pleural effusions, esophageal thickening (*arrowhead*), or possible contrast extravasation

low-grade fevers and mild tachycardia. Left untreated, these leaks will continue to progress and can lead to significant morbidity. Esophageal surgeons must therefore maintain a high index of suspicion in order to not miss these often imperceptible findings.

Early fulminant leaks are the most life-threatening manifestations of anastomotic leaks. They are typically the result of complete or near-complete necrosis of the neoesophagus, usually due to compromised arterial blood supply or venous drainage. Careful preparation of the gastric conduit is of paramount importance in order to avoid this dread complication. These patients will typically present in profound vasodilatory shock within 48–72 h of esophagectomy. Prompt recognition, resuscitation, and operative intervention are required in order to avoid significant morbidity and/or death.

Clinically apparent thoracic leaks in patients undergoing Ivor-Lewis esophagectomy can be a source of significant morbidity. Presentation can vary considerably. Possible signs include changes in character or quantity of chest tube drainage, new pleural effusions or pneumonias, worsening chest pain, fever, tachycardia, new onset atrial fibrillation, and worsening leukocytosis. Any change in clinical status must therefore be assumed to be the result of an anastomotic leak until proven otherwise. Late leaks may present as a fistula to the trachea or right main stem bronchus with recurrent pneumonias and aspiration of gastric contents (Fig. 3.2). Lastly, clinically apparent cervical leak after transhiatial or three-hole esophagectomy will typically present with low grade fevers, new-onset atrial fibrillation, neck erythema and cellulitis, severe halitosis, and possibly purulent drainage. Prompt recognition on physical exam is again of utmost importance.

Regardless of classification, identification of an anastomotic leak requires a high index of suspicion in order to recognize the subtle early clinical findings mentioned previously. Several imaging studies can help confirm the diagnosis of a leak. The most commonly used study is a contrast esophagram with gastrografin followed by barium in order to improve sensitivity (Fig. 3.1a). Unfortunately, the sensitivity of contrast swallow studies for routine identification of a leak has been reported as low as 45−80%, and as many as 40% of leaks may be missed [27, 28]. For this reason, many centers no longer obtain routine esophagrams. Our practice continues to be obtaining an esophagram on the seventh postoperative day to evaluate gastric emptying as well as to evaluate for anastomotic leakage. CT scans may

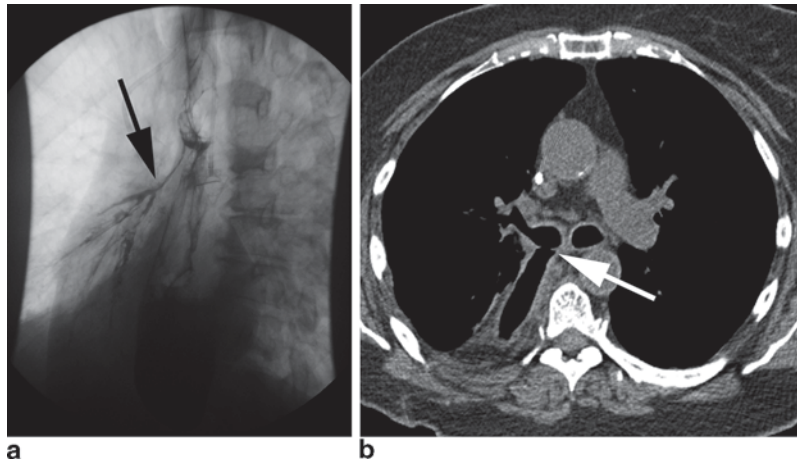

Fig.3.2 Chronic leaks can fistulize to adjacent organs including the tracheobronchial tree as seen here on esophagram (*black arrow*) (**a**) and CT scan (*white arrow*) (**b**)

reveal any number of findings consistent with a leak such as a new pleural effusion, esophageal thickening, or possible contrast extravasation (Fig. 3.1b). As a result, however, the specificity of these findings for a leak is significantly lower than esophagram. Nevertheless, one study has shown that the addition of a CT scan to a contrast swallow can increase sensitivity and negative predictive value for the identification of a leak to 100 % [28]. Other useful imaging tests include upper endoscopy, which allows for direct visualization of the degree of mucosal involvement and quantification of amount of healthy conduit remaining (Fig. 3.3). Additionally, it has the added advantage of allowing for possible therapeutic interventions such as stenting and dilation as will be discussed later in this chapter.

Prevention and Management of Anastomotic Leaks

As previously mentioned, the ideal management of a leak is to prevent one from occurring at all through careful planning, patient selection, and technical care. A technical discussion regarding the creation of a gastric conduit is beyond the scope of this chapter, as is further detailed discussion of colon and jejunal interposition. Keys to any anastomosis are the basic surgical principles

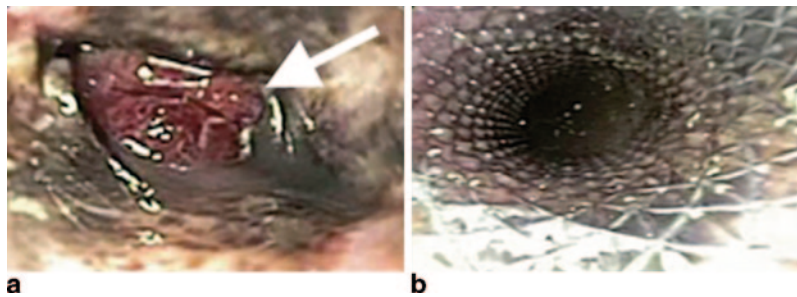

Fig.3.3 Esophagoscopy may reveal mucosal irregularities, visualization of the anastomotic dehiscence (*arrow*), and/or mucosal ischemia (**a**) Endoscopic stent placement is becoming an appealing less invasive treatment for anastomotic leaks (**b**)

of adequate blood supply and lack of tension. As previously mentioned, preservation of the right gastroepiploic artery and venous drainage along the lesser curve during the creation of the gastric tube is paramount. Preservation of the right gastric artery is ideal, if possible, as long as this does not compromise length and the ability to create a "tension-free" anastomosis. Maintaining the integrity of these vessels is critical as placement of the anastomosis occurs at the gastric tip, the site of least vascular supply and thus greatest ischemia.

Pre-esophagectomy ischemic preconditioning of the conduit, a procedure in which the arterial blood supply to the stomach (excluding the right gastroepiploic artery) is ligated either surgically or angiographically several days prior to esophageal resection, has been the focus of much recent research. Theoretically, exposure of the gastric tip to ischemic conditions prior to the creation of the anastomosis would avoid acute ischemia and improve blood flow at the time of surgery, thereby decreasing leak rates. While some studies have suggested decreased morbidity with this technique, no significant improvement in leak rates have been identified [29–31]. To date, a single prospective study has been completed regarding this question. Patients underwent laparoscopic ischemic conditioning followed by minimally invasive esophagectomy, and found no improvement in perfusion of the gastric conduit trip [31]. Further, the concept of intentionally creating ischemia of the conduit has been met with much resistance among surgeons and has failed to gain steam.

Unfortunately, despite all attempts at prevention, anastomotic leaks will still occasionally occur. Appropriate management of an anastomotic leak is dependent upon the severity of the clinical presentation. Clinically silent leaks can often be treated nonoperatively with antibiotics (if located intrathoracic), cessation of oral intake with enteral nutritional support via feeding jejunostomy placed at the time of the index operation, and adequate drainage, either via opening of the neck incision with cervical anastomoses or percutaneous chest tube drainage for intrathoracic anastomoses. Such patients will typically recover without long-term morbidity other than increased likelihood of developing an anastomotic stricture [2–4].

On the other end of the spectrum, early fulminant leaks require prompt recognition and surgical intervention in order to prevent overwhelming sepsis and death. Leaks of this nature require urgent operative reexploration with resection of the necrotic conduit. If caught early and the remaining proximal esophagus is healthy, reconstruction with colon or jejunal interposition can be attempted. If the operative field is significantly inflamed or infected, a substernal approach for the new conduit may be attempted. If the patient exhibits signs of severe sepsis, if the proximal esophagus is not healthy enough to reconstruct, or if the patient is too unstable for reconstruction, the only option remaining is proximal esophageal diversion with a cervical esophagostomy and placement of enteral feeding access. Recurrent, chronic leaks may as a last resort require proximal diversion as well. In this setting, it may often seem easier to avoid resection of the necrotic conduit at the time of initial reoperation and "live to fight another day." Unfortunately, later conduit resection at the time of reconstruction is typically met with considerable difficulty secondary to dense adhesions, making an already difficult operation significantly worse. Furthermore, leaving the necrotic conduit *in situ* creates an ongoing source for infection and worsening inflammatory response. In our experience, it is advantageous in the long run to resect the necrotic neoesophagus at the time of esophageal diversion.

Cervical leaks, while more common than intrathoracic leaks, are in many ways more easily managed than intrathoracic leaks. Patients with mild systemic symptoms and or evidence of early local wound infections can be treated with opening of the neck incision, enteral nutritional support, and, if cellulitis of the incision is present, antibiotics. More severe symptoms may occasionally require wound washout. Typically, with local wound care and adequate nutrition, the wound will form granulation tissue and the leak will heal over time without long-term morbidity. Occasionally, progression of symptoms requires

debridement and revision of the anastomosis. If this does occur, buttressing of the anastomosis with available muscle, most commonly the sternocleidomastoid, can be used to reinforce the closure. Rarely does ongoing, chronic leakage require resection of the conduit.

Morbidity after intrathoracic anastomotic leak is more common and can have considerably more consequences than cervical leaks. Luckily, the incidence of intrathoracic leaks is quite low (Table 3.1), and recent analysis of the Society of Thoracic Surgeons (STS) database has shown no difference in mortality rate between cervical and intrathoracic leaks [5]. Drainage of enteral contents into the right pleural space can result in significant systemic symptoms. Aside from the immediate institution of antibiotics and cessation of oral intake, patients will typically require wide drainage of the pleural space. For stable patients with small, contained leaks, this can often be accomplished percutaneously with resolution of the leak within a few weeks [4, 32]. Any unstable patient, or a patient not improving with chest tube drainage, should be expeditiously returned to the operating room.

At the very least, surgical therapy should consist of wide pleural drainage and debridement of any devitalized tissue. The origin of the leak in this situation can be either the anastomosis or the gastric staple line. Therefore, both should be carefully inspected. If the anastomosis appears well perfused and viable, debridement with primary suture repair can be attempted. In this setting, small to moderate anastomotic dehiscences can be reinforced with viable muscle, such as intercostal, serratus, latissimus, or myocutaneous pectoralis major muscle flaps. Commonly used options include intercostal muscle flaps and omentum. These have the advantage of providing complete tissue coverage of the anastomosis with healthy muscle that maintains excellent viability and vascular supply. Omentoplasty has been shown to reduce incidence of anastomotic leak when used to reinforce the anastomosis at time of initial esophagectomy and is excellent option to reinforce a revised anastomosis [33]. Unfortunately, little to no omentum is typically left at the time of reexploration after tubularization of the gastric conduit. Finally, a complete disruption of the anastomosis requires resection of the conduit back to healthy, viable tissue. If there is minimal leakage of enteric contents into the thoracic cavity along with healthy tissue available in the conduit and proximal esophagus with adequate length, a new anastomosis can be fashioned. However, care must be taken not to violate the two foremost principles of surgical enteric anastomoses: adequate blood supply and no tension. If there is any doubt in regard to this, cervical esophageal diversion with subsequently reconstruction, potentially with a substernal conduit, should be considered.

The final step in the management of an anastomotic leak involves early esophageal dilation in order to prevent stricturing and promote easy flow of oral contents through the neoesophagus. Strictures occur significantly more frequently after anastomotic leak, with one study showing an odds ratio of 3.8 for the development of a stricture after leak, and often require serial dilations [6]. Several case series have reported that anywhere from zero to 82% of strictures were preceded by an anastomotic leak [34]. STS database analysis has shown postoperative dilation is required 7.7% of the time after anastomotic leak [5]. Early dilation will help to prevent chronic difficulties with reflux and dysphagia and should be a routine part of leak management.

Future Directions

As experience with self-expanding esophageal stents grows, this modality is being more frequently used for the treatment of contained leaks in conjunction with percutaneous drainage and antibiotics (Fig. 3.3b). A recently published review from Dasari et al. pooled data from 24 case series ranging in size from 3 to 25 patients [35]. The authors reported a technical success rate of over 90% and clinical success rate of 81%. Benefits of stenting may include decreased postoperative morbidity, length of stay, and cost. However, stenting often requires multiple reinterven-

tions as stent migration is a common problem given the nonstrictured lumen, with Dasari et al. reporting an overall migration rate of 20% and reintervention rates of 17% for endoscopic therapy and 10% for surgical therapies. Other risks include the unlikely possibilities of further anastomotic dehiscence due to the stent and stent-related bleeding. Additionally, long-term stricture rates and dysphagia remains to be seen as long-term results are lacking, and further prospective analysis is still required. If a stent is used, we recommend removal 3–4 weeks after placement in order to minimize these potential complications.

Recent advances in endoscopic therapies also include clip placement and endoscopic vacuum-assisted closure, in which a VAC sponge is inserted into the necrotic cavity under endoscopic visualization. The vacuum tube is brought out through the nose and connected to 125 mmHg continuous suction. The sponge is then changed twice weekly until the cavity was closed. The largest published case series of this technique included 39 patients found an 84% closure rate and 9% stricture rate [36]. Obvious concerns with this technique, though, include multiple endoscopies to replace the sponge as well as the need for persistent nasogastric vacuum tubing. Additionally, it is unclear how large of a defect can be closed using this technique.

The use of endoscopic clips (both through the scope and over the scope) and suturing devices have been reported in several case series to be possible [37]. It should be noted that the majority of these were in patients with spontaneous perforations, though a few reports included esophageal anastomotic leakage. These methods are fast and relatively safe. However, they are limited in regards to the size of fistula or perforation which can be closed given the size of the clip. Additionally, if the clip were to fail and fall off, the consequences could potentially be significant. Literature with regard to these techniques is currently limited to small case series, and further study, especially in regard to their use for closure of anastomotic perforations, is needed before they can be routinely recommended.

Finally, a relatively new concept with regard to leak prevention is the use of spectroscopy and near-infrared angiography to evaluate tissue perfusion at the conduit tip. A few small case series have identified a larger degree of conduit ischemia in patients who developed anastomotic complications [38–41]. The sensitivity of this method in predicting leakage, however, remains to be seen. Furthermore, how to interpret such data remains to be seen. Should tissue with "inadequate" perfusion be resected in order to anastomose tissue with better blood supply, or will the resultant shorter conduit have increased tension, thereby increasing possibility of leakage? These questions will need further clarification with larger, prospective studies.

Conclusion

Since the inception of esophagectomy, anastomotic leak has been the most feared possible complication. While leak rates have decreased over time, esophageal leak remains relatively common when compared with rates of enteric anastomotic leaks elsewhere in the body. Careful handling and preservation of the gastric conduit is the most important modifiable risk factor for the development of an anastomotic leak. Early recognition requires a high index of suspicion and vigilance, as leaks can often be missed. Management typically requires either drainage or revision of the anastomosis, and rarely is conduit resection required outside of a fulminant leak. Careful attention to risk factors for leaks can minimize their occurrence. Finally, when identified early and appropriately managed, catastrophic outcomes can be minimized.

Key Points on Avoiding an Esophageal Anastomotic Leak

1. Carefully maintain arterial blood supply of the gastric conduit through the right gastroepiploic artery.

2. Preserve as much of the venous drainage along the lesser curvature of the conduit as possible.
3. Leak rates may be higher with cervical anastomotic leaks, however morbidity is typically considerably less.
4. Minimize anastomotic tension through adequate mobilization of the conduit and its blood supply (i.e., Kocher maneuver of the duodenum and dividing the left and short gastric arteries in the case of a gastric conduit).
5. Creating a conduit of ideal width (4–5 cm) to allow for easy emptying while not compromising collateral blood flow.

Key Points on Diagnosis and Managing an Esophageal Anastomotic Leak

1. Maintain a high index of suspicion.
2. Contrast esophagram will show most leaks, but is not 100 % sensitive.
3. Early drainage is key.
4. Early resuscitation and operative intervention is necessary with fulminant leaks.
5. Small, clinically silent leaks can be managed with nonoperative interventions including drainage, cessation of oral intake, enteral nutritional support via feeding jejunostomy, and variably antibiotics.

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Transhiatal Esophagectomy—Intraoperative Disasters

4

Mark B. Orringer

Introduction

In the mid-1970s, transhiatal esophagectomy (THE) without thoracotomy and the cervical esophagogastric anastomosis (CEGA) was rediscovered [1]. Prior to that time, the operation was seldom used, primarily in patients undergoing a laryngopharyngectomy for carcinoma and esophageal replacement with stomach [2, 3]. THE circumvented the leading complications associated with a traditional transthoracic esophageal resection and intrathoracic esophagogastric anastomosis—(1) respiratory insufficiency associated with a combined thoracoabdominal operation and (2) mediastinitis from an intrathoracic esophageal anastomotic leak. Detractors of the operation argued that the "blind" mediastinal dissection would inevitably result in uncontrollable hemorrhage, and inability to do as complete a mediastinal lymph node dissection as with the traditional open approach made it an unacceptable operation from an oncologic standpoint. With now more than 30 years of experience with THE, these latter concerns have not been realized, and numerous reports in the surgical literature have documented the relative safety and efficacy of this approach and with survival comparable to that achieved with transthoracic esophagectomy for carcinoma [4–8]. As a result, the author regards THE and CEGA as the approach of choice in patients requiring esophageal resection and reconstruction for both benign and malignant diseases [9].

As is the case with every major operation, a successful outcome is strongly influenced by careful patient selection and a highly organized and consistent intraoperative approach. Intraoperative "disasters," primarily hemorrhage and airway tears, associated with THE are fortunately rare and are often retrospectively predictable by assessing the appropriateness of patient selection for the operation. In our report of 2007 THEs, the operation was possible in 98 % of those in whom it was undertaken [9]. However, there were four (0.19 %) intraoperative deaths from uncontrollable hemorrhage occurring during transhiatal mobilization of the esophagus from the posterior mediastinum. Inordinate intraoperative bleeding (>4000 ml) occurred in 8 additional patients: 4 *intramediastinal* due to either a torn azygos vein (3) or large prevertebral collateral vein (1); 3 *intraabdominal* due to portal hypertension from cirrhosis (2) or splenic vein injury (1); and 1 from a right ventricular laceration during chest tube insertion. What was popularized 30 years ago as a "blunt esophagectomy" has become much more of a controlled mediastinal dissection through the hiatus, clamping vascular esophageal attachments with 13″ long right-angle clamps, and dividing and ligating them through the hiatus. Thus, the average intraoperative blood loss has fallen from a median of 510 ml in those operated upon between 1976 and 1998 to 300 ml in those operated upon between 1998 and 2006

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Table 4.1 Intraoperative blood loss with transhiatal esophagetcomy[a] (2007 patients). (Reproduced with permission from [14] © Wolters Kluwer 2005)

	Group I (1976−1998)			Group II (1998–2006)		
	No.	Range (cc)	Mean (cc)	No.	Range (cc)	Mean (cc)
Benign	276	100–4000	795	203	50–2000	366
Carcinoma	*778*	35–3700	635	*739*	15–3100	368
Total	*1054*	*35–4000*	*677*	*942*	*15–3100*	*368 ($p \leq 0.0001$)*

[a] Excludes 4 intraoperative deaths, 3 from Group I and 1 from Group II, 2 with benign disease and 2 with carcinoma, and 8 surviving patients, 6 in Group I and 2 in Group II, who experienced inordinate intraoperative blood loss (>4000 cc.)

($p < 0.0001$) (Table 4.1). Overall, a thoracotomy was performed to control mediastinal bleeding during the esophagectomy in nine patients (<1%) and was successful in five.

Both massive intraoperative bleeding and a tracheal tear complicate <1% of all THEs. Neither of these events is commonly mentioned in review articles on the operation. Because these are such relatively uncommon occurrences, a periodic intraoperative "fire drill"—"walking through" the steps of controlling untoward mediastinal bleeding or an airway tear encountered during a THE, including indications for a thoracotomy and selection of the appropriate side—may prove lifesaving if these "disasters" occur.

Indications and Contraindications to THE

The surgeon considering a THE must be keenly aware of clinical "red flags" that may portend major intraoperative hemorrhage or injury to the adjacent airway. In the majority of patients requiring an esophageal resection and reconstruction, THE and a CEGA are applicable. In the last reported series of 2007 THEs by the author and his associates, there were 1525 (76%) operations for carcinoma and 482 (24%) for benign disease (Table 4.2) [9]. In patients with **achalasia**, the common indications for esophageal resection were a failed prior esophagomyotomy, often with a subsequent reflux stricture, and a tortuous megaesophagus (>6 m) [10]. Technical features unique to achalasia and increasing the likelihood of bleeding during a THE include (1) adherence of the myotomized segment to the descending thoracic aorta; deviation of the megaesophagus into the right chest; (2) larger than usual aortic esophageal arteries; and (3) a wider than usual cervical esophagus, which is more difficult to mobilize and encircle. While the need for an esophagectomy for a **reflux stricture** has been dramatically reduced by the advent of proton pump inhibitors (PPIs), the number of **failed** laparoscopic **antireflux operations** is increasing, many after multiple procedures, or with perihiatal mesh, often with erosion into the esophagus. In the author's experience, the likelihood of achieving long-term reflux control and/or relief of dysphagia after two or more prior antireflux operations is so low that esophageal resection and reconstruction are the "best" alternative *if* a reoperation is advised. However, the decision to resect the esophagus for benign disease should not be made lightly. Complaints of occasional reflux or intermittent dysphagia associated with a recurrent hiatal hernia, for example, may be less problematic in the long run than an esophageal anastomotic stricture or chronic dumping syndrome which may follow an esophagectomy. With **mesh erosion** into the esophagus, there is little option other than an esophageal resection. The distal periesophageal and esophagogastric junction inflammatory reaction associated with a mesh erosion may be extensive and result in bleeding as the inflammatory mass is mobilized away from the adjacent aorta. Parenthetically, although the mesh erosion is at the esophagogastric junction, a THE and CEGA is a better option than a limited distal esophagectomy and low intrathoracic esophagogastric anastomosis, particularly in an infected field due to local sepsis from the erosion. This latter operation insures lifelong gastroesophageal reflux and should never be done for benign disease. The author has

Table 4.2 Indications for transhiatal esophagectomy (2007 patients). (Reproduced with permission from [14] Wolters Kluwer 2005)

	Number (%)		
Patients	Group I-1063 pts	Group II-944 pts	Total-2007
	1976–1998	1998–2006	1976–2006
Benign conditions	278 (26%)	204 (22%)	482 (24%)
Neuromotor dysfunction	92 (33%)	47 (23%)	139 (29%)
Achalasia	69	44	113
Spasm/dysmotility	21	3	24
Scleroderma	2	0	2
Stricture	74 (27%)	21 (10%)	95 (20%)
Gastroesophageal reflux	40	7	47
Caustic ingestion	18	6	24
Radiation	4	2	6
Other	12	6	18
Barrett's mucosa with high-grade dysplasia	53 (19%)	90 (44%)	143 (30%)
Recurrent gastroesophageal reflux	21 (8%)	6 (3%)	27 (6%)
Recurrent hiatus hernia	14 (5%)	14 (7%)	28 (6%)
Acute perforation	15 (5%)	9 (5%)	24 (5%)
Acute caustic injury	5 (2%)	1 (1%)	6 (1%)
Other	4 (1%)	16 (8%)	20 (4%)
Carcinoma of the intrathoracic esophagus			
Site	*785 (74%)*	*740 (78%)*	*1525 (76%)*
Upper third	35 (4%)	16 (2%)	51 (3%)
Middle third	164 (21%)	63 (9%)	227 (15%)
Lower third and/or cardia[a]	586 (75%)	661 (89%)	1247 (82%)

[a] Includes pathologic gastric carcinomas involving the cardia and lower esophagus

recently learned of such a patient who developed a low esophagogastric anastomotic leak following a limited transabdominal resection for mesh erosion, survived this, and presented more than 2 years later with an aorto-esophageal fistula at the site of the prior anastomotic leak—an extremely rare cause of late major hemorrhage associated with an intrathoracic esophageal anastomosis. This was controlled with an endovascular aortic stent.

While in the current experience of the author and his associates with more than 3000 THEs, this operation has been possible in 98% of those requiring an esophagectomy, and the safe surgeon must recognize that there *are* contraindications to proceeding with the procedure. Patients with upper and mid-third esophageal cancers invading the adjacent airway (proven with bronchoscopy and biopsy, which should always be performed as a part of the preoperative evaluation) are not candidates for a THE. When an esophageal tumor is located in the mid-esophagus in proximity to the carina and main bronchi, at approximately 25 cm from the upper incisor teeth at esophagoscopy, a more difficult transhiatal esophageal mobilization than with a distal carcinoma is usually encountered, and the risk of an airway tear is increased. Those with histologically documented stage IV disease (distant metastasis) are similarly not candidates for resection; this includes the patient found to have "just" a 1-cm liver metastasis at the time of abdominal exploration. Systemic disease cannot be cured with local therapy (i.e., surgery). Without question, the single most important contraindication to proceeding with a THE is the surgeon's assessment of esophageal mobility on palpation through the hiatus. Fixation of the esophagus or its contained tumor to adjacent mediastinal structures can result in an untoward bleeding from a torn aorta or azygos

vein or a tracheal tear during an attempted THE. Surgical judgment is critical in such situations. Prior radiation therapy does not preclude a THE, but the technical difficulty of mobilizing the esophagus may be greatly increased.

Preoperative Risk Factors for Bleeding with a THE

While it may seem obvious, a careful history to rule out **bleeding tendencies** or a family history of **clotting disorders** should always be obtained. The patient population requiring an esophagectomy is often older, and a number of conditions more common in this group result in the need for **anticoagulation** and **platelet inhibitors,** which may result in untoward bleeding with a THE unless carefully monitored and discontinued for an appropriate time before surgery. Three of the most frequent indications for anticoagulation among these patients are chronic atrial fibrillation, coronary artery stents, and prior thromboembolic disease, particularly that in association with neoadjuvant chemotherapy and radiation therapy for esophageal carcinoma [11–13].

A history of **prior esophageal surgery**, particularly an esophagomyotomy, which may result in the exposed esophageal submucosa adhering to the adjacent descending thoracic aorta, may portend a more difficult esophagectomy; especially with reoperations, bleeding from the spleen may occur during the upper abdominal gastric mobilization as left upper quadrant adhesions are divided. It has long been my practice in these operations to confront the gastric fundus mobilization and division of the high short gastric vessels as soon as possible after opening the abdomen while the surgical team is at its freshest and inadvertent splenic injury due to less likely retraction. As the dissection is carried superiorly through the diaphragmatic hiatus and the esophageal mobilization commenced, especially in those who have had a prior esophagomyotomy, narrow Deaver retractors should be placed into the hiatus and sharp dissection of the esophagus from the aorta under direct vision carried out. Blunt dissection of the esophagus adherent to the aorta may have dire consequences. In the patient with a megaesophagus of achalasia, deviation of the "sigmoid" esophagus into the right chest is common, and not only dissecting into the right chest but also beneath the azygos vein may be hazardous.

The presence of **mediastinal calcification** due to old granulatous disease on the preoperative chest radiograph and CT scan, particularly in the subcarinal region, may be the harbinger of potential bleeding during the transhiatal esophageal mobilization in this area. While such calcification per se does not preclude a THE, if the surgeon encounters increased difficulty mobilizing the subcarinal esophagus, there must be a low tolerance to convert to an open thoracotomy and free the esophagus from the mediastinum under direct vision.

Portal hypertension is a relative contraindication to esophagectomy and has been responsible twice for rare massive intraoperative abdominal bleeding in our patients. The author regards the presence of **ascites** from liver disease as an absolute contraindication to esophagectomy. Even if untoward bleeding does not occur, venous congestion of the mobilized stomach due to portal hypertension may have devastating consequences if an esophagogastric anastomosis is attempted.

Finally, it has been the personal observation of the author that obese, "**soft**," often elderly **women** have experienced the preponderance of intraoperative massive bleeding during a THE, perhaps being more prone to an azygos vein tear because of general tissue laxity. Such a body habitus or tissue strength does not preclude a THE, but should alert the surgeon to the need to proceed cautiously.

General Considerations

The patient is positioned supine, the neck extended by placing a small rolled sheet under the scapulae, and the head turned to the right and supported on a soft head ring. The operative field is **wide** and includes the skin of the neck, chest, and abdomen from the angle of the

mandible superiorly to the pubis inferiorly and anteriorly to both mid-axillary lines. There must be adequate room to place a chest tube low in the anterior axillary lines as indicated. Two suction lines with Yankauer suckers are routine, one near the patient's head and the other at the lower end of the table. After the abdominal phase of the operation and before beginning the transhiatal esophageal mobilization, the Yankauer sucker at the head of the table is removed and replaced with a longer 28 Fr Argyle Saratoga sump catheter. This catheter is inserted into the posterior mediastinum through the cervical wound after each phase of the esophageal mobilization (posterior, anterior, and lateral) and the mediastinum inspected through the hiatus to establish that excessive bleeding is not occurring. As a general rule, the operation commences with mobilization of the stomach through the upper midline abdominal incision. Exposure and division of the high short gastric vessels are carried out first, when the operative team is fresh, and untoward traction on the left upper quadrant retractor with resultant injury to the spleen is less likely to occur. Splenic injury necessitating a splenectomy has occurred in approximately 4% of our THE patients, especially in those who have had prior fundoplications that must be taken down if the stomach is going to serve as an esophageal replacement and reach to the neck for a construction of a CEGA. The need for a splenectomy for control of bleeding is uncommon, but when required, especially in a "re-do" abdomen, care must be taken to preserve the integrity of the right gastroepiploic artery, the primary blood supply of the gastric esophageal substitute. In patients undergoing a THE for a distal esophageal Barrett's adenocarcinoma occurring in association with a large paraesophageal hiatal hernia, care must be taken to deliver the greater curvature of the stomach out of the hiatus before commencing division of what appears to be the high short gastric vessels. It is easy in such patients to mistakenly divide the right gastroepiploic artery erroneously felt to be a short gastric vessel.

Anesthetic Considerations

An epidural catheter for postoperative analgesia, a standard endotracheal tube, and a Foley catheter are routinely used. As indicated above, the patient is positioned supine. Two large bore peripheral intravenous lines and a radial artery catheter for continuous monitoring of the blood pressure are placed and well secured, and the arms are padded and placed at the sides. Although the anesthetist may feel uncomfortable about not having direct access to the IVs intraoperatively, this positioning gives the surgeon and his assistant optimal access to the neck, chest, and abdomen from both sides of the table. To avoid prolonged hypotension from cardiac displacement, the surgeon and the anesthesiologist both watch the monitored blood pressure together while the surgeon's hand is in the posterior mediastinum performing the transhiatal esophageal mobilization. Intraoperative monitoring of urinary output is important in these patients with impaired swallowing, many of whom have had preoperative bowel prep, as hypotension due to low intravascular volume is common.

During performance of the transhiatal esophageal mobilization, constant communication between the surgeon and the anesthetist is crucial. As the hand is advanced upward into the mediastinum through the diaphragmatic hiatus, both the surgeon and the anesthetist must monitor the radial artery blood pressure in order to minimize untoward hypotension associated with displacement of the heart by the surgeon's hand. If the surgeon's hand is kept well posteriorly against the spine, hypotension from anterior displacement of the heart is less. After 5–10 s of hypotension in the patient who is not hypovolemic, the blood pressure should quickly return to the normal range within seconds of removing the hand from the mediastinum. This is NOT the time for the anesthesiologist to be correcting hypotension with pressor agents. **Persistent hypotension** after the surgeon's hand is withdrawn from the mediastinum signals either the need for volume replacement or unrecognized mediastinal hemorrhage, not the need for pressors.

Conduct of the Operation

It cannot be overemphasized that THE is not a random wrenching of the esophagus from the posterior mediastinum. The operation has component parts that have been well described elsewhere [14] and will only be briefly mentioned here:

1. the *abdominal phase*: exploration, assessment of the suitability of the stomach as an esophageal replacement, gastric mobilization, a Kocher maneuver, pyloromyotmy, and insertion of a feeding jejunostomy tube;
2. the *cervical phase*: mobilizing and encircling the cervical esophagus, blunt dissection of the upper thoracic esophagus in the superior mediastinum;
3. the *mediastinal dissection* of the esophagus (to be discussed further below);
4. preparation of the gastric conduit, transposition through the posterior mediastinum, and abdominal wound closure;
5. the *cervical esophagogastric anastomosis*.

Considerations about potential major intraoperative bleeding or airway injury are related to the mediastinal dissection of the esophagus. The dissection begins in the abdomen through the diaphragmatic hiatus as the surgeon palpates the esophagus to assess its mobility. Fixation to the spine, descending thoracic aorta, or the airway is a "red flag" that a persistent attempt at resecting the esophagus transhiatally may end in disaster. In the typical case, however, the surgeon inserts one hand through the diaphragmatic hiatus posterior to the esophagus. This hand is advanced superiorly along the prevertebral fascia, constantly against the spine to minimize anterior displacement of the heart and untoward hypotension (Fig. 4.1). Simultaneously, the encircled cervical esophagus is retracted anteriorly as a "sponge-on-a-stick" is advanced through the cervical incision and down into the superior mediastinum dissecting the esophagus free from the prevertebral fascia. Eventually the stick sponge being advanced downward into the mediastinum from "above" meets the fingers inserted through the hiatus from "below," and the first phase of the posterior mediastinal "tunnel" is created

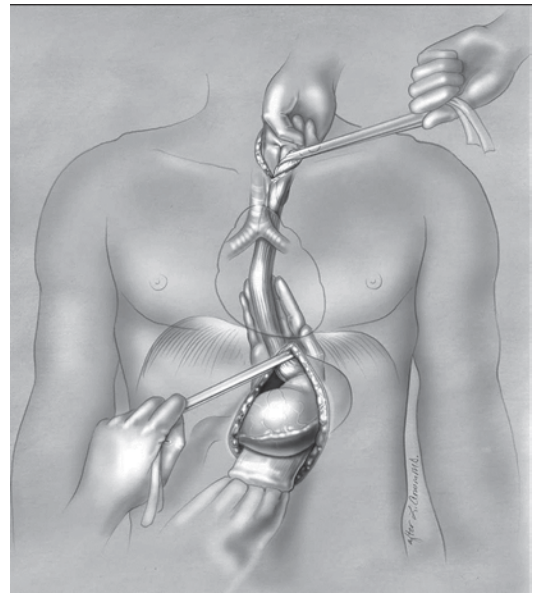

Fig. 4.1 The transhiatal esophageal mobilization begins posteriorly, the surgeon's hand inserted through the hiatus with the volar aspect of the fingers sweeping the esophagus away from the prevertebral fascia and a similar posterior dissection of the upper thoracic esophagus through the cervical incision. (Reproduced with permission from [9] © Elsevier)

(Fig. 4.2). The 28 French Argyle Saratoga sump catheter is inserted through the cervical incision into the mediastinum along the spine, is used to evacuate blood and assess for unusual bleeding, and is then removed. The posterior dissection of the esophagus is generally through relatively avascular tissue planes.

Anterior dissection of the esophagus through the hiatus is a mirror image of the posterior dissection. The esophagogastric junction is retracted inferiorly by gentle downward traction on the mobilized stomach. The surgeon's hand is placed against the anterior surface of the esophagus palm downward and is advanced superiorly into the mediastinum, gently dissecting the esophagus from the posterior pericardium and then the carina (Fig. 4.3). In the neck, the cervical esophagus is retracted superiorly and laterally as two fingers dissect progressively downward along the anterior surface of the esophagus, mobilizing it away from the posterior membranous trachea (Fig. 4.4). The force of the dissection, no matter

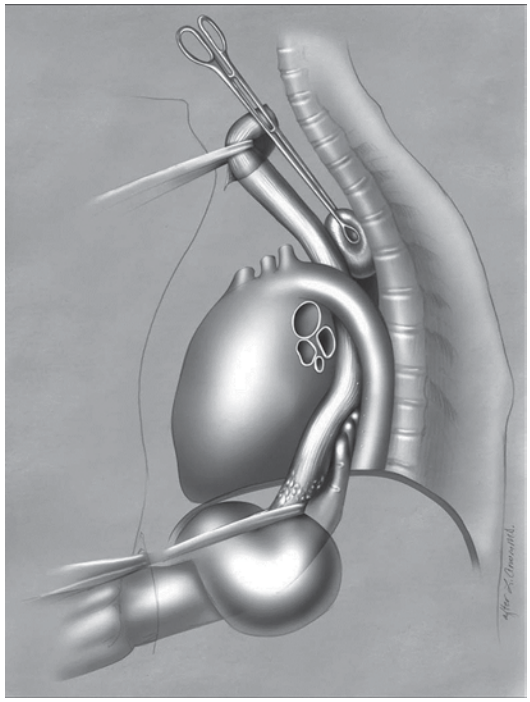

Fig. 4.2 A "half-sponge-on-a-stick" is advanced downward through the cervical incision along the prevertebral fascia until it can be palpated by the fingers inserted from "below" through the hiatus, thereby establishing the first portion of the posterior mediastinal tunnel. (Reproduced with permission from [9] © Elsevier)

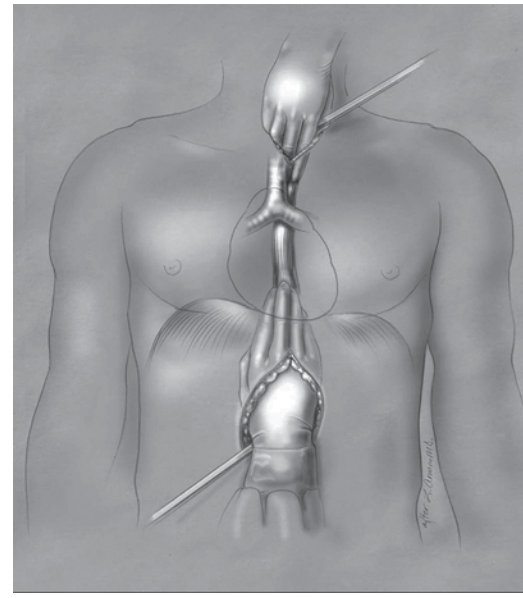

Fig. 4.3 Anterior dissection of the esophagus is performed as a "mirror image," this time with the volar aspects of the finger against the anterior esophageal wall. The posterior membranous trachea is vulnerable to injury as the esophagus is mobilized away from the airway from "below" and "above." (Reproduced with permission from [9] © Elsevier)

how gentle, most be directed posteriorly to avoid a tear of the airway. When the fingers inserted through the cervical wound meet those inserted through the hiatus, the "anterior tunnel" is complete, and the Saratoga sump catheter is again inserted to monitor for untoward bleeding and then removed. Lateral periesophageal attachments are divided between long (13″) right-angle clamps inserted through the hiatus and ligated, minimizing the "blunt" dissection.

With the anterior and posterior esophageal attachments now divided, the cervical esophagus is progressively elevated out of the neck wound as the lateral attachments of the upper thoracic esophagus are swept away by blunt dissection (Fig. 4.5). This results in an approximately 5–8 cm length of circumferentially mobilized upper thoracic esophagus. The hand-inserted palm downward through the diaphragmatic hiatus is advanced upward along the anterior surface of the esophagus until the circumferentially mobilized upper thoracic esophagus is identified by palpation (Fig. 4.6). The esophagus is "trapped" against the spine by the fingers, and with a progressive downward "raking" motion, the remaining lateral esophageal attachments and vagal branches are gently avulsed (Fig. 4.7). Larger vagal branches can be delivered downward until visible through the hiatus and divided using a long right-angle clamp and electrocautery (Fig. 4.7 inset). With mobilization of the thoracic esophagus now completed, the cervical esophagus is elevated several centimeters out of the neck wound, the cervical esophagus divided with a stapler (Fig. 4.8), and the esophagus drawn downward and out of the mediastinum by gentle traction on the stomach.

While it is tempting at this point to "admire" the resected esophagus and for all present at the table to palpate a tumor if present, this should be resisted. As soon as the esophagus is out of the posterior mediastinum, a Deaver retractor is

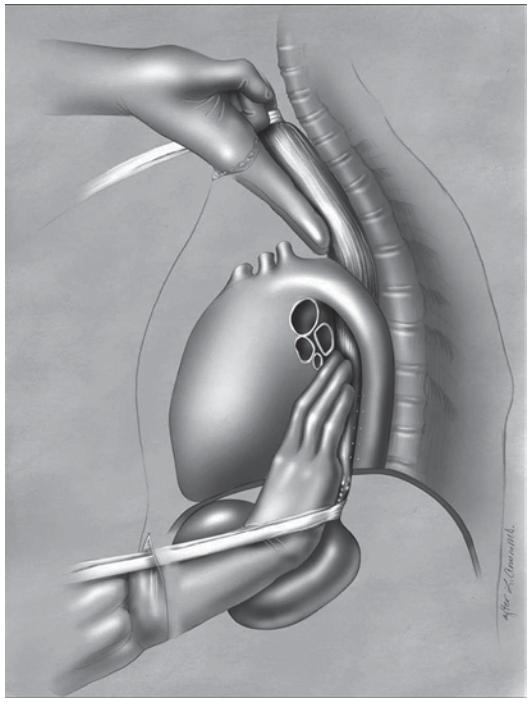

Fig. 4.4 The attachments between the trachea and esophagus are generally flimsy and avascular. As the dissection proceeds, the fingers must exert their force posteriorly, away from the membranous trachea, to avoid a tear. (Reproduced with permission from [9] © Elsevier)

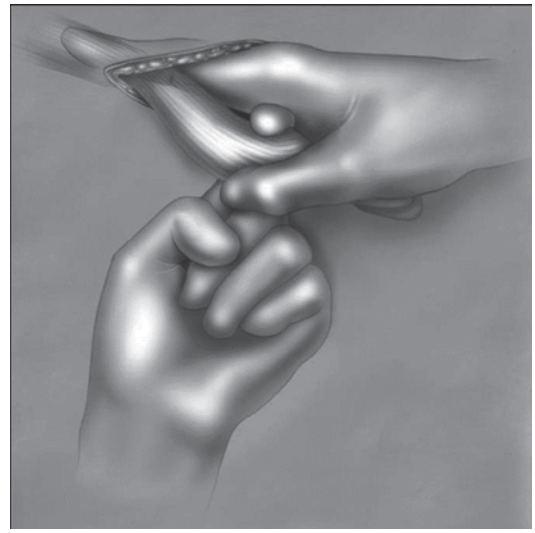

Fig. 4.5 After establishing the anterior and posterior esophageal "tunnels," the additional mobility of the esophagus allows it to be elevated out of the cervical wound for several centimeters by one finger "hooked" beneath it as the index finger of the opposite hand sweeps the lateral esophageal attachments aside. The upper thoracic esophagus is thus entirely circumferentially mobilized and is released back down into the upper mediastinum for the next phase of the esophageal mobilization. (Reproduced with permission from [9] © Elsevier)

inserted into the hiatus and an inspection made for unusual bleeding and entry into one or both pleural cavities (requiring chest tube placement). Routinely, one or two large abdominal laparotomy pads are packed through the hiatus into the mediastinum with long forceps, and while protecting the recurrent laryngeal nerve in the cervical wound, two narrow thoracic packs are advanced downward into the superior mediastinum against the packs placed from below. All packs placed into the mediastinum through either the abdominal or thoracic incisions are "tagged" with a hemostat to avoid inadvertent intraoperative loss and an incorrect count at the end of the case. Once the mediastinum has been packed to allow both pressure and natural hemostatic mechanisms to control any oozing that might be present, and any required chest tubes have been inserted in the appropriate anterior axillary lines and connected to drainage, attention can then be turned to removing the esophagus and upper stomach and fashioning the gastric conduit.

Bleeding Scenarios During THE

In the rare situation in which sudden **unexplained**, **prolonged severe hypotension** occurs during with the esophageal mobilization, even after the surgeon removes his/her hand from the posterior mediastinum, unrecognized bleeding must be suspected. If there is no sign of excessive bleeding from the hiatus or the cervical incision, bilateral 28 French chest tubes should be placed quickly low in the anterior axillary lines, advanced to the apices, connected to suction, and an assessment made for internal bleeding into a chest cavity by evaluating chest tube output. Intravascular volume replacement is achieved through two large bore peripheral IVs placed routinely in these operations. If on retraction of

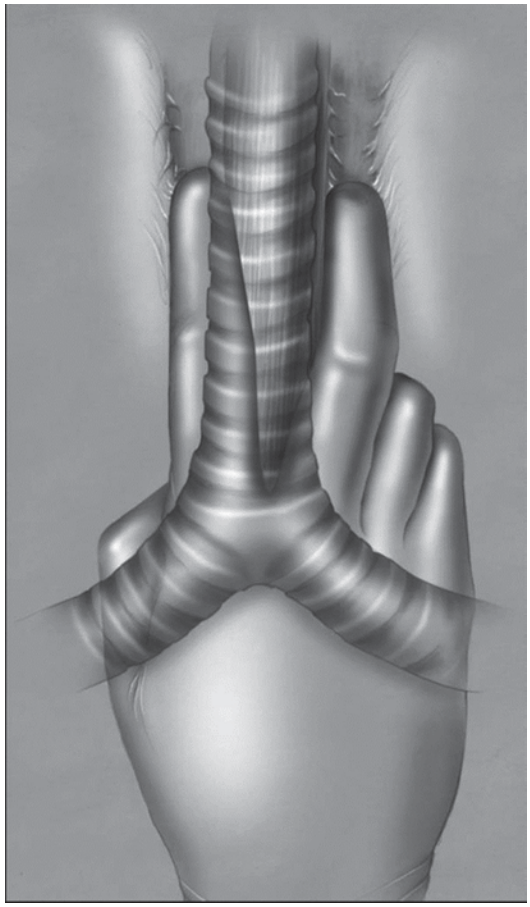

Fig. 4.6 The hand inserted through the diaphragmatic hiatus is advanced superiorly behind the trachea until the segment of completely circumferentially mobilized upper thoracic esophagus can be identified by palpation and "trapped" against the spine between the index and middle fingers. (Reproduced with permission from [9] © Elsevier)

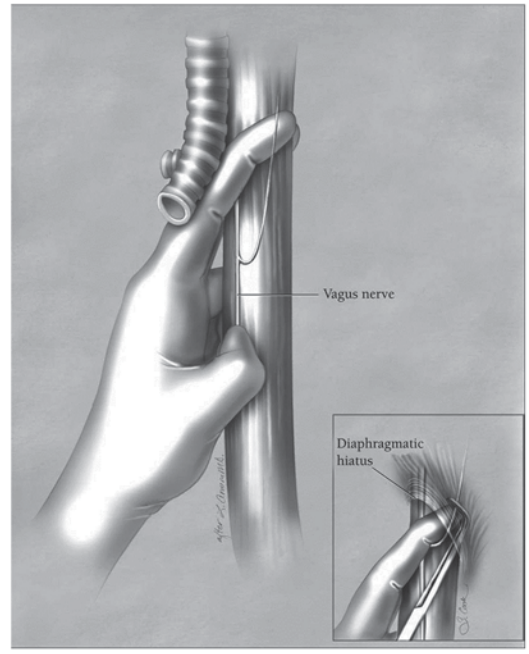

Fig. 4.7 Lateral esophageal attachments and smaller vagal fibers are avulsed by a downward "raking" motion of the fingers that are kept against the spine. Inset—More substantial vagal fibers can be pulled downward until visible through the retracted hiatus and divided using a long right-angle clamp and electrocautery. (Reproduced with permission from [9] © Elsevier)

the hiatus and inspection of the mediastinum, it is determined that appreciable "high" mediastinal bleeding is occurring and draining into the chest through an opening in the pleura (generally on the right and from a torn azygos vein), the posterior mediastinum should be packed quickly through the hiatus with two large laparotomy packs from "below" and two narrow thoracic packs placed behind the esophagus through the cervical wound (Fig. 4.9) (The recurrent laryngeal nerve in the tracheoesophageal groove is protected with the fingers as the packing is carried out.) (Fig. 4.9 inset). The abdomen is quickly closed with 4–5 through and through No. 2 sutures and the incision covered with an adhesive surgical drape (Fig. 4.10 inset). Similarly, the cervical wound is quickly closed with a running nylon suture and covered with an adhesive surgical drape. The patient is turned to the left side, positioned and padded for a **right** posterolateral thoracotomy. The chest is entered through a fifth intercostal space incision and the bleeding site identified and controlled (usually by ligating and suture-ligating the torn azygos vein). Exposure may be facilitated by palpating the carina and having the anesthesiologist advance the endotracheal tube as it is guided into the left mainstem bronchus by the surgeon's fingers. Single lung ventilation of the left lung can then be instituted. If the esophagus has not been removed yet, the esophageal mobilization is completed. The patient is then turned supine once again, positioned as before, and the esophageal replacement with the stomach completed

Fig. 4.8 Once the thoracic esophagus has been completely mobilized, several centimeters are elevated into the cervical wound and the esophagus divided obliquely (not transversely) from front to back so that the anterior tip is longer than the posterior. The esophagus is then delivered downward and out of the mediastinum by gentle traction on the stomach. (Reproduced with permission from [9] © Elsevier)

as originally planned by bringing the stomach through the posterior mediastinum and carrying out the CEGA.

A more common "bleeding scenario" occurs when after dividing the cervical esophagus with the stapler and delivering the mobilized esophagus out of the mediastinum, **dark venous blood** is seen flowing **from the hiatus** and often from the cervical wound as well. Exposure of the posterior mediastinum for control of bleeding is always easier when the esophagus has been removed. If it has not been, and major venous bleeding is identified during performance of the esophagectomy, for example, flowing out of the cervical incision, if possible, quick blunt division of the few relatively small remaining periesophageal attachments allows removal of the esophagus and better visualization through the hiatus. Once the esophagus has been removed, the 28 Fr. Argyle Saratoga sump catheter at the head of the table is quickly inserted into the cervical wound and advanced into the posterior mediastinum to evacuate blood. In the abdomen, as described above, a narrow Deaver retractor is inserted into the hiatus, and the posterior mediastinum is packed tightly with two large laparotomy packs, which are advanced well superiorly to the level of the carina with the help of a long Russian forceps. The sump catheter is removed from the neck wound, and the superior mediastinum is packed tightly with two narrow thoracic packs continually protecting the recurrent laryngeal nerve by placing a finger across the tracheoesophageal groove as the packs are advanced into the wound (Fig. 4.9). While hemodynamic stability is assessed by the anesthesiologist and intravenous fluids are administered to assure an adequate intravascular volume, bilateral chest tubes are placed low in the anterior axillary lines, advanced to the apices of the chest, and connected to under water seal suction drainage (Fig. 4.10). The output from each side is assessed. If the bleeding seems to be controlled, the anesthesiologist is given time to administer more IV fluids and blood as indicated. With a normal blood pressure, and after waiting 5 min for natural hemostatic mechanisms to come into play, the cervical thoracic packs are slowly and sequentially removed from the superior mediastinum and the wound assessed for bleeding. If no blood wells up from the superior mediastinum and out of the cervical wound, attention is redirected to the abdomen. The abdominal packs are slowly and sequentially removed from the posterior mediastinum through the diaphragmatic hiatus, and the Deaver retractor is inserted into the hiatus to facilitate exposure. With the sump suction catheter inserted into the superior mediastinum through the cervical wound, the low and mid-posterior mediastinum is inspected for the source of bleeding, aided by a standard Yonkaur suction to "spot suck." Statistically, a tear of the azygos vein during THE is the most likely source of dark major venous bleeding from the mediastinum, and at times after suctioning clotted blood from the mediastinum, the thrombosed end of the completely divided azygos vein may be seen. A large hemoclip may be placed across the end of the divided vein through the diaphragmatic hiatus in those cases where visualization

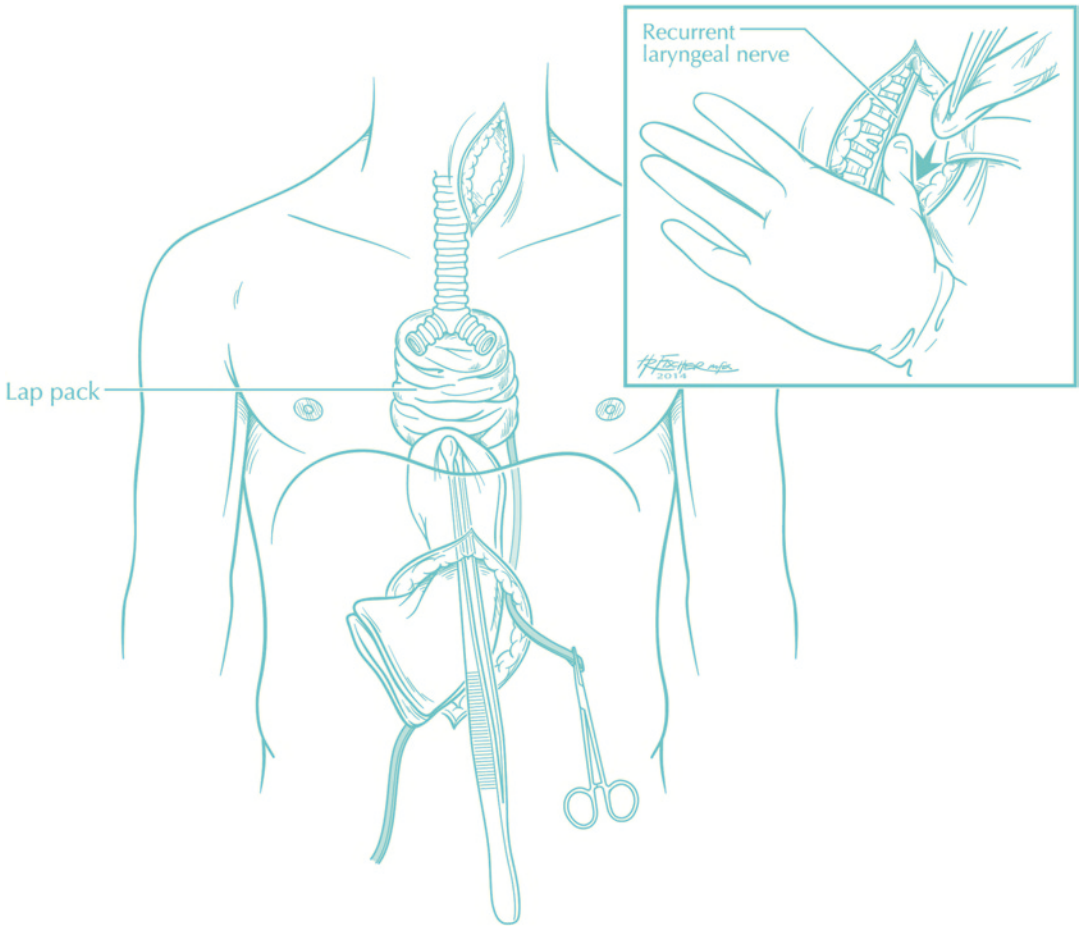

Fig. 4.9 If posterior mediastinal bleeding is documented, in order to tamponade the bleeding, two large laparotomy packs are quickly advanced upward through the retracted hiatus into the mediastinum using long Russian forceps, and two narrow "thoracic" packs are advanced downward into the mediastinum through the cervical incision (*inset*). The recurrent laryngeal nerve in the tracheoesophageal grove is protected by a finger held across it to prevent direct contact between the forceps and the nerve as packing of the superior mediastinum is performed

through the hiatus is possible. If no bleeding site can be seen while looking up into the mediastinum through the hiatus, the cervical wound has no bleeding, and the chest tube output is minimal, the mediastinum should be repacked as above (two large laparotomy packs from below through the hiatus, and two narrow thoracic packs from above through the cervical wound while protecting the recurrent laryngeal nerve). The esophagus is separated from the stomach using progressive applications of the GIA stapler 5–6 cm distal to the esophagogastric junction and preparing the gastric conduit for esophageal replacement. The specimen is removed from the field, and after oversewing the gastric staple suture line, attention is redirected to the mediastinum where another 10–15 min have passed allowing for further natural hemostasis. The mediastinal packs are slowly removed and the mediastinum inspected. If the field is "dry," the stomach is transposed through the hiatus into the posterior mediastinum and the tip delivered into the cervical wound for construction of the CEGA. On the other hand, if after removing the packs from the mediastinum, excessive dark venous bleeding from "high up" and to the right of the midline is encountered,

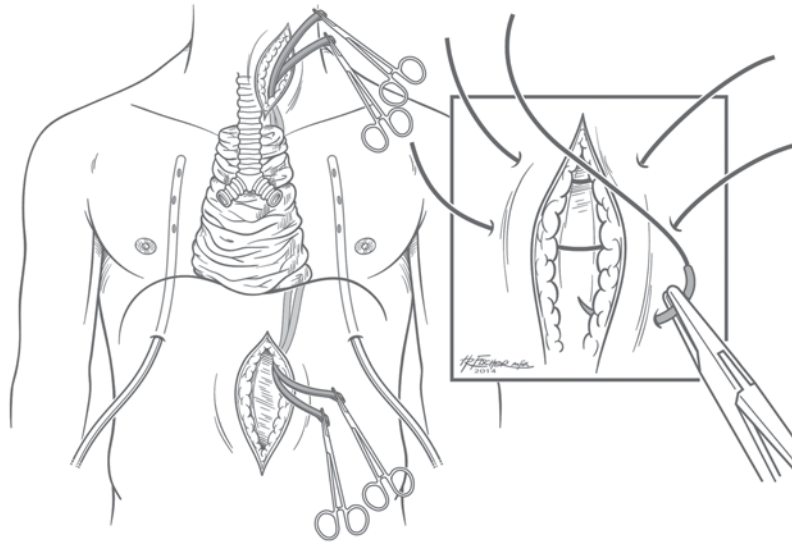

Fig. 4.10 When bleeding within the posterior mediastinum is documented, the priority is tamponade. This is achieved with two large laparotomy packs pushed high into the posterior mediastinum through the hiatus and two narrow "thoracic" packs inserted into the superior mediastinum through the cervical incision. Bilateral chest tubes are placed to ensure that ongoing bleeding into either chest is not occurring. After 5–10 min of control of the bleeding with this pressure, during which time intravascular volume can be replaced and fashioning of the gastric conduit carried out, if a "second look" into the mediastinum indicates persistent bleeding, the mediastinum is repacked, the abdominal incision is closed quickly with three or four through-and-through heavy sutures (*inset*), the cervical wound similarly closed quickly, both incisions covered with adherent plastic surgical drapes, and the patient turned and positioned for a posterolateral thoracotomy

an azygos vein tear is virtually a certainty. The mediastinum is quickly repacked from below through the hiatus and above through the cervical wound as described above, the abdominal and cervical wounds quickly closed and covered with adhesive plastic surgical drapes, and the patient turned to the left side for a fifth intercostal space right posterolateral thoracotomy.

The third and even more frightening scenario involves **bright red arterial bleeding** from the hiatus either during performance of the transhiatal dissection or immediately after the esophagus has been removed from the mediastinum. With arterial bleeding, there may not be time to complete the esophagectomy before the bleeding must be addressed. The Argyle Saratoga sump catheter is quickly inserted into the posterior mediastinum through the cervical wound to evacuate blood and facilitate exposure. Exposure of the posterior mediastinum is achieved with a Deaver retractor placed into the hiatus and "spot suction" with the Yankauer suction from the lower end of the table. If the bleeding site is identified as being from **an aortic esophageal artery**, it is clamped through the hiatus with a long right-angle clamp and ligated. The mediastinum is then carefully packed as above and inspected again after an additional 5 min have passed. If there is no further bleeding, the operation proceeds as planned. It cannot be overemphasized that when performing a THE in a patient who has undergone a prior esophagomyotomy, the exposed esophageal submucosa may be fused to the adjacent descending thoracic aorta. An ill-advised attempt at blunt dissection between the esophagus and aorta may end in a disastrous **aortic tear**. In most cases, the esophagomyotomy involves the distal esophagus, and if a transthoracic approach to the aorta is required for repair, a left posterolateral thoracotomy in the sixth intercostal space is the preferred approach to the low descending aorta. This should be done if mediastinal packing temporarily controls the bleeding, which resumes when the packing is removed. The mediastinum

should be packed again, the abdominal and cervical wounds closed quickly as described above, and the patient turned to the right side. The groin should be prepped and draped into the field to allow access to the femoral vessels in the event of the need for aortic cross-clamping and institution of aortofemoral bypass to repair the injury. If the surgeon is unfamiliar with techniques of aortic bypass, support from cardiac surgery colleagues should be requested immediately. Massive bleeding from the mid or upper thoracic aorta is not likely to be controllable through the hiatus, and an urgent repositioning of the patient and a left posterolateral thoracotomy through the fifth intercostal space may be attempted for control/repair. This is the worst-case scenario of bleeding associated with a THE, and salvage of the patient before fatal exsanguination occurs is unlikely.

Tracheal Tear

It has been emphasized repeatedly that in performing the transhiatal esophageal mobilization from the level of the carina and superiorly, the fingers must be kept as posteriorly as is possible to minimize the risk of injury to the posterior membranous trachea. One of the worst experiences in the performance of a THE is the sudden rush of cool air over the fingers in the posterior mediastinum. The anesthesiologist will generally then "sound the alarm" that he is "losing air" from his anesthetic circuit. There can be little doubt that a posterior membranous airway tear has occurred. This is not a time for bronchoscopy. The anesthesiologist should be told to quickly untape the endotracheal tube so that it is completely mobile. At the same time, the surgeon's hand is quickly inserted through the hiatus anterior to the esophagus with the palm and volar aspects of the fingers facing forward. As the subcarinal area is approached and the hand slowly advanced superiorly behind the trachea, the posterior membranous trachea is carefully palpated to define the site of the tear and control the air leak with gentle pressure (Fig. 4.11a). The injury is usually distal to the endotracheal tube balloon. The anesthesiologist is told to deflate the endotracheal tube balloon and advance the tube further into the airway as the surgeon guides the tube into the left mainstem bronchus (Fig. 4.11b). This may require several passes but eventually coordination of occlusion of the right mainstem orifice by pinching it and simultaneous advancement of the tube will result in a successful left-sided intubation. When the end of the tube is felt several centimeters beyond the carina down the left mainstem bronchus, the balloon cuff is gently inflated, and single lung ventilation of the left lung instituted. The anesthetist should secure the tube in place. Adequate oxygenation is confirmed. With the air leak controlled, there are several options for management of the airway tear.

If the airway tear appears to be relatively small, the transhiatal esophageal mobilization can be completed, the stomach brought through the posterior mediastinum, and the CEGA constructed. The cervical wound is closed over a ¼″ Penrose drain placed into the superior mediastinum to permit egress of any escaping air. The patient is awakened from general anesthesia as soon as possible and extubated to eliminate positive airway pressure. It has been reported that some tracheal tears "seal off" against the wall of the adjacent intrathoracic stomach and do not require suturing. However, this is such a rare complication of THE that no one has reliable experience as to which tears may be managed expectantly as above. The author is most comfortable addressing the problem directly before the patient is awakened. Posterior membranous tears of the lower trachea and carinal area involving the mainstem bronchi are repaired through a right posterolateral thoracotomy in the fifth intercostal space. After initiating single lung ventilation, securing the airway, and documenting satisfactory oxygenation and hemodynamics, the abdomen is temporarily closed with interrupted heavy through and through sutures as described above in the section on major intraoperative bleeding, the neck wound is closed, and both incisions covered with adhesive plastic drapes. The patient is turned to the left side, and the right thoracotomy performed. The mediastinal pleura is opened at the level of the azygos vein, which is divided and suture-ligated. The carina rests immediately under the azygos vein. This exposure provides

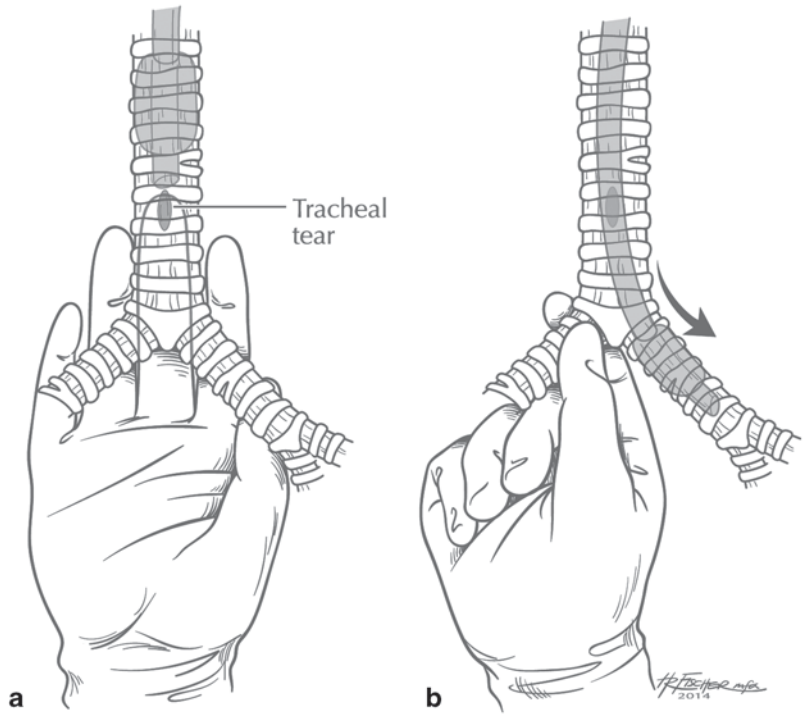

Fig. 4.11 **a** Identification of the site of the posterior membranous tracheal tear and temporary control of the air leak is achieved with the volar aspect of the middle finger inserted through the diaphragmatic hiatus. **b** As the orifice of the right mainstem bronchus is partially occluded by pinching it, the anesthesiologist simultaneously advances the endotracheal tube into the left mainstem bronchus so that single lung ventilation of the left lung can be instituted and maintained until the airway injury is repaired

access to the entire intrathoracic posterior membranous trachea, the carina, the right bronchus, and the first several centimeters of the left mainstem bronchus. If the esophagectomy has not been completed, it is done so now. The membranous tracheal tear is repaired with interrupted 4-0 polydioxanone (PDS) sutures. The endotracheal tube is left undisturbed with its tip in the left mainstem bronchus and not withdrawn into the trachea where positive airway pressure may disrupt the tracheal repair. The patient is then turned supine once again, positioned as before, the adhesive surgical drapes removed, and the abdominal and cervical wounds reopened. Gastric transposition through the posterior mediastinum and construction of the CEGA are performed. The superior mediastinum is drained with a ¼″ Penrose drain brought out through the cervical incision. The patient is extubated, preferably in the operating room, to avoid injury to the airway suture line by an indwelling endotracheal tube.

A third alternative approach is the use of a partial upper sternal split to gain access to the posterior trachea for repair of the injury. From experience with mediastinoscopy for the evaluation of mediastinal lymphadenopathy in patients with lung cancer, it is known that the carina can generally be reached through a suprasternal incision. It is reasonable, therefore, to attempt repair of a posterior membranous tracheal tear above the carina through a partial sternotomy. Once the endotracheal tube has been guided down the left mainstem bronchus and the airway is secure, the standard oblique left anterior cervical incision paralleling the anterior border of the sternocleidomastoid muscle used for a THE is extended downward in the midline over the upper sternum, just across the sternomanubrial junction (Fig. 4.12). A partial upper sternal split is then carried out. If the esophagus has been extracted, visualization of the posterior membranous tra-

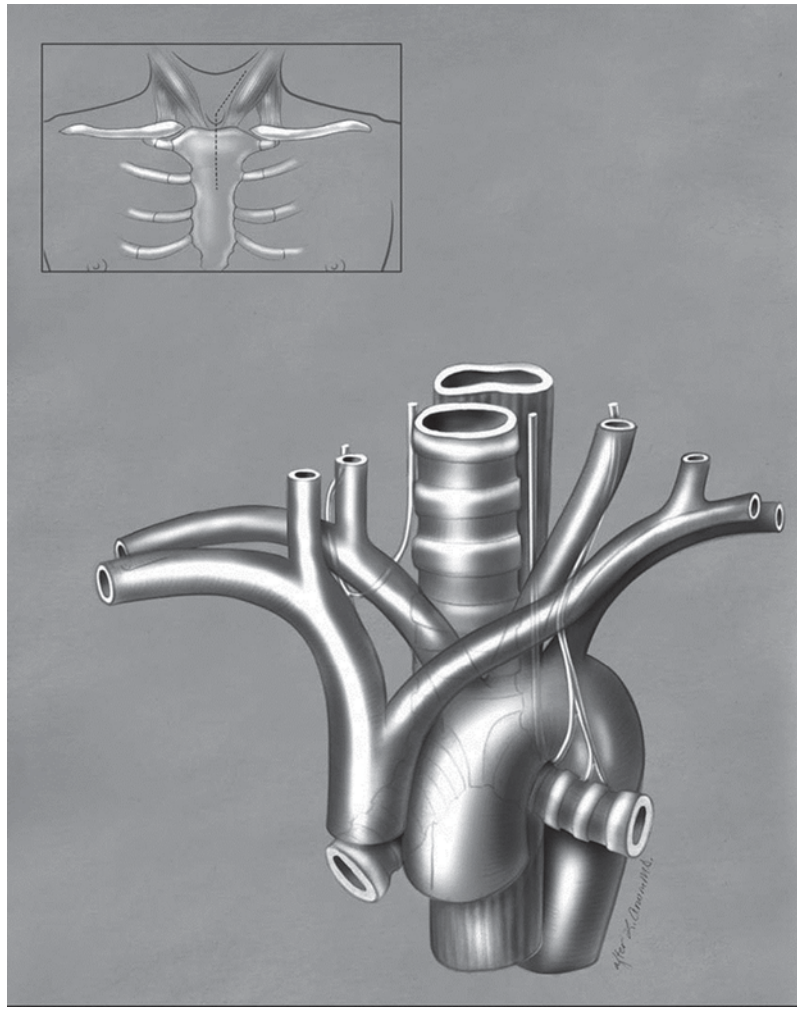

Fig. 4.12 A tear of the posterior membranous trachea recognized after transhiatal mobilization and removal of the esophagus may be managed by extending the oblique anterior left cervical incision downward in the midline over the manubrium across the sternomanubrial junction. A partial sternotomy is performed, and after insertion of a small sternal retractor, access to the posterior membranous trachea to the level of the carina allows direct suturing of the tracheal wound and avoids the need for a thoracotomy. (Reproduced with permission from [9] © Elsevier)

chea is generally feasible. The tracheal tear is repaired with interrupted 4-0 PDS suture, and the esophageal replacement with stomach completed without the need to reposition the patient. If the tracheal tear cannot be adequately visualized through this approach, the cervical/partial sternotomy and abdominal incisions are temporarily closed as described above, and the patient is turned to the left side for a transthoracic tracheal repair through the right chest as described.

Among 3200 patients who have undergone a THE at the University of Michigan since 1976, there have been eight (0.25%) tracheobronchial tears, four repaired through a right thoracotomy and four through a partial sternal split. All healed without added postoperative morbidity.

Summary

Disastrous intraoperative events—major mediastinal bleeding and tracheal tears—occur in < 1 % of patients undergoing a THE. Their successful management requires a well thought-out protocol and knowledge of the best approach to the site of the injury. Because of their relative infrequency, facility in management is seldom achieved by repetitive direct treatment. It is therefore prudent that surgeons undertaking a THE periodically "rehearse" with their operative team the approach to intraoperative bleeding or an airway tear occurring during the procedure, so that efficient and effective treatment can be undertaken when these disasters are encountered. Recognition of telltale risk factors such as a mid-third esophageal carcinoma or stricture, mediastinal calcification on CT scan, a prior esophagomyotomy, a prior esophageal perforation, or an obese, "soft" body habitus may alert the surgeon to the possibility of major intraoperative technical problems and hopefully their avoidance.

Key Points: Avoiding Catastrophic Complications—Mediastinal Bleeding and Airway Injury—During Transhiatal Esophagectomy

1. Be especially vigilant in patients with a history of **prior esophageal surgery**, particularly a thoracic esophagomyotomy or megaesophagus of achalasia.
2. In those with a prior **thoracic esophagomyotomy**, dissect the esophagus away from the descending aorta sharply and under direct vision through the hiatus, not bluntly.
3. **Mediastinal lymph node calcifications** on preoperative CT scans may portend a more difficult mediastinal esophageal dissection, particularly in the subcarinal region.
4. Perform the blunt mediastinal esophageal dissection with the **volar aspects of the fingers against the esophagus.**
5. When dissecting the esophagus away from the trachea working through the hiatus and the cervical incision, push toward the esophagus and **NOT** the posterior membranous trachea.

Key Points: Diagnosing and Managing Catastrophic Complications—Mediastinal Bleeding and Airway Injury—During Transhiatal Esophagectomy

1. Dark venous blood issuing through the hiatus from the high mediastinum during a THE is most often due to a **torn azygos vein.**
2. Bright red blood issuing through the hiatus during dissection of the distal half of the esophagus is most often due to a **bleeding thoracic aortic vessel or an aortic injury**.
3. During the transhiatal esophageal mobilization, feeling **a sudden rush of air** at the same time that the anesthesiologist reports loss of air in his/her circuit is indicative of a posterior membranous tracheal tear.
4. If excessive mediastinal **bleeding** through the hiatus occurs, **the mediastinum should be packed** immediately with two large abdominal packs through the hiatus from "below" and two narrower "thoracic packs" placed through the cervical incision from "above" (while protecting the left recurrent laryngeal nerve), allowing volume replacement and stabilization of the patient.
5. If an intraoperative **tracheal tear** occurs, the anesthesiologist should **advance the endotracheal tube**—guided by the surgeon's hand through the hiatus—**into the left mainstem bronchus** so that single lung ventilation with the endotracheal balloon distal to the tear can be established.

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Chyle Leak After Esophageal Surgery

5

Elena M. Ziarnik and Jonathan C. Nesbitt

Abbreviations

MIE	Minimally invasive esophagectomy
NPO	Nil per os
TPN	Total parenteral nutrition
VATS	Video-assisted thoracoscopic surgery

Introduction

A post-esophagectomy chylothorax is an uncommon complication with associated high morbidity and mortality if improperly managed. It occurs in approximately 3% of patients and is usually noted by the occurrence of a pleural effusion or the drainage of white fluid from the chest tubes following the postoperative initiation of enteral feeds. Immediate medical and interventional measures are necessary to prevent significant nutritional and fluid losses. Selection of the most appropriate method for management is based on the severity of the chyle leak and the condition of the patient.

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Historical Review

Gasparo Aselli is credited with the discovery of the lymphatic system, and Vesalius named the thoracic duct *vena alba thoracis* because of the milky white character of chyle in the 16th century [1]. Mascagni was the first to describe the thoracic duct in detail in 1787 [2]. A report by Bargebuhr described a series of 40 patients with nontraumatic chylothorax, all related to neoplasms of the abdomen and thorax [3].

Though the first reference to a traumatic chylothorax was made by Langelot in 1663, Quinke is credited with the first description of one in 1875 [4]. Zesas wrote a review in 1912 of 24 patients with traumatic chylothorax, of which 12 died [5]. In the 19th century, descriptions of repair of thoracic duct injuries began to appear. In 1922, Lee concluded that injuries should be repaired if possible and ligated otherwise, following his own experimental work with ligation and review of the literature [6]. The significance of this report lies in its challenge to the idea that thoracic duct drainage was essential to life. The turning point in the treatment of chylothorax came in 1948 when Lampson and associates successfully treated a chylous fistula by ligating the thoracic duct in the chest [7]. At the time of this report, the mortality from nontraumatic and traumatic chylothorax was 100 and 50%, respectively [8]. In the subsequent decade, mortality dropped to less than 10% and currently is well below 5% [9].

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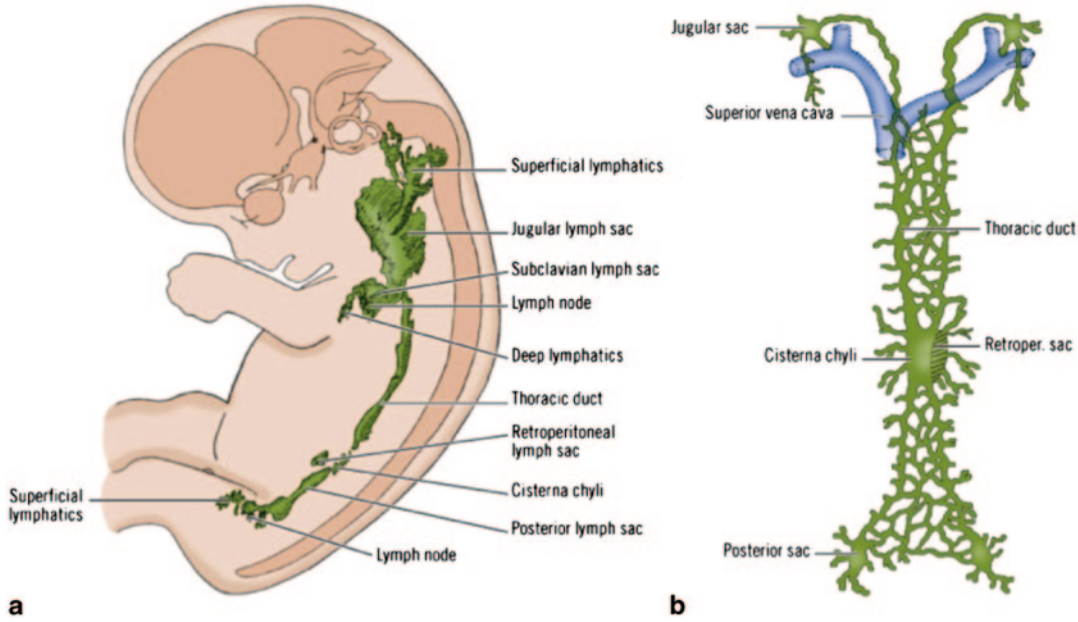

Fig. 5.1 Embryologic development of the lymphatic system. (Reprinted with permission from [48])

Basic Science

Embryology

The lymphatic system begins to develop in the 5th week of gestation. Lymphatic sacs were described by Sabin in 1916 as originating from the endothelium of adjacent veins [10]. She noted six lymphatic spaces; paired jugular sacs, paired iliac sacs, a single retroperitoneal sac, and the cisterna chyli (Fig. 5.1). The lymphatic sacs then become buds that follow planes of least resistance and progress toward the periphery.

The thoracic duct is formed from downward growth of the jugular sacs and upward growth of the cisterna chyli [11]. In the embryo, the thoracic duct exists as bilateral symmetrical plexus of lymphatic vessels. The communicating vessels enlarge and fuse, eventually leading to obliteration of the upper third of the right duct and the lower two-third of the left duct leaving the adult thoracic duct. The plexus of lymphatic drainage results in multiple connections between the thoracic duct and adjacent veins, including the azygos and intercostals, and allows chyle to reach the blood stream after duct ligation.

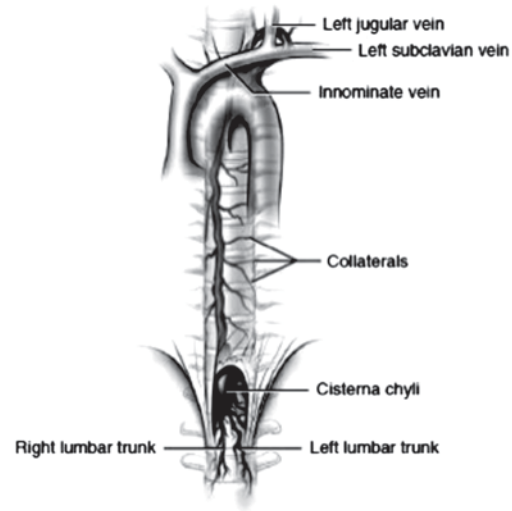

Fig. 5.2 Adult anatomy of the thoracic duct. (Reprinted with permission from [48])

Anatomy

The anatomy of the thoracic duct is known for its variability. The cisterna chyli originates in the abdomen from the union of two lumbar lymphatic and one intestinal trunk (Fig. 5.2 **).** The standard

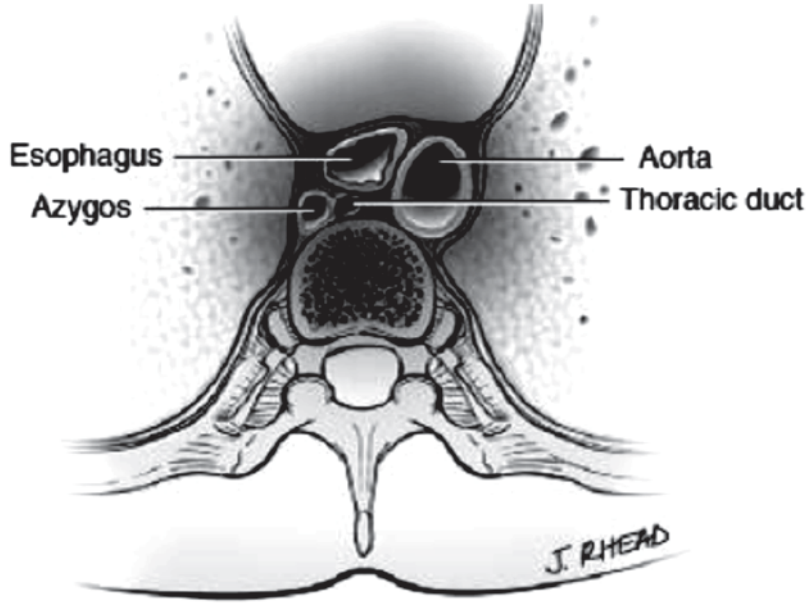

Fig. 5.3 Adult anatomy of the thoracic duct, relationship to mediastinal structures. (Reprinted with permission from [48])

position of the cisterna chyli is adjacent to the vertebral column and to the right of the aorta at the level of L2, but it can be found from T10 to L3. The thoracic duct ascends from the cisterna chyli in the posterior mediastinum through the aortic hiatus. The aortic hiatus resides at the level of T10. Moving cephalad, the duct lies along the anterior surface of the vertebral column, posterior to the esophagus, between the aorta and the azygos vein and anterior to the right intercostal arteries. This anatomic region is emphasized because this is the optimal location for duct ligation in the chest [12]. The thoracic duct typically crosses behind the aorta to the left at T5–T7 and continues its ascent behind the aortic arch and to the left of the esophagus until it reaches the level of the left subclavian artery posteriorly. The change in laterality of the duct position explains the development of a right-sided chylothorax if the duct is injured below T5 and a left-sided chylothorax if the duct is injured above T5. Collateral drainage into the azygos, intercostal, and lumbar veins occurs 40–60 % of the time.

The course of the duct continues cephalad until approximately 3 cm above the level of the clavicle when it traverses laterally. The duct is then positioned anterior to the vertebral artery and vein, innominate vein, and phrenic nerve and medial to the anterior scalene muscle. The duct terminates by joining the venous drainage system near the confluence of the left subclavian and left internal jugular veins, but has also been reported to drain into the left innominate vein, left or right internal jugular or the left vertebral vein (Fig. 5.3) [13–15].

The duct is known to have unidirectional valves of variable number and location. A valve is always present, however, at the junction of the thoracic duct and the venous supply to protect against the reflux of blood into the lymphatic system [16].

Other small lymphatic pathways exist. A small and short right thoracic duct drains lymph from the right head, neck, arm and chest wall via the jugular trunk. A bronchomediastinal trunk drains lymph from the right lung, heart, and left lung. And an additional trunk drains lymph from the dome of the liver, right chest wall, and right diaphragm via the right internal mammary trunk.

Variations in anatomy include lymphatic duct doubling, left-sided course, right-sided course, bilateral termination, or azygos vein termination.

In addition, in the neck, the duct can run posteriorly to the vertebral and subclavian veins [17].

Physiology

Chyle consists of lymph (comparable to blood plasma) and emulsified fats (free fatty acids). It is formed within the small intestine during digestion of fatty foods. Long-chain fatty acid molecules diffuse into the low-pressure wall of the intestinal villi. They form micelles and are reassembled into triglycerides. The triglycerides are coated with cholesterol and protein to form chylomicrons that then enter lacteals before flowing into the larger lymphatic vessels. The higher pressure in intestinal veins allows only smaller products of digestion, such as short- and medium-chain triglycerides (MCT), amino acids and sugars, to diffuse directly into the blood stream, the portal system. Fat is absorbed into intestinal lymphatics and transported into venous blood flow in less than an hour.

Lymph flow in the thoracic duct comes from the liver, intestines, and extremities, with the liver and intestines contributing 95%. Many factors influence the volume of lymph flow through the thoracic duct. Basal rate of flow is estimated to be 0.95 ml/min or 1.38 ml/kg body weight/hour. Flow rates can increase with oral intake and abdominal massage up to 3.9 ml/min [18].

Composition of Chyle

The concentration of fat, protein, and lymphocytes within chyle is variable depending on the timing, type, and amount of food ingested. During the period of fasting, ductal lymph fluid is clear. The milky white color occurs from the absorption of chylomicrons following fat ingestion. Chyle is considered bacteriostatic and causes a very little pleural reaction due to its alkaline pH (Table 5.1).

Table 5.1 Composition of chyle. (Adapted from [47])

Component	Amount (per 100 ml)
Total fat	0.4–5.0 g
Cholesterol	65–220 mg
Protein	2.2–5.9 g
Albumin	1.2−4.1 g
Globulin	1.1–3.6 g
Fibrogen	16–24 g
Antithrombin	25% of plasma concentration
Prothrombin	25% of plasma concentration
Fibrinogen	25% of plasma concentration
Sugar	48–200 g
Electrolytes	Similar to plasma
Cellular elements	
Lymphocytes	400−6800/L
Erythrocytes	50–600/L

Lipids As noted, the main component of chyle consists of emulsified fats, or free fatty acids. The concentration of fat in chyle is directly related to ingested quantity and composition of fat and can range from 14 to 210 mmol/L. Up to 60% of ingested fat, consisting mostly of long-chain triglycerides (12 or more carbon atoms in size), is absorbed into the lymphatic channels. Small-chain triglycerides, considered less than 6 carbon atoms in size, are absorbed directly into the portal venous system. MCT (6–12 carbon atoms in size) are also absorbed passively into the portal system, though only 30–40% of MCTs are directly absorbed.

Protein Chyle is a transporter of extravascular protein back to the vascular space. Total protein concentration in chyle is generally half that of protein concentration in the plasma, ranging from 21 to 59 g/L [18]. In large chyle leaks, significant protein losses can occur.

Electrolytes The electrolyte content of lymph in the thoracic duct is the same as that of plasma. Fat-soluble vitamin concentrations in chyle are proportional to the amount ingested. Pancreatic lipase, amylase, and deoxyribonuclease can also flow into the lymph system and are subsequently transported to the blood stream by way of the thoracic duct.

Lymphocytes Lymphocytes contribute the main cellular element of thoracic duct lymph. Ninety percent are T-lymphocytes. Lymphocytes are in constant to and fro circulation from lymph

Table 5.2 Causes of chylothorax. (Adapted from [47])

Congenital anomalies
Trauma
Birth trauma
Blunt trauma
Penetrating trauma
Surgical trauma
Cervical lymph node dissection
Thoracic
Ligation of patent ductus arteriosus
Coarctation repair
Esophagectomy
Thoracic aortic aneurysm repair
Resection of mediastinal tumor
Pulmonary resection
Sympathectomy
Abdominal
Abdominal lymph node dissection
Neoplasms
Lymphoma, breast cancer, lung cancer
Miscellaneous
Subclavian vein thrombosis
Radiation
Tuberculosis

nodes to the bloodstream. Prolonged drainage of lymph due to a thoracic duct injury can significantly deplete lymphocytes with resultant immunosuppression.

Chylothorax

Etiology/Cause

Chylothorax occurs when lymphatic fluid accumulates within the pleural space. Though a chylothorax can occur spontaneously, it is usually related to an injury to the thoracic duct or one of its branches. Other causes include occlusion of the lymphatic system from venous thrombosis, neoplastic infiltration, or radiation. The causes are listed in Table 5.2.

Post-esophagectomy Chylothorax

Thoracic operations most commonly associated with chylothorax include aortic procedures (incidence of 0.2–0.5%), pulmonary resection with lymphadenectomy (incidence of 0.42–2.3%.), and esophagectomy. The incidence of chylothorax after esophagectomy ranges from 0.5 to 10.5%, irrespective of the approach to resection [19–22]. A meta-analysis completed by Rindani and colleagues evaluated 44 reports involving 5483 patients with an incidence of chylothorax of 2.8% [23]. Patients who had a transthoracic esophagectomy (2675) and those who had a transhiatal esophagectomy (2808) developed chylothoraces with an incidence of 2.1 and 3.4%, respectively. In a report by Dugue of 850 patients undergoing Ivor-Lewis esophagectomy, the incidence of chylothorax was 2.7% [24]. Orringer reported <1% incidence for 1085 patients who underwent a transhiatal esophagectomy [25]. Merigliano reported 1787 esophagectomies with an incidence of chylothorax of 1.1% [26]. Of the 1787 patients evaluated, 1237 patients underwent a transthoracic approach and 464 patients had a transhiatal approach with chylothorax incidence of 1 and 1.3%, respectively. Minimally invasive esophagectomy (MIE) has reported rates of chylothorax similar to those of open approaches. Shen reported 344 MIEs with a chylothorax incidence of 2.9% [27]. A postoperative chyle leak is also more likely to occur in direct relationship with the aggressiveness of a mediastinal lymph node dissection [28].

Diagnosis

Clinical Features

Clinical features related to chylothorax often present in a delayed fashion because postoperative patients frequently have a limited dietary intake. As oral or enteral intake occurs, lipids are absorbed through the intestinal tract and into the lymphatic system that travels through the region of the resected esophagus. If thoracic duct channels have been disrupted and are not ligated, the pleural cavity will gradually fill with chyle. Clinical complaints are related to compression of the lung by the chylous effusion and include dyspnea, cough, and fatigue. If pleural drainage

tubes are present, a milky effluent will occur. The quantity of accumulated or drained fluid depends upon the degree of thoracic duct injury and amount of enteral intake. High-volume drainage (> 1–2 L/day) can occur with losses of fluid, electrolytes, and lymphocyte reserves.

Fluid Studies

After thoracentesis or catheter drainage of the suspected effusion, the diagnosis of chylothorax is supported by nonclotting, milky-colored fluid. Chyle can resemble pus, but it is odorless, and no bacteria are seen on Gram stain. Clear fluid does not rule out chylothorax, particularly in patients on limited diets. The rate of daily fluid accumulation, alone, is a key piece of data. A higher-than-usual volume of serous drainage (700–1200 ml/day) is characteristic of a thoracic duct injury and chylothorax. In such circumstances, a complete blood count of the fluid with differential that shows lymphocytes > 90 % is diagnostic.

Biochemical and microscopic examination of the pleural fluid is important. Diagnostic findings include triglyceride level > 110 mg/dL and/or a concentration greater than plasma triglyceride level. Pleural fluid triglyceride concentrations, however, can be less than 110 mg/dl in 15 % of patients with a chylothorax. Therefore, lipoprotein analysis can be performed as another diagnostic tool. A microscopic examination that shows chylomicrons is also diagnostic of a chylothorax and can be used as a confirmatory test if the triglyceride levels are equivocal. On microscopy, fat globules will clear with alkali or ether and will stain with Sudan III.

Imaging

Chest radiography and computed tomography will often show a unilateral pleural effusion in an undrained chest cavity. Other findings can include bilateral effusions, a widened mediastinum, and a pericardial effusion. Though uncommonly performed and usually unnecessary, lymphangiography can show the site of injury [29]. This procedure involves injection of 10 mL of ethiodized oil into the lymphatic vessels in the dorsum of the foot. Coupled with lymphangiography, post-procedure computed tomography of the chest can be highly accurate in localizing a chyle leak [30].

Treatment

The best treatment of chylothorax is prevention. Attention to the anatomy of the thoracic duct and its variability is required to avoid injury to the structure and its tributaries. Because of the proximity of the thoracic duct to the esophagus and aorta, intrathoracic aortic and esophageal procedures carry a particular risk for duct injury. The judicious use of tying and clipping of the lymphatic, periaortic, and periesophageal tissues during dissection minimizes the risk of chylothorax occurrence. The duct and lymphatic channels are not often visualized at the time of surgery because flow through the duct system is minimal as a result of a patient's nil per os (NPO) status prior to surgery. If the duct must be visualized during an operation, for inspection or repair, 30 cc's of fluid that is rich in fat (milk or olive oil) can be given orally or through a nasogastric tube 1 h prior to anticipated exposure of the duct. Another method to prevent postoperative chyle leakage is ligation of the thoracic duct at the level of the aortic hiatus. Guo and colleagues reported a group of 135 minimally invasive esophagectomies for cancer [31]. Of the 65 patients who had prophylactic thoracic duct ligation, one patient developed a chylothorax, whereas 7 chylothoraces occurred in 65 patients who did not have ligation of their ducts. No complications occurred from duct ligation.

Patients who have received preoperative therapy (radiation or chemoradiotherapy) and who develop a chylothorax after resection of a malignancy, such as esophageal cancer, are less likely to respond to conservative measures. The lymphatic collaterals seldom heal spontaneously because radiation therapy to the periesophageal tissues damages the adjacent lymphatic network and reduces their healing capacity.

Management is determined by the amount of chyle drainage. The objectives of treatment are to drain and minimize chyle production, which, in turn, allows time for the establishment of rerouting of chyle flow within lymphatic collaterals and fusion of the pleural surfaces (pleurosymphysis), which obstructs the free flow of chyle into the pleural space. Patients who respond promptly to conservative measures within 48 h are likely to seal their leak. If high-output drainage occurs over 1–2 L/d, patients can quickly become nutritionally and immunologically depleted. Morbidity and mortality are known to increase if such quantities of drainage continue beyond 5–7 days, and these patients are unlikely to respond to conservative therapy. If the patient is able to tolerate a second operation, surgical exploration with duct ligation is indicated [20, 21, 28].

Conservative Management

Conservative management is considered first-line therapy for most cases of postsurgical chylothorax and includes drainage of the pleural space to establish complete re-expansion of the lung, nutritional support, and medication to reduce the flow of chyle.

Drainage of the pleural space is effectively achieved with tube thoracostomy. Additionally, it assists with lung re-expansion and daily measurement of chyle flow. Thoracentesis can be effective, but often needs to be repeated to achieve adequate drainage and full lung expansion.

Nutritional support is a key component to management. If patients have less than 500 cc/d of chyle flow, usually they can continue oral intake. But the diet is modified to minimize the consumption of long-chain triglycerides that increase chyle flow. A high-protein, low-fat diet with oral or nasogastric tube feeding of MCT can be used. Restriction of long-chain triglycerides avoids the breakdown of the compound into monoglycerides and free fatty acids that are carried as chylomicrons into the lacteals and then into the thoracic duct. MCTs are commercially available in liquid or capsule form for use as a nutritional supplement three to four times per day. Common adverse effects are nausea, occasional vomiting, abdominal pain, and diarrhea.

To achieve the most optimal outcome with conservative management, complete fasting and total parenteral nutrition (TPN) must be used [30]. Complete bowel rest is the best method to minimize chyle production. Even water taken by mouth can increase the flow of chyle by 20% [18]. Fasting has been shown to be associated with success rates as high as 80% [32, 33] compared with use of a modified enteral diet where successes have been reported to be as low as 23% [21, 34–36].

Somatostatin and its analog octreotide have also been shown to decrease the flow of chyle in cases of postoperative chylothorax [37–39]. These agents act by inhibiting gastrointestinal and endocrine function, which, in turn, decreases foregut secretions [40]. Dosing of octreotide is 100–500 μg subcutaneously three times per day [41]. When used in conjunction with a strict dietary regimen, somatostatin typically reduces chyle drainage within 48 h. Daily monitoring of output is important to ensure continued dissipation, and resolution can be seen within a 2-week period. Side effects are typically minor and include flushing, nausea, diarrhea, abdominal distension, and hyperglycemia.

Percutaneous catheterization and embolization of the thoracic duct has shown success in limited series. For patients who are refractory to previously mentioned management techniques, who are debilitated, and who are poor operative candidates, embolization should be considered. The procedure involves pedal lymphangiography and transabdominal accession of the cisterna chyli. The technique has low associated morbidity, but can be constrained by variations and size of the lymphatic channels. Success has been reported to range from 45 to 70% [42, 43].

If patients with high-output drainage (> 1 L/d) do not promptly improve within 48 h from the initiation of conservative management, surgical intervention should be considered [28]. Shah and colleagues reported significant failure of conservative management if patients continued to have chest tube output over 11 cc/kg/d after beginning the treatment [44]. Dugue and colleagues used

an output of chyle based upon body-weight ratio as an indicator of conservative treatment success and suggested that an output of less than 10 cc/kg/d at day 5 of conservative treatment is justification to continue conservative management [24]. Merigliano and colleagues recommended early duct ligation to avoid complications related to nutritional and immunologic depletion caused by delayed surgical intervention [26]. As a general guideline, if drainage remains unabated more than 500 cc/d for 5–7 days following the initiation of treatment, surgical intervention should be considered.

Most cases of chylothorax that resolve with conservative management will do so within 2 weeks of the implementation of treatment. During this time of bowel rest and TPN, thoracostomy tube output must be closely monitored to ensure progressive dissipation of the drainage. Ideally, drainage should be less than 100 cc/d before allowing oral intake. Particular attention is given to the quantity and quality of drainage as oral intake is re-instituted. If drainage character and volume do not increase with oral intake, the pleural drainage tubes can be removed.

If drainage subsides but does not completely resolve, chemical pleurodesis can be performed to enhance the process. Though a number of chemical agents have been used, the most common sclerosants include talc and doxycycline. Success of this procedure is challenged by high-output chylous leaks and should only be performed in patients with complete evacuation of fluid, with full lung expansion, and with less than 300–500 cc/d of drainage.

Surgical Management

The timing of surgical intervention is influenced by the rate of chyle drainage, the response to conservative therapy, and the risk for further surgery. A key consideration is the condition of the patient since the risk of a thoracotomy to correct a chyle leak can be associated with a mortality rate over 20% [24, 45].

The objectives of surgical intervention are to evacuate all fluid from the pleural cavity, to fully re-expand the lung, and to control of the lymph leak. These can be achieved with pleuroperitoneal shunting, direct ligation of the thoracic duct at the level of the leak, mass ligation of the thoracic duct below the level of the leak, pleurectomy, and pleurodesis.

Pleuroperitoneal shunts have been successfully used for management of patients with refractory chylothoraces and are options for management of difficult patients who have exhausted other treatments or who are too ill to underdo more major surgery. The shunts can usually be placed easily and with little risk. They, however, require regular pumping by the patient or family members to be effective for long term [46].

The most definitive management of a post-esophagectomy chylothorax involves exploration of the chest cavity by thoracotomy or thoracoscopy. Patients with a unilateral chylothorax can be managed with an ipsilateral thoracic procedure because the duct and the site of leakage usually can be accessed from the side of the effusion. For patients with bilateral chylothoraces, however, the entire thoracic duct region must be visualized and is optimally exposed where it resides in the lower aspect of the right pleural cavity.

The thoracic duct and adjacent accessory lymphatic channels are typically located in the supradiaphragmatic position within the recess between the spine, aorta, and esophageal bed. The duct is indiscreet and blends with the soft tissues in this region. To facilitate intraoperative identification of the lymphatic pathways, fat in the form of cream or olive oil is administered by a nasogastric tube. The material is absorbed through the bowel wall into the lacteals within an hour after administration. The lymphatic channels become engorged with chyle, and the site of injury can be visualized by the leakage of milky fluid.

Closure of a chyle leak is performed either by direct occlusion or by mass ligation of the thoracic duct and adjacent lymphatic pathways below the level of the area of injury or leakage. Direct closure is performed using clips or pledgetted suture ligatures applied to the injured site. Mass ligation involves passing a ligature completely around all tissues located between the aorta, spine, esophageal bed, and pericardium

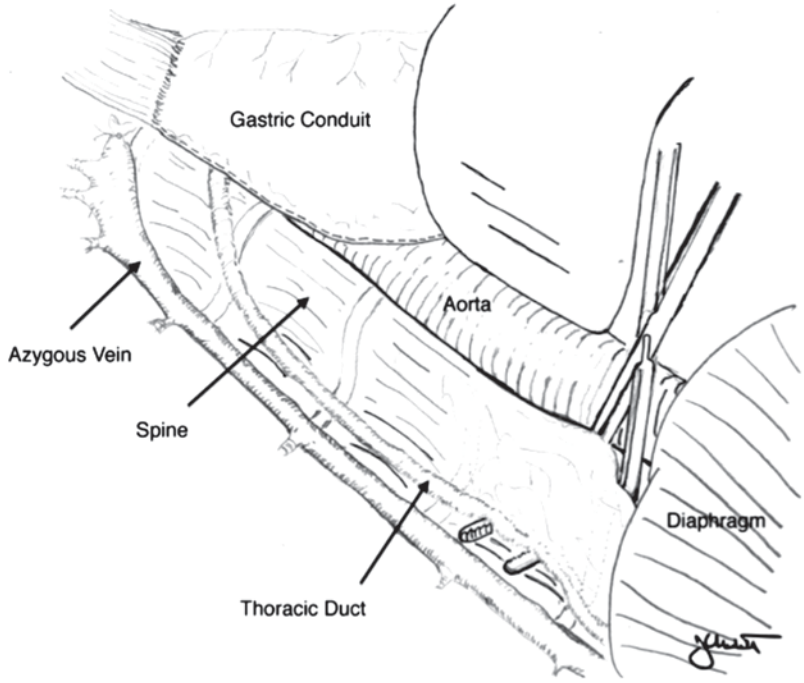

Fig. 5.4 Mass ligation of the thoracic duct through a right thoracotomy incision. A right angle clamp is placed around the lymphatic tissues at the level of the diaphragm. All tissues between the aorta, spine, esophageal bed, and azygous vein are incorporated. The azygous vein can also be included with the ligation

(Fig. 5.4). The hemiazygous or azygous vein can be included within the ligature that is positioned near the level of the aortic hiatus to ensure occlusion of the duct well below the site of injury. Double ligation is prudent to ensure complete isolation and occlusion. Some surgeons advocate ligation of the duct above the site of injury, but this is typically unnecessary. The same technique of supradiaphragmatic direct or mass ligation is also used if thoracic duct injury is noted or suspected at the time of the initial esophageal operation. Immediate and complete cessation of leakage should happen and is an assurance of a satisfactory result that occurs in over 95 % of patients.

Following closure of the leak, fibrin glue can be applied to the region to enhance its sealing. A mechanical pleurodesis is also performed to enhance pleurosymphysis. Pleural tubes are positioned to monitor subsequent lymph drainage and to optimize complete lung expansion. The results with ligation of the thoracic duct are excellent with 90–100 % resolution of the leak. In unusual cases where lymph drainage continues following ligation, aberrant pathways may be present. In such circumstances, lymphangiography is helpful to better define the lymphatic anatomy and to enhance the surgical outcome.

Summary

The keys to successful management of a post-esophagectomy chyle leak are early recognition and prompt intervention to correct the problem (Fig. 5.5 **algorithm**). Conservative management can result in the resolution of the leak if the quantity of drainage declines promptly within the first 48 h of treatment and continues to drop to less than 100 cc/d by the end of day 7–10 of treatment. Surgeons should have a low threshold for recognizing when conservative management fails and when surgical intervention is indicated. When correction of a chyle leak occurs without delay, overall recovery is enhanced and further morbidity is avoided.

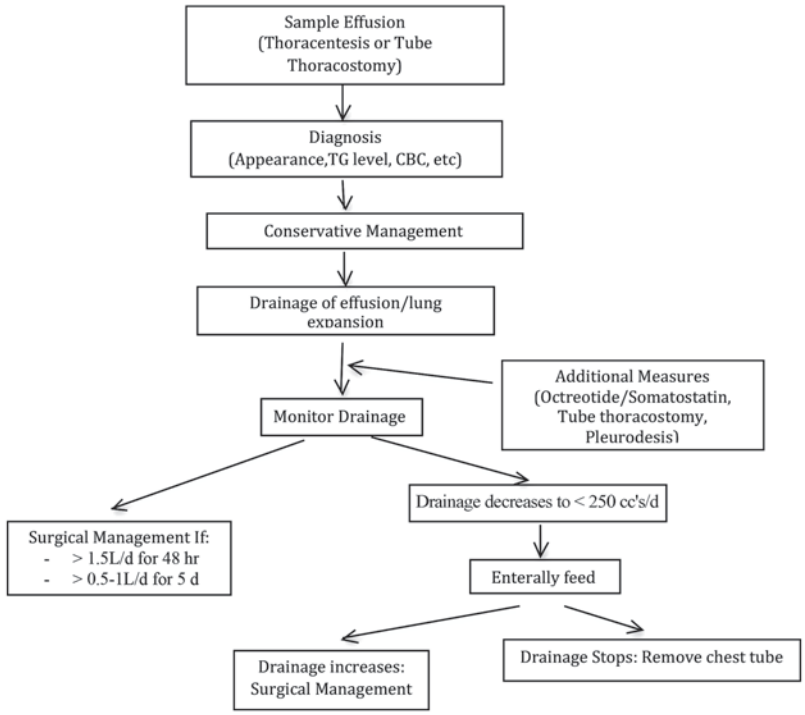

Fig. 5.5 Treatment algorithm for chylothorax

Key Points on Avoiding an Esophageal Anastomotic Leak

1. Chylothorax is an important but infrequent cause of pleural effusion.
2. The most common causes of chylothorax are iatrogenic and neoplastic.
3. Diagnosis is made by the analysis of the pleural fluid.
4. Prompt treatment is indicated to avoid pleural and nutritional complications.

Key Points on Diagnosis and Managing an Esophageal Anastomotic Leak

1. If the injury is identified intraoperatively, the thoracic duct should be ligated proximal to the injury.
2. If injury is identified postoperatively, initial conservative treatment consists of management of the pleural effusion, nothing per os (NPO) status, and TPN.
3. If conservative management fails, operative intervention is indicated and requires proximal ligation of the thoracic duct by thoracotomy.

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6 Management of Airway, Hoarseness, and Vocal Cord Dysfunction After Esophagectomy

Laura Dooley and Ashok R. Shaha

Introduction

Vocal cord paralysis (VCP) can have a great impact on the quality of life. Change in voice quality and loudness can affect even the nonprofessional voice user. At times VCP can also be life threatening—airway obstruction due to bilateral paralysis with the urgent need for a tracheostomy or recurrent aspiration pneumonia from inability to fully protect the airway.

The etiology of unilateral VCP can be separated into a few main categories. Nonlaryngeal malignancy and iatrogenic (surgical trauma) account for about 50% of all causes of vocal cord immobility followed by an idiopathic etiology, nonsurgical trauma, and intubation-related etiologies. Common nonlaryngeal malignancies such as lung cancer with spread of disease into the aortopulmonary window, thyroid, esophageal, and skull base lesions are frequently found when working up unilateral vocal cord dysfunction. Nonlaryngeal malignancy is commonly cited as the most common cause of unilateral VCP; however, iatrogenic nerve injury is likely the most common cause for otolaryngology referral [1]. Common iatrogenic surgical procedures causing unilateral vocal cord paresis include anterior cervical spine procedures, Ivor-Lewis esophagectomies, gastric pull-up, thyroidectomy, thymectomy, neck dissection, carotid endarterectomy, mediastinoscopy, and cardiothoracic surgery (CABG, pulmonary lobar resection). Endotracheal intubation, prolonged nasogastric tube placement, and even esophageal stethoscope placement have been implicated in vocal cord dysfunction [1]. Bilateral paralysis is overwhelmingly due to iatrogenic injury (82%) and is mainly seen after total thyroidectomy.

This chapter will focus on unilateral and bilateral adult VCP in the setting of esophagectomy.

Vocal Fold Dysfunction

The incidence of recurrent laryngeal nerve (RLN) injury after esophagectomy has been reported to be anywhere between 2 and 20% [2]. It is more often associated with cervical anastomoses and three-field LN dissection, especially when removal of bulky proximal tumors or extensive lymph node dissection is required [2]. There are three possible mechanisms for injury to the nerve: traction, dissection, and transection. Frequently, injuries from retraction of the RLN, inadvertently clamping the nerve, or stripping the nerve of its blood supply can occur, causing the patient symptoms, albeit more likely of a transient nature. Injury to the RLN during esophagectomy is more common on the left side due to

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the mediastinal direction of the nerve as it courses around the arch of the aorta.

Differentiating the paralyzed cord from the cord that is paretic after surgery can be difficult. This is especially true when the nerve was not directly visualized and preserved at the time of surgery. When RLN injury does occur, it increases the incidence of perioperative pulmonary complications. Pneumonia in this setting is common, most likely due to aspiration, not only of food and liquids at meals but aspiration of saliva, as the patient no longer has a competent glottis and cannot fully close the airway to clear secretions [2].

While up to 40% of patients with vocal fold dysfunction in the immediate postoperative setting will resolve their symptoms, the other 60% will have persistent dysfunction [2]. Patients with persistent VCP, who complained of severe hoarseness at 1 year postoperatively from inability to close the glottis during exertion, showed debilitation in performance status and pulmonary function at 3 years post-op [3]. Even in those who do not complain of hoarseness and dysphonia, approximately one-half of them have a decrease in phonation time [4]. Up to 20% of all esophagectomy patients will report severe hoarseness due to permanent recurrent nerve paralysis, resulting in poor quantity of food intake at 24 months postoperatively, restricted daily activity, and difficulty in talking at 60 months or more after the operation [5]. Persistent RLN paralysis continues to deteriorate the patient's quality of life until it is adequately treated. In the setting of RLN sacrifice or iatrogenic injury, early treatment of the paralyzed cord should be undertaken.

Symptoms of Unilateral Vocal Cord Dysfunction

The symptoms of unilateral vocal cord dysfunction are related to lateral displacement (abduction) of the vocal cord causing glottic insufficiency as the cords no longer meet in midline during adduction. The most commonly reported symptom is a change in the patient's voice, usually hoarseness, though it can vary from vocal fatigue and decreased volume to complete aphonia. A breathy weak voice results from air escape during phonation due to the lateralized cord. The voice can also sound "wet" when secretions are retained in the pyriform sinus due to the inability to create a forceful cough. Swallowing difficulties are also seen along with a weak and ineffective cough. When the superior laryngeal nerve is also involved or injured, the patient will also lose sensation in the ipsilateral larynx, making the risk for aspiration higher. Injury to the superior laryngeal nerve is most common in high skull base lesions or surgery when the proximal vagal nerve is injured but can occasionally occur during esophagectomy and other procedures in the superior neck. With time, most patients compensate and will obtain a stronger voice, although it will not return to what the patient reports as their "normal" preoperative voice. The larynx attempts to compensate by supraglottic hyperfunction; where structures of the supraglottic larynx (false vocal cords or arytenoids) constrict to oppose each other. The supraglottic larynx can also constrict in the anterior to posterior direction with the epiglottis folding back and meeting the arytenoids cartilages to close the larynx. This hyperfunction attempts to mimic the closure of the true vocal cords.

Another common complaint from patients with VCP is reporting the feeling of being short of air or breath. This is mainly reported during conversation and is due to ineffective glottis closure, resulting in air leak and inability to project the voice. In an attempt to compensate, patients will strain the laryngeal musculature causing vocal fatigue. This lack of valsalva mechanism, which requires a closed glottis, makes exertional activity difficult (lifting, pushing, and straining).

Symptoms of Bilateral Vocal Cord Dysfunction

The clinical presentation of bilateral vocal cord dysfunction is different from unilateral dysfunction. The main complaint with bilateral dysfunction is shortness of air or stridor, with patients developing biphasic stridor immediately on ex-

tubation or within several hours. These patients often have a normal voice. Usually the cords are fixed in a paramedian position with just a 1–3-mm gap [1]. Patients can many times compensate and maintain adequate oxygen saturations remarkably well especially at rest. However, if a patient is struggling and working hard (may see retractions) to pull air through the narrowed glottis, they can quickly decompensate and require intervention. In this setting, the oxygen saturation is not a good representation of the patient's overall condition and many times is a late marker of decompensation.

Evaluation of the Vocal Cords

Evaluation of the vocal cords and larynx after esophagectomy should be undertaken on postoperative day 1, in the setting of a hoarse patient or one in whom the nerves were put at risk or knowingly sacrificed. Appropriate evaluation of the vocal cords to rule out dysfunction requires fiberoptic laryngoscopy; this can be done by a trained person, at the bedside. While visualizing the vocal cords, it is useful to have the patient perform an eee-sniff maneuver, where the patient alternates between phonating an "e" sound and sniffing vigorously. This causes the vocal cords to adduct and abduct maximally and is a good way to test for paresis [1]. Some residual adduction may be seen due to bilateral innervations of the interarytenoid muscle. Another useful technique is to measure the patient's maximal phonation time. This is done by having the patient take a deep breath and phonate the "ee" vowel sound for as long as possible. Normal maximal phonation time is at least 25 s. With vocal cord paresis or paralysis, this is usually reduced to less than 10 s [1]. Underlying chronic obstructive pulmonary disease (COPD) and asthma can influence this and must be taken into account.

When viewing the larynx through the fiberoptic laryngoscope, the examiner should also evaluate for tracheobronchitis, laryngeal edema from intubation irritation, and arytenoid dislocation. All of these can cause hoarseness in the postoperative setting that is unrelated to RLN injury. Laryngeal edema and tracheobronchitis are common causes of hoarseness in the recently intubated patient due to the contact irritation from the endotracheal tube, especially in patients with a history of reflux, tobacco exposure, and chronic cough—patients with chronic irritation of the larynx. It can cause dysphagia and aspiration when severe, especially in the compromised and susceptible patient. Laryngeal edema is self-limiting and should resolve with time; however, a short course of steroids can be given to hasten recovery in the appropriate patient. Antibiotics are rarely indicated except in the setting of complicated tracheobronchitis that is believed to be secondarily infected. Arytenoid dislocation is a controversial topic with most parties believing it is a rare entity. Arytenoid dislocation is mainly seen as a result of traumatic intubation and can be the etiology of the voice dysfunction. To evaluate for arytenoid dislocation, the professional looks for a difference in vocal fold level or height and the absence of the jostle sign. The jostle sign is a brief lateral movement of the arytenoid cartilage on the immobile side during glottis closure that is caused by contact from the mobile arytenoid. The evaluation for arytenoid dislocation is best done with videostroboscopy in a clinic setting.

When the vocal cord is not functioning postoperatively, at times it is difficult to know whether the nerve has been cut accidently or is nonfunctioning due to trauma and stretch, as paralysis and paresis present the same. A laryngeal electromyography (EMG) in this setting can provide prognostic information. A denervated nerve will show fibrillation potentials, absent or decreased motor unit potentials, and positive waves while normal or polyphasic waves are seen during reinnervation of the vocal cord and predict recovery for most patients [8]. Knowing whether the cord is paralyzed permanently is important in the counseling of the patient as well as offering therapeutic interventions. An abnormal EMG can also help differentiate from cricoarytenoid dislocation, which should have a normal EMG. However, the best way to test for cricoarytenoid dislocation is observation and palpation of the posterior glottis during direct laryngoscopy in the operating room.

Table 6.1 Products for vocal cord injections

Material	Length of effect	Comments
Gelfoam™[a]	4–6 weeks	Long track record, short duration
Zyplast™[a] (Bovine collagen)	4–6 months	Allergy testing required
Cymetra™ (Micronized alloderm™)	2–4 months	No allergy, longer prep time, expensive, unpredictable reabsorbtion
Fat	2+ years	Autologous, forgiving, donor site morbidity, unpredictable length
Fascia	3 months	Effects last up to 1 year
Teflon™[a]	Permanent	Long lasting, granuloma formation, migration, VF stiffness
Radiesse™ voice (Ca hydroxylapatite)	2+ years possibly permanent	Long lasting
Radiesse™ voice gel	1–2 months	Temporary

[a] Rarely used anymore

Whether or not the vocal cord is paralysed or just paretic, a good course of action is to involve the speech pathologist to evaluate swallowing in order to avoid silent aspiration. A modified barium swallow is warranted in all patients. Identifying aspiration will decrease the risk of respiratory complications from 18 to 11 % [2]. Occasionally, aspiration can be treated with specialized maneuvers that can create a safe swallow, such as the supraglottic swallow (patients are instructed to tightly hold their breath while swallowing, then to cough immediately after the swallow and before resuming breathing) or turning the head to the affected side during the swallow to help approximate the vocal cords during swallowing. The speech therapist can teach these maneuvers and evaluate their effectiveness during their evaluation.

Treatment of Unilateral Vocal Cord Dysfunction

Treatment of patients with vocal cord dysfunction should be tailored to the individual. It is acceptable to observe a patient with a weak voice who is not found to be aspirating. However, those who are aspirating or are not tolerating the deficit from the nonfunctioning vocal cord are candidates for intervention, either temporary or permanent, based on the surgeon's knowledge of the status of the nerve. In all patients, referral to a speech or voice therapist for voice strengthening, breath support, swallowing exercises, proper vocal use, and psychological support is appropriate. Best results are obtained when the patient sees the speech therapist prior to intervention as well as after surgical intervention.

Injection Augmentation

The injection of material into the vocal cord is an excellent method of improving vocal cord function for weeks to months. With numerous products in the market currently (see Table 6.1), there are several options in material whose duration of action is variable and treatment can be individually tailored to the patient's needs. Teflon is rarely used anymore due to its propensity to migrate and form granulomas. Newer synthetic agents have many times replaced teflon, fat (due to its inconsistent reabsorption), and bovine collagen (due to proposed need for allergy testing). Injections are an excellent option to improve voice and dysphagia while awaiting return of vocal cord function, usually up to 6 months. Longer lasting injections can also be considered in the setting where the RLN was known to be sacrificed. Radiesse™ Voice Gel for temporary injections (does not contain calcium hydroxylapatite) and Radiesse™ Voice for long-term injections have become popular at our institution due to the ease of preparation and injection and consistent long-term results. Vocal fold injections can be considered routinely in patients with a glottis gap up to 3 mm, after which the gap is difficult to fully correct [6]. These procedures do not interfere with

spontaneous recovery, and the injection can be repeated as needed. Vocal cord injection will not compromise future laryngeal framework surgery if required [6, 7].

Multiple techniques have been described for vocal cord injections. The intended injection location is in the paraglottic space or to the medial or lateral aspect of the thyroarytenoid muscle, depending on the material used. Placement of the injection lateral to the vocal process will allow the process to rotate medially [8, 9]. Care to avoid a superficial injection into Reinke's space is paramount as a superficial injection can impair or cause loss of the vibratory function of the vocal fold, with worsening of voice. In the correctly selected patient, an in the office awake injection (transcutaneous or per-oral approach) has equal results as to those that are placed in the operating room under general anesthesia via direct laryngoscopy with telescopic or microscopic guidance [8]. Cummings and colleagues reported an 85 and 88% subjective improvement of dysphagia and aspiration after hydroxylapatite medialization thyroplasty [7].

Framework Surgery for Unilateral Vocal Cord Dysfunction

Framework surgery for unilateral vocal fold dysfunction is a standard treatment for long-term VCP in the nonradiated neck, with medialization laryngoplasty (type 1 thyroplasty) and arytenoid adduction being the most widely performed procedures. Any framework surgery must be carefully considered in the radiated neck as chondroradionecrosis is a devastating though rare complication. Many times, long-lasting injections, even when needing to be repeated, are a safer option than framework surgery in this special population.

Medialization laryngoplasty is a long-term solution that medializes the paralyzed vocal cord to allow contact during vocalization with the contralateral cord. The procedure can be and usually is done under local anesthesia. A window is created in the thyroid cartilage preserving the inner perichondrium, and an implant (preformed or carved by the surgeon) is placed in the middle third of the vocal cord. Placement can be tailored specifically for each patient based on where the cord has lateralized and where the greatest glottis gap is located. Voice quality can be measured intraoperatively since the procedure is done under local anesthesia and adjustments in placement and size of the implant can be done while the patient is in the operating room. Due to the trauma and placement of a foreign body, a good voice on the operating room table can and will become rough and breathy due to edema in the subsequent days. It is recommended the patient be observed overnight in the hospital in case of significant airway edema and three doses of IV steroids be given. While medialization laryngoplasty is expected to be a permanent solution to medialize the vocal cord, the procedure can be reversed and the implant removed or adjusted as needed.

Arytenoid adduction can be an added procedure for selected cases, mainly those with a large posterior gap and vocal processes that do not contact during phonation. Arytenoid adduction is done by suturing the muscular process of the immobile arytenoid to the anterior cricoid cartilage. This lowers the position of the vocal process, medializes and stabilizes the vocal process, and rotates the arytenoid cartilage [1]. In the properly selected patient, arytenoid adduction is an important adjunct.

Treatment of Bilateral Vocal Paralysis

The initial management and concern in bilateral vocal paralysis is securing the airway. In a patient with stridor and who is in distress, intubation is the best method of securing the airway while a more definitive plan can be discussed and agreed upon. Reintubation with the administration of steroids can be done for 48–72 h with a subsequent trial of re-extubation versus tracheostomy. A temporary tracheostomy can be undertaken in a controlled situation if cord function is not thought to return within the next several days. Permanent tracheostomy while an excellent means of securing the airway is many times unacceptable

to the patient since there are alternative options available. Long-term surgical options to improve airway can be undertaken, however, they come at the price of voice and swallowing. Any opening or widening of the airway to create better flow will allow greater air escape during phonation. It can also compromise swallowing and lead to aspiration pneumonia in the susceptible patient as the vocal cords will not fully adduct.

Laser transverse cordectomy is the most commonly used procedure to widen the airway. A laser is used to transect the true vocal fold anterior to the vocal process, and the incision is extended laterally to involve the false vocal fold. This detaches the thyroarytenoid muscle from the arytenoid and allows the thyroarytenoid to contract anteriorly, which will create a posterior space. This can be repeated on the contralateral vocal cord as well if needed. Unilateral cordectomy will enlarge the airway a couple millimeters; however, patients see a reduction in their shortness of breath and most have an acceptable voice [10, 11].

The other routinely used procedure is a laser arytenoidectomy, where the entire arytenoid is removed along with a small wedge from the posterior vocal fold. This is usually modified and either the posterior or lateral aspect of the arytenoid is left in place. The results of this technique have been reported to be comparable to the transverse cordotomy and may possibly cause less vocal dysfunction due to less disruption of the membranous vocal fold.

While these procedures can allow for decannulation, they still only provide a marginal airway and have a worse voice quality than can be obtained with a tracheostomy. Tracheostomy would remain the best option for acute airway distress in the setting of bilateral VCP.

These patients are best managed in a team environment with the consultant's role being to maintain the airway, perform a full work-up, avoid aspiration, and continue with long-term follow-up. Long-term follow-up is important as those who were compensating and not aspirating without intervention may subsequently require future intervention as the vocal cord ages and undergoes normal age related changes (bowing). Repeat injections or augmentation to framework surgery may also be required in the setting of the aging larynx.

Key Summary Points

1. Symptoms of vocal cord dysfunction are primarily related to voice changes, air movement, and aspiration. Voice changes include changes in phonation and "breathy" voice.
2. Unilateral vocal cord injury must be differentiated from bilateral injury. While unilateral injury causes voice changes and increased risk for aspiration, bilateral injury can cause stridor and can be an airway emergency.
3. Treatment for unilateral injury includes observation, temporary medialization procedures, and more definitive surgical reconstruction.
4. Treatment for bilateral injury includes initially securing the airway. Permanent tracheostomy or surgical intervention may be needed for those patients in whom spontaneous recovery does not occur.

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Severe Reflux-Induced Esophagitis

7

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Introduction

Reflux-induced esophagitis is a condition characterized by inflammation of the esophageal squamous epithelium, caused by persistent and prolonged gastroduodenal reflux. The damage to the mucosa can progress to the point of becoming extremely debilitating, causing pain, esophageal dysfunction, and an overall diminished quality of life. Moreover, it may lead to severe complications, such as ulcers, bleeding, strictures, metaplasia, and epithelial dysplasia, which can eventually evolve to esophageal adenocarcinoma.

Pathophysiology

Reflux-induced esophagitis is caused by gastroesophageal reflux disease (GERD), a chronic condition in which the esophagus is pathologically exposed to gastric contents, such as acid and pepsin, and to alkaline reflux of duodenal origin, composed of bile salts and pancreatic secretions [1].

GERD is extremely common in the western world, where it is estimated to affect about 10–20% of the population, especially overweight, middle age, white males, whereas it is less prevalent in Asia [2]. It represents one of the most widespread outpatients' diseases in the USA and has become a serious burden for the health care system, and it is likely to increase in the near future due to rising obesity and bad eating habits [3].

Physiologically, several defensive mechanisms protect the esophagus from reflux, with the lower esophageal sphincter (LES) being the most important. This contributes to the creation of a high-pressure zone between the stomach and the esophagus and, together with the intrinsic esophageal, cardial musculature, and the crural diaphragm, prevents the upward transit of lower digestive contents in the esophageal lumen.

GERD develops as a consequence of the overcoming of the aforementioned barriers, through different mechanisms [4], such as

- Incompetence of the LES;
- Transient lower esophageal sphincter release (TLESR), mediated by vagal reflexes triggered by gastric distension;
- Peristaltic dysfunction;
- Ineffective esophageal acid clearance;
- Weak esophageal contractions;

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Table 7.1 Los Angeles classification of esophagitis

A	One (or more) mucosal break< 5 mm that does not extend between the peaks of two mucosal folds
B	One (or more) mucosal break> 5 mm long without continuity between the peaks of two mucosal folds
C	One (or more) mucosal break continuous between the peaks of two or more mucosal folds but involving less than 75 % of the circumference
D	Mucosal breaks involving at least 75 % of the esophageal circumference

- Delayed gastric emptying, which shows an increased risk in patients with diabetes and scleroderma [5];
- Increased intra-abdominal pressure;
- Decreased production of saliva, which has the capability of buffering the acid.

Specific conditions such as hiatal hernia and obesity [4] can predispose to the development of GERD as well as several habits such as smoking, alcohol, and caffeine use, medications that decrease the LES tone (Ca^{2+}channel blockers, anticholinergics, beta-agonists including inhalers, narcotics, nitrates, theophylline, opioids, neuroleptics, benzodiazepines, tricyclic antidepressants), and hormones such as estrogen and progesterone [6].

Erosive esophagitis is present in only one-third of patients with GERD symptoms [7], and the frequency and severity of reflux episodes poorly predict its occurrence [8,9].

In the past, chemical damage was thought to be the cause of esophageal erosion, but recent data suggest that it is an inflammatory-mediated process that triggers esophagitis. Cytokines released in response to acid reflux may attract immune cells, which are ultimately responsible for the mucosal damage. This hypothesis would explain the high interindividual variability in response to acid reflux and shed light on different healing patterns, leading to normal esophageal mucosa in some patients, whereas inducing a metaplastic process in others. Individual immune response and signaling pathways, which determine cell proliferation and differentiation, may play a role: It has been hypothesized that acid and bile salts could selectively modulate the expression of certain intestinal transcription factors (i.e., CDX2) in esophageal cells, thus triggering the metaplastic evolution. A complex molecular integration, beyond the mere chemical damage, would contribute to explain why not only the corrosive acidic reflux, but also the apparently less harmful alkaline reflux is capable of triggering an esophageal inflammatory response [10].

The inflammatory response could also affect the overall esophageal function, causing dysmotility [11], which might account for the tendency of esophagitis to self-exacerbate through a vicious feedback. In fact, impaired motility affects the ability of the esophagus to clear the refluxed acid content, leading to worsening of esophagitis.

Classification

Esophagitis is classified according to Los Angeles criteria [12], introduced in 1994 (Table 7.1).

Grades A and B are the most common and, compared to C and D, have an increased response to proton pump inhibitors (PPIs) (as high as 90 %). On the other hand, the most severe grades only heal in 50 % of the cases [13], have a higher tendency to relapse when medications are withdrawn, and have a fourfold increased risk at 2 years of developing Barrett's esophagus (BE), with respect to A and B grades [14,15].

There is only a weak correlation between degree of damage, esophagitis grade, and symptoms severity; however, there seems to be a link between erosive esophagitis and contact time with acidic juice.

Symptoms

Typical symptoms of GERD are heartburn and regurgitation. Other common symptoms are dysphagia, epigastric pain, bloating, belching, and nausea.

Symptoms are typically worsened by heavy meals, after the ingestion of certain foods, espe-

cially fatty ones, coffee, tea, spices, and acidic foods such as tomatoes and citrus fruits. They are often present at night when lying down, because this position impairs upper digestive clearance. For this reason, nocturnal reflux is usually associated with increased complications, severe esophagitis, and intestinal metaplasia (BE) [16].

Extra-esophageal, or atypical, symptoms such as chest pain, chronic cough, laryngitis, asthma, and hoarseness can also be present and muddy the clinical picture of GERD; respiratory symptoms are due both to the reflux itself and to the bronchospasm induced by vagal stimulation. Their response to PPIs and antireflux surgery (ARS) is not as satisfactory as that of typical symptoms.

Only one-third of patients with erosive esophagitis have symptoms [7], and some people with a rich constellation of symptoms do not show esophagitis (nonerosive reflux disease—NERD). There is a strong correlation between longstanding esophageal reflux disease and adenocarcinoma, and the risk is associated with disease severity, frequency, and duration [17]. As a consequence, an endoscopy should always be performed in the case of alarm symptoms such as weight loss, dysphagia, gastrointestinal blood loss, anemia, chest pain, and epigastric mass on palpation [18,19].

It is paramount to perform a differential diagnosis, in order to exclude conditions with overlapping symptoms, such as cardiac disease, gallbladder diseases, gastrointestinal tumors, peptic ulcers, eosinophilic esophagitis, infections, functional heartburn, and benign esophageal disorders such as achalasia, distal esophageal spasm, nutcracker esophagus, and diverticula.

Mortality in esophagitis is linked to its complication, mostly to adenocarcinoma. It is otherwise infrequent, having been reported in the year 2000 to be as low as 0.46/100,000 [20]. The most frequent causes of mortality, besides neoplastic degeneration, are hemorrhage (38%), ulcer perforation or esophageal rupture (29%), aspiration pneumonia (19%), and complications of ARS (11%) [20].

Diagnosis

The goal of diagnostic tests is to assess the following:

- the presence and degree of esophagitis;
- the underlying cause of reflux esophagitis; and
- the presence of complications.

The gold standard for detection of esophagitis is **endoscopy**. Patients presenting with typical reflux symptoms are commonly given an empiric course of PPIs; endoscopy is performed in those who fail or have an unsatisfying response to medical treatment. Upper endoscopy shows esophagitis only in 1/3 of patients with GERD symptoms [7] and is even less frequent after treatment with PPIs [21]. It is important to study the anatomy of the gastroesophageal junction (GEJ) (presence of hiatal hernia or diverticula), to rule out complications and to obtain esophageal and gastric biopsies to exclude the presence of concurrent diseases (i.e.,*Helicobacter pylori* infection or eosinophilic esophagitis). Moreover, endoscopic ultrasound (EUS) is at times useful to assess the degree of esophageal wall involvement.

Twenty-four hours pH monitoring is the only technique capable of objectively detecting the presence of acidic reflux. It is helpful in case of symptoms with a negative endoscopy. Moreover, it should always be performed before ARS, both as a definitive confirmation test and as a predictor of surgical outcomes.

Impedance monitoring allows detection of both acidic and alkaline reflux, adding sensitivity to pH monitoring. It is particularly useful when performed in patients on PPI therapy, in which reflux becomes mostly nonacidic [22].

Esophageal manometry is used to evaluate LES function and esophageal peristalsis and to rule out the presence of esophageal motility disorders.

Barium esophagram is not helpful for the detection of esophagitis itself, but it rather reveals severe complications such as strictures and Schatzki's rings and gives information on esophageal anatomy. It can also indicate the presence of a hiatal hernia, or other pathologic disease processes (e.g., neoplasms).

Bilitec consists of a fiber optic system for duodeno-gastroesophageal monitoring. It allows detecting duodenal reflux concomitantly in different sites of the upper GI, and it can be coupled with pH monitoring. It has been noticed that patients with concomitant gastric and duodenal reflux have a worse mucosal injury and higher severity of complications, compared to patients who present only one of the two components. Furthermore, patients with BE have a higher exposure to duodenal juice [23,24,25] than those who do not have metaplasia.

Treatment

There are three main treatment options for reflux-induced esophagitis: medical therapy, endoscopic treatment, and surgery. However, a multidisciplinary approach is often useful to address erosive esophagitis.

The therapeutic role and effectiveness of lifestyle modifications are controversial; however, these are often among the first advices given to patients after the diagnosis of GERD. The general recommendations are to avoid foods that stimulate LES relaxation such as tea, coffee, peppermint, chocolate, alcoholic beverages, and irritant foods such as citrus fruits and tomatoes. Moreover, it can be useful eating several hours before lying down, sleeping with the head lifted by 20 cm to favor esophageal clearance, and quitting smoking. Weight loss in overweight patients has been shown to improve symptoms even in refractory cases [26], likely by decreasing intra-abdominal pressure.

Medical therapy is the first line of treatment [27], with PPIs being the most effective group of medications [28]. PPIs should be prescribed to all patients with moderate to severe symptoms, or with a confirmed diagnosis of erosive esophagitis. PPIs are the most common class of medications prescribed in the USA [29]; they are very effective in healing esophagitis and improving its symptoms, and they are the most useful drugs in maintaining erosive esophagitis in remission. They should be initially prescribed at their minimum effective dose [30], and dose adjustment should be considered after evaluation of patient's response. After 1–2 months of therapy, erosive esophagitis is healed in 84–95% of patients; however, symptoms resolve only in 75–85% [4]. PPIs block the hydrogen–potassium ATPase (H^+/K^+ATPase) by covalently binding it on to the apical surface of the parietal gastric cells. PPIs do not decrease the amount of reflux, but they only make the gastric content less harmful by modifying the acidic and nonacidic content: acid decreases from 45 to 3%, while the nonacidic fraction increases form 55–97% [31]. As a consequence, the reflux still occurs, but it is not acidic, with a pH commonly raised above 4. Although duodenal reflux is not affected by PPIs, and some authors suggested that their use might increase its damaging potential [32]: bile acids are inactivated when surrounded by acidic environment, but after PPI therapy, the pH raises above 4 and bile salts are converted to their ionized form, which are able to cross epithelial cell membrane and cause intracellular damage.

PPIs have also reduced efficiency in treating extra-esophageal symptoms [33], which are commonly caused by the presence of reflux more than its quality.

Patients with esophagitis often require a lifelong therapy since medications do not address the disease's etiology; in fact, about 80% of patients will have recurrence of esophagitis approximately 1 year after the discontinuation of therapy [33].

Side effects of PPIs occur in about 1–5% of patients and consist mostly of diarrhea, headache, constipation, abdominal pain, nausea, and rash [29]; when severely affecting the patients, they are managed by switching to a different medication, since a considerable degree of subjective variability exists, even though most of the side effects are class dependent. PPIs are generally safe, but concerns have been raised during prolonged use. The continuous suppression of gastric acid causes hypo- or achlorhydria, which might affect some nutrients' absorption such as iron, vitamin B12, magnesium, calcium, and proteins [4]. Hypochlorhydria also decreases the acidic natural defense against bacteria, increasing the odds of overgrowth; an increased risk for *Clostridium*

difficile, *Salmonella*, and *Campylobacter*-related diarrhea has been reported [34]. Increased incidence of community-acquired pneumonia (CAP) has also been associated with PPI use [35].

Histamine2-receptor antagonists (H2RA) were also prescribed in the past, but several trials have established the superiority of PPIs over H2RA both in symptoms control and in esophageal healing, due to their capability of blocking the final step of acid secretion.

Surgery. Elective ARS can offer a definitive cure for esophagitis in selected patients, since it reestablishes a competent LES and allows for repair of concurrent hiatal hernias. Surgery has been shown to have the best outcome in patients with typical symptoms, objectively proven reflux, and good response to medical therapy [36]. The most common indications for ARS are dependence upon medical therapy, intolerance or noncompliance to therapy, and life-lasting treatment for young patients. ARS eliminates both acidic and biliary reflux in >90% of patients with BE [37], and the effect on alkaline reflux represents a major advantage of ARS over medical therapy. Randomized data have shown no difference in remission rate between maintenance PPI treatment and laparoscopic Nissen fundoplication at 5-year follow-up. The same study showed that while acid regurgitation was more prevalent in the PPI group, side effects of fundoplication, such as dysphagia, bloating, and flatulence, were more represented in the surgical group [38].

ARS has been reported to be more successful than medical therapy in stopping the progression to BE and adenocarcinoma [39]. Moreover, some studies have shown a higher likelihood of regression of Barrett's metaplasia and dysplasia after ARS [40,41].

The most used surgical procedure is the Nissen fundoplication, introduced in 1956, which consists of confectioning a 360° gastric wrap around the esophagus. Floppy Nissen is a modification of the original technique, which allows reducing dysphagia and gas bloat syndrome that occurred in as many as 40% of the patients with the traditional Nissen procedure. Floppy Nissen involves creation of a 2–3-cm-long gastric wrap around a bougie dilator (52–56 Fr).

In patients with severe motility disorders or suboptimal esophageal peristalsis, a partial fundoplication is generally performed in order to lower the risk of postoperative dysphagia. Partial posterior fundoplication (270° Toupet) has been introduced in the 1960s as an alternative to the Nissen fundoplication. In the short term, Toupet had good results in terms of reflux control, and it has been shown to decrease postsurgical dysphagia and bloating with respect to Nissen [4]. However, some studies report that it is less effective than total fundoplication, with a recurrence rate of reflux as high as 50% after 5 years [42,43].

ARS is mostly performed laparoscopically, since minimally invasive techniques grant significant advantages over open ARS, in terms of decreased pain, faster recovery, shorter length of hospital stay, and low morbidity and mortality.

Surgical complications occur in less than 5% of patients and mostly consist of bleeding and damage to the surrounding structures (spleen, esophagus, stomach, and vagus nerve). Postsurgical course is typically characterized by feeling of fullness and mild swallowing difficulties, especially with solid foods, but most patients return to normal after 6 weeks [44].

Nissen fundoplication has been reported to resolve reflux symptoms in up to 95% of patients. Its most common long-term complication is dysphagia, occurring with a frequency ranging from 3 to 25%, depending on the published series, and eventually leading to reoperation in up to 15% of patients. Less frequently patients complain of early satiety, bloating, and flatulence.

ARS has been reported to heal esophagitis in up to 87% of patients [45], with symptoms improvement in 95%. Recurrence of esophagitis after fundoplication ranges from 5 to 15% [46] and can lead to reoperation in about 6% of patients [47]. Recurrence of esophagitis is usually associated with a failed surgical procedure.

Surgical costs are justified by long-term success, savings on prolonged medical therapy, overall better control of disease, and increased health-related quality of life (HRQoL) when compared to PPIs [48,49]. Importantly, according to some authors, ARS is superior to medical therapy in limiting the progression of low-grade dysplasia

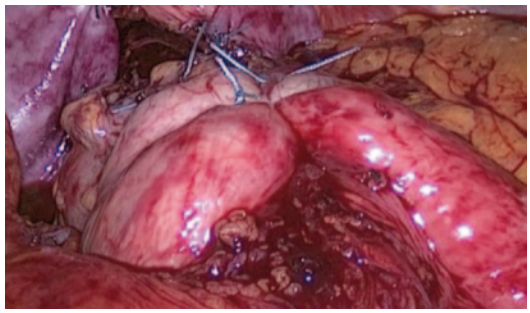

Fig. 7.1 Laparoscopic view of floppy Nissen fundoplication

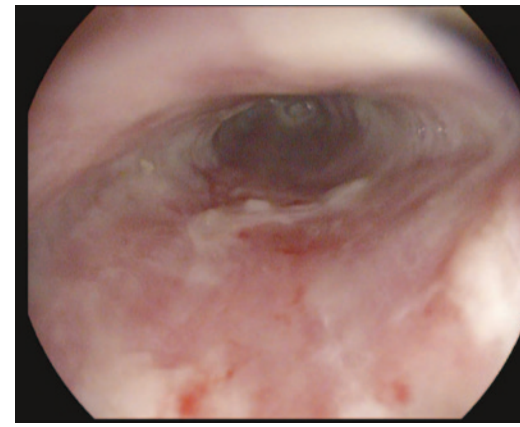

Fig. 7.2 Endoscopic view of grade C esophagitis with ulcerations

(LGD) to high-grade dysplasia (HGD) or cancer [50], and it leads to regression from LGD to BE in 93.8% versus only 63.2% with medical therapy [50]. This statistically relevant difference is probably due to the ability of surgery of limiting not only the acidic reflux, but also the biliopancreatic one.

New minimally invasive approaches for ARS include placement of a magnetic device around the GEJ to help maintaining LES continence or implantation of an electrical stimulator connected to electrodes in the LES that stimulates contractions. The LINX Reflux system used for sphincter augmentation through the employment of titanium beads showed encouraging results for uncomplicated GERD, reducing acid exposure with fewer side effects than ARS [51]. Even though these novel techniques have good potential, further studies are required to confirm their efficacy.

Finally, it should not be forgotten that although ARS lowers the risk of progression to cancer, it does not eliminate the risk of neoplastic progression in patients with BE, especially if there is recurrence of GERD. Endoscopic surveillance after surgery is recommended for patients with BE (Fig. 7.1).

Endoscopic techniques are relatively new approaches appealing for high-risk patients. These techniques include transoral incisionless fundoplication, suturing devices that create a gastroesophageal valve from inside the stomach, transmural fasteners, staplers, and radiofrequency devices used to induce muscular hypertrophy at the level of LES and gastric cardia. The efficacy of the latter approach may be due to increased wall thickness, LES pressure, decreased TLESR, decreased tissue compliance, acid sensitivity, and exposure [52]. However, according to some authors, endoscopic techniques are inferior to surgery in terms of decreased esophageal acid exposure, healing of esophagitis, and symptoms resolution [4].

Complications

Complications of esophagitis are strongly related to its chronicity, since continuous exposure to gastroduodenal reflux can progressively aggravate the disease.

Ulcers (Fig. 7.2): Erosive esophagitis can lead to ulcerations; these may be responsible for significant morbidities such as severe upper GI hemorrhages, strictures (12.5%), and esophageal perforations (3.4%) [53]. Chronic blood loss from active esophageal ulcers may cause iron deficiency anemia. Ulcerations are diagnosed with endoscopy, and a biopsy is always indicated to rule out malignancy. Ulcers in reflux esophagitis tend to be recurrent; therefore, appropriate therapy must be targeted to neutralize the underlying acid reflux and allow tissue healing.

Esophageal shortening and narrowing occur as a result of repeated, prolonged injury: Acidic reflux causes inflammation, edema, and

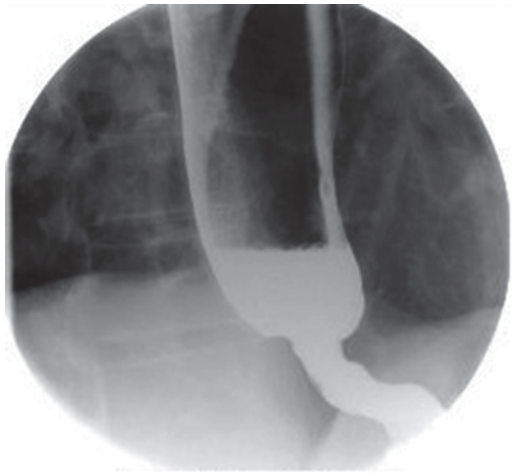

Fig. 7.3 Barium esophagram showing esophageal stricture

in the longrun destruction of muscolaris mucosae, leading to the formation of strictures at the level of the circular muscle; eventually, when fibrosis of the outer longitudinal muscle occurs because of transmural inflammation, the esophagus shortens. Esophageal shortening may also be found in patients with a failed antireflux procedure or with a mixed hiatal hernia that causes the upward migration of the GEJ [54]. 2–4% of patients undergoing antireflux procedures have a short esophagus [55].

Short esophagus is addressed surgically, most commonly using a Collis gastroplasty as an esophageal lengthening procedure. This can be completed laparoscopically, and an antireflux procedure is routinely added.

Strictures (Fig. 7.3) are the result of chronic inflammation and of repeated cycles of ulceration and healing, with subsequent fibrous tissue and collagen deposition, scar formation, and retraction. The process starts with a reversible phase characterized by edema and muscular spasm and then evolves to the formation of erosions. Location in distal esophagus, at the squamocolumnar junction, is a hallmark of peptic strictures, which are also usually shorter than 1 cm. Strictures observed more proximally are unlikely due to reflux. Peptic strictures can be found in 7–23% of patients with untreated GERD with severe erosive esophagitis, mostly in the elderly, and in 25–44% of patients who concomitantly have BE [56]. Their incidence has decreased steeply in parallel to the diffusion of PPIs. Factors predisposing to the development of peptic strictures include prolonged reflux, hypotensive LES, dysfunctional motility, hiatal hernia, bile reflux, and advanced age [53]. Symptoms are relatively nonspecific and influenced by stricture severity: dysphagia is the most frequent and can be accompanied by typical GERD symptoms. Food stasis causes halitosis and is also responsible for further mucosal damage and aspiration pneumonia.

Strictures can be divided into simple and complicated (Table 7.2) [57].

Alternatively, strictures can be classified into three subtypes (mild, moderate, and severe), according to the parameters such as diameter, length, and difficulty in dilating the stricture [58]; this distinction aims to help choosing the most appropriate treatment for every subgroup.

Diagnostic workup for peptic strictures must include endoscopy to perform biopsies and rule out malignancies. Esophagram (Fig. 7.3) is very helpful in visualizing the esophageal narrowing and proves particularly valuable in severe strictures, when the endoscope cannot pass through. Therapy's aim is to improve dysphagia, and avoid obstruction and recurrence.

Medical therapy plays a poor role once the stricture is already established; however, PPIs are fundamental to heal the concomitant esophagitis and prevent disease progression. Dilation is the primary therapy [59] and should be the first operative step: It can be attempted with the endoscope itself when the strictures are mild, but it is usually performed through bougies (Savary-Gilliard or Maloney) or balloon-type dilators, with or without guidewire assistance. Complex strictures often require guidewire and fluoroscopy for safe placement of the dilators. Self-dilation can seldom be offered to carefully selected patients [37].

Dilation is generally safe; however, the potential risk of hemorrhage and perforation ranges between 0.1 and 0.4% [59]. The occurrence of procedural complications can be reduced by performing the dilation progressively through

Table 7.2 Types of esophageal strictures [57]

Simple	Symmetrical, focal, concentric, with an esophageal luminal diameter of > 12 mm allowing the endoscope passage
Complicated	Long (> 2 cm) irregular, narrowing the luminal diameter to less than 12 mm

multiple sessions and avoiding dilating more than 3 mm each time [37]. Dilation should be associated with either acid suppression medical therapy or ARS to enhance success [60]. However, even with aggressive therapy, only 60–70 % of patients have complete resolution of symptoms, and multiple repeated dilations are often required [59]. To date, no randomized controlled trials have compared ARS versus medical management and serial bougienage; however, a retrospective study suggested that optimal reflux control with ARS results in decreased need for repeated dilation and better symptomatic outcome [61].

If satisfying dilation is not achieved after multiple sessions, strictures are deemed refractory, and the use of endoprosthesis (metal or plastic stent) should be considered [4]. Esophageal stenting and local steroid injections can be an auxiliary therapeutic option for refractory or recurrent strictures; the latter in particular has the capacity of inhibiting the inflammatory response, limiting collagen deposition [62]. Combining these two treatments with acid suppression therapy successfully reduces both the need for dilations and the time between sessions [37]. Presence of hiatal hernia, ineffective acidic therapy (low dose, poor compliance), or alkaline reflux may predispose to disease recurrence.

Rarely, esophagectomy is indicated for recurrent or refractory strictures with underlying intractable esophagitis and a severely damaged esophagus [58]. Most commonly, an esophagectomy is necessary with gastroplasty or colonic/jejunum interposition [63].

Schatzki's Rings are circular narrowed areas constituted by esophageal and gastric mucosa with fibrous and connective tissues, which are usually observed at the GEJ. They have a similar etiology to peptic strictures, and they also lead to dysphagia causing food impaction in the esophageal lumen. If this event occurs abruptly, endoscopic food extraction is indicated; the procedure is safer when performed with an endoscope covered by an overtube, in order to avoid aspiration in the bronchial tree. Conversely, pushing food in the stomach is not advisable as it may lead to perforation. Schatzki's rings are diagnosed through barium swallow and endoscopy. The therapy of choice is bougie dilation associated with PPIs that are administered after dilation, which dramatically reduce esophageal rings' incidence and recurrence.

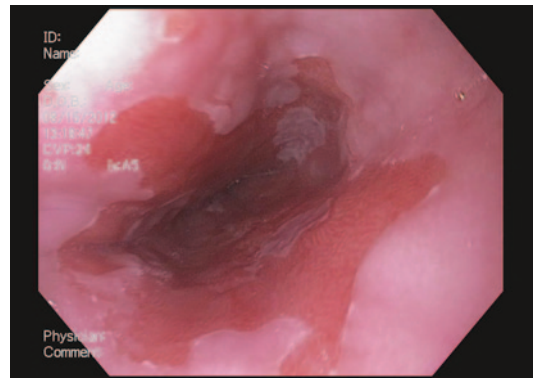

Fig. 7.4 Endoscopic view of Barrett's esophagus

Respiratory complications may arise in patients with esophagitis, mainly as a consequence of long-standing GERD. Aspiration of acid and alkaline reflux can acutely cause chemical pneumonia; chronic acid exposure may lead to asthma and permanent lung damage such as fibrosis and bronchiectasis. Both medical therapy and surgery are less successful in patients with respiratory symptoms than typical symptoms. However, surgery offers the advantage of eliminating non-acid reflux episodes as well and therefore may be more appropriate in these types of patients.

Barrett's esophagus (Fig. 7.4). About 10 % of the patients with erosive esophagitis [6] show an intestinal type of metaplasia called BE, in which patches of columnar epithelium with typical intestinal goblet cells replace the normal stratified squamous esophageal epithelium in the distal esophagus. Affected patients have

a higher acid exposure than those with erosive and nonerosive esophagitis without BE [64]. The metaplastic transformation occurs as an adaptive response to injury exerted by reflux on the physiologic esophageal lining. High-grade esophagitis has a high damaging potential, and its healing through metaplastic columnar epithelium makes the esophagus more resistant to reflux injury, but at the same time, may trigger significant dysplastic changes: LGD, pre-invasive HGD, and adenocarcinoma. BE is a pre-cancerous condition and needs to be identified and surveilled to allow for prompt intervention in case of degeneration. Risks for BE are longstanding disease, erosive esophagitis, advanced age, male gender, obesity, smoking, hiatal hernia [37], and peptic strictures (triplicate the risk).

Identifying patients with BE on the basis of symptoms only is impossible, and this weak clinical correlation hampers BE's early diagnosis and monitoring.

The true prevalence of BE is not known, but this condition is estimated to affect 1.6% of the general population, with rising incidence: an alarming 159% increase from 1993 to 2005 has in fact been observed [37]. BE is detected in 3% of patients who have had GERD for less than 1 year and in more than 20% of those who had symptoms for 10 years [65].

Male to female ratio for BE is 3:1, and the average patients' age is 55 years. BE does not cause symptoms per se, but it carries a substantial risk of progression to adenocarcinoma each year.

The gold standard for diagnosis is endoscopy with biopsy. Since severe erosive esophagitis can impair detection of BE, aggressive PPI therapy should be administered in patients with known esophagitis in order to heal the esophageal mucosa and maximize the diagnostic potential of endoscopy [66]. It is advisable to perform an endoscopy to screen for BE in all patients with a long history of disease (5–10 years) [67] or when patients with GERD are >50 years of age. If the endoscopy is positive, guidelines advise for an endoscopic surveillance program at specific intervals according to their histological pattern [30]:

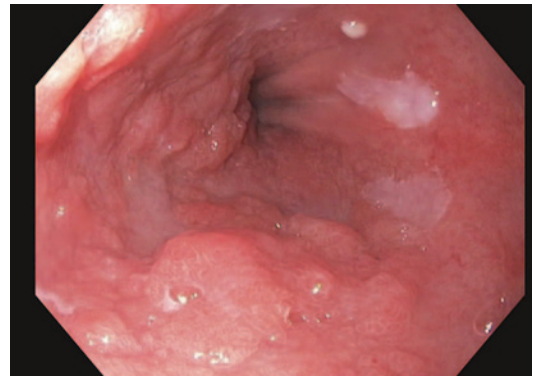

Fig. 7.5 Endoscopic view of early-stage esophageal cancer arising in Barrett's mucosa

- Every 3–5 years if there is no evidence of dysplasia;
- Every 6 months for LGD;
- Every 3 months for HGD in patients not receiving endoscopic or surgical therapy.

If BE is nondysplastic, it has a 0.25−0.4% risk of progression to carcinoma each year, which rises to 0.6−5% in BE with LGD [68, 69].

Both the American Gastroenterologic Association and the British Society of Gastroenterology acknowledge endoscopic radiofrequency ablation (RFA) as the first line of treatment for patients with HGD, but no data sustain its use in BE with LGD and without dysplasia [70]. Complete eradication of metaplasia has been reported to be persistent after 3 years in 91% of patients with intestinal metaplasia, in 96% of patients with HGD, and in 100% of those with LGD [70]. The most worrisome consequence of BE ablation is the persistence of disease within the submucosa covered by normal neosquamous epithelium: the so-called "buried glands" phenomenon. This event is rare but potentially dangerous since it is difficult to monitor these glands for possible degeneration and there are reported cases of cancer that arise underneath a normal squamous mucosa.

Endoscopic mucosal resection (EMR) is a valid technique to better assess the presence of cancer within an irregular esophageal mucosa (Fig. 7.5) or even underneath a normal epithelium. With EMR, several centimeters of mucosal and submucosal layers can be removed, thus allowing for precise staging of the lesion and

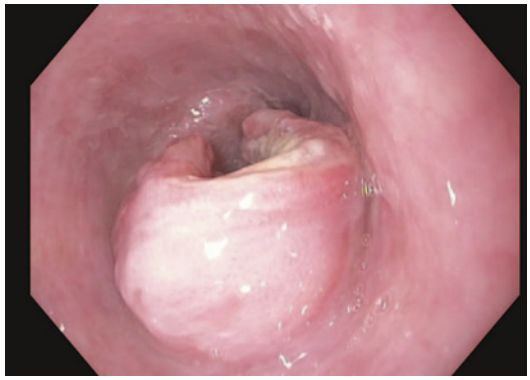

Fig. 7.6 Endoscopic view of advanced esophageal cancer

possible complete resection if no breach to the deep layers of esophagus has occurred.

EMR is usually indicated for focal lesions, but it can be associated with RFA for treatment of broader BE areas, with an eradication rate of dysplasia and cancer ranging from 85 to 100%. Additionally to being a valid option, this procedure guarantees a better life quality, and less morbidity and mortality compared to esophagectomy.

When endoscopic therapy fails, in case of long segments of BE with multifocal cancer, or when the patient is noncompliant with the need for a demanding endoscopic surveillance program, esophagectomy should be considered.

Esophageal adenocarcinoma (Fig. 7.6**)** is the most dreadful evolution of severe reflux disease. Its incidence is rapidly increasing in the western world, especially in white males, after the age of 50. The poor prognosis of this disease underlines the importance of individuating and starting endoscopic surveillance in patients at risk. Patients with BE have an overall 0.5% yearly progression rate to esophageal adenocarcinoma [71], but there is a 7% yearly incidence in patients with HGD [72].

No endoscopic screening is required for the general population, but endoscopy should be considered for patients with multiple risk factors, such as age > 50, male gender, obesity, Caucasian race, chronic GERD, and hiatal hernia [68,73]. Early detection of cancer decreases mortality and increases options for treatment. The mainstay of therapies for locally advanced esophageal adenocarcinoma is neo-adjuvant therapy followed by esophagectomy. Endoscopic mucosal and submucosal resection, possibly combined with RFA, should be considered for early stages with good prognosis [74].

Conclusion

Severe reflux esophagitis is a disease characterized by a broad-spectrum presentation. It can be kept under control with several therapeutic strategies, but if not properly addressed, it may progress to severe complications.

Five Key Points on How to Avoid Complications

- Do not overlook symptomatology; always consider reflux esophagitis in the differential diagnosis of upper GI manifestation, especially in patients with long history of GERD.
- Once the disease is diagnosed, esophagitis should be graded according to the Los Angeles criteria and risk factors assessed; when necessary, the patients should be monitored.
- Administer appropriate and targeted medical therapy and check for its efficacy and patients' compliance.
- Appropriately select patients who are ideal candidates for surgery and target the surgical technique according to their characteristics.
- If the patient is a surgical candidate, consider surgery early in the disease process before the development of complications.

Five Key Points on Diagnosing and/or Managing the Complications Either Intraoperatively or Postoperatively

- The best diagnostic technique to diagnose complications is endoscopy associated with biopsy to evaluate the presence of metaplasia or dysplasia.
- EMR is the best tool for staging early esophageal cancer.

- Consider adding a fundoplication for refractory endoscopic treatment of GERD complications.
- Intraoperative assessment for the presence of short esophagus is key for the success of ARS.
- Esophagectomy is a good option for the "unsalvageable" esophagus and offers patients' good long-term quality of life.

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Intraoperative Solutions for the Gastric Conduit that Will Not Reach

8

Ali Aldameh

Colon as an Alternative Conduit

The stomach is the preferred conduit for esophageal replacement in majority of the cases for its reliable blood supply, low intraluminal bacterial burden, and the need for only a single anastomosis. Occasionally, the stomach is not available because of previous abdominal or gastric surgery or involvement with tumor [1–5]. The esophageal surgeon should be equipped with the knowledge and skills to use alternative conduits for reconstruction. Most surgeons will then utilize the colon as a second option for an alternative conduit. The left colon in particular has an advantage over the right colon in that its lumen is smaller and more closely approximates that of the esophagus. The vascular anatomy on the left is more consistent than on the right; however, involvement by atherosclerotic disease of the inferior mesenteric artery is more common than in any other mesenteric vessel. Preoperative evaluation is crucial in all cases where colon is anticipated as a conduit. Complete surgical history including knowledge of prior abdominal surgery that may have interrupted either the arterial blood supply or venous drainage of the colon that may render a segment of the colon unusable is important. The inferior mesenteric vein drains into the splenic vein, and prior severe pancreatitis or other causes of splenic vein thrombosis may render the left colon unusable as a conduit because of inferior mesenteric vein thrombosis. Colonscopy and CT angiography are performed in the preoperative evaluation to rule out colonic disease or vascular anomalies including neoplasia, stricture, or extensive diverticulosis. Mechanical and antibiotic bowel preparations are administered prior to surgery.

A midline laparotomy is performed, and the abdomen is explored for metastatic disease. The peritoneal attachments of the left colon to the retroperitoneum are divided along the white line of Toldt. We use an umbilical tape from the proposed proximal line of transection of the esophagus through the proposed route of placement of the conduit to the point of proposed anastomosis to the stomach. The umbilical tape length is used to estimate the conduit length that is needed and can then be used to measure an appropriate length of colon.

The vessels supplying the left colon are visualized by transillumination and the middle colic artery is test clamped. A palpable pulse should still be present in the marginal artery. If there is any question, a Doppler probe is used to assess the quality of the pulse, a clamp is then left in place, and the conduit inspected for adequate perfusion. Once the conduit is deemed of satisfactory quality, we proceed with the esophagectomy. The left colon is then prepared. The omentum is separated from the left colon and splenic flexure that is to be used as a conduit. The middle colic artery is divided, and the mesentery is divided

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as close as possible to the root, away from the marginal artery of Drummond. The colon is reanastomosed with a single interrupted 3.0 silk anastomosis and the mesenteric defect is closed. The proximal anastomosis is then constructed; this allows better determination of conduit length and ensures that the conduit will sit properly in the neck. The proximal end of the conduit is retrieved into the neck by use of an endoscopic camera bag attached to suction tubing. We prefer the posterior mediastinal (in situ) route as this is the shortest route between the stomach and esophagus **(**Fig. 8.1**).** The surgeon should be prepared to accept that in some cases the posterior mediastinal route is unavailable because of prior infection and prior gastric conduit leak with subsequent scarring. In these cases, the substernal is preferred. If a substernal approach is used, we resect the manubrium or a portion of the manubrium to prevent obstruction, prevent angulation, and to allow adequate space for the colon. The proximal anastomosis is typically constructed with a single- or two-layer hand-sewn anastomosis of the end of the esophagus to the side of the antimesenteric taenia. The anastomosis is constructed over a nasogastric tube with its tip positioned in the center of the stomach. The conduit should be monitored for arterial insufficiency or venous engorgement. We then complete the gastrocolic anastomosis with a large EEA stapler or in a side-to-side functional end-to-end stapled manner. Finally the conduit is sutured to the crus to prevent migration of the colon into the chest or herniation of abdominal viscera into the chest.

In cases where the left colon is involved with extensive diverticular disease or atherosclerotic occlusion of the inferior mesenteric artery, and splenic vein thrombosis with thrombosis of the inferior mesenteric vein, it is unusable as a conduit. The right colon is an acceptable conduit and is used as an alternative conduit that will reach the esophagus in the neck.

The right colon is inspected and its retroperitoneal attachments are dissected and lysed. The mesentery of the right colon is transilluminated and the ileocolic, right colic, marginal, and middle colic arteries identified. Clamps are placed on the ileocolic and right colic arteries, and the right colon is inspected for adequate perfusion through the marginal artery. The right colon is then harvested, leaving the marginal artery intact. An appendectomy is performed. Appropriate lengths of right colon are divided with a GIA 75-mm stapler, and the colocolonic anastomosis is performed in a single layered interrupted fashion. The proximal end is drawn up into the neck carefully to prevent trauma or injury to the harvested colon. The proximal anastomosis is then completed cre-

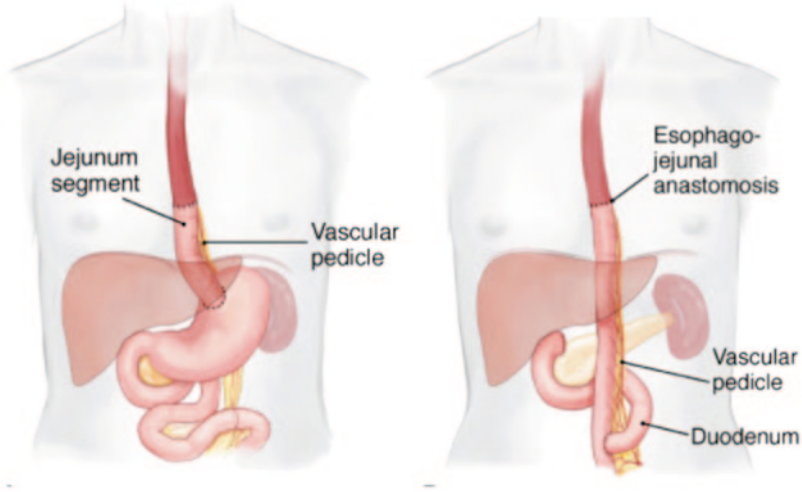

Fig. 8.1 We prefer the posterior mediastinal (in situ) route as this is the shortest route between the stomach and esophagus

ated via a single-layer end of esophagus to the side of the colon along the taenia. Finally we construct the cologastric anastomosis with either an EEA staplers or a side-to-side stapled technique.

Jejunum as an Alternative Conduit

Replacement of the esophagus with jejunum is indicated when the stomach is not suitable because of prior surgery or involvement with disease. Jejunum is then used to replace a portion of the esophagus as a free graft, pedicled graft, or Roux-en-Y replacement Fig. 8.2. Replacement of a distal esophageal peptic stricture should be performed with colon or jejunum in preference to stomach. Interposition of an isoperistaltic segment of intestine is preferable to gastric pull-up, which has a very high incidence of recurrent severe reflux. Roux-en-Y jejunal replacement may be used to replace the stomach and distal esophagus after total gastrectomy including distal esophagectomy. Free jejunal graft is indicated in limited reconstruction of the cervical esophagus. However, total esophageal replacement cannot be accomplished with jejunum alone as the length is insufficient to reach the neck. Important detailed history to exclude patients with disease of the small bowel due to inflammatory bowel disease or previous surgery is crucial in the preoperative preparation. Mechanical bowel preparation is not necessary for jejunal interposition; however, if the jejunum is found to be unacceptable as a conduit or if the blood supply to the jejunum is inadvertently damaged during harvest, rendering it unusable as a conduit, the colon should be readily available and prepared for reconstruction.

After total gastrectomy and distal esophageal resection, Roux-en-Y replacement may be used for reconstruction. Main indications include proximal gastric tumors or esophageal resection into the upper chest. With meticulous preparation, Roux-en-Y configuration will reach the neck, but this is variable; however, it will not reliably reach the cervical esophagus. When it is used after total gastrectomy, jejunum is divided approximately 30 cm beyond the ligament of Treitz. The jejunum is elevated outside the abdomen, and the vascular arcade is transilluminated. The proposed point of division is identified, and the line of division of the mesentery is identified along with the proposed division of several vessels of the mesentery, which will allow transposition of the jejunum up into the chest. The feeding vessel is identified and preserved. The serosal surface of the mesentery is scored, and the vessels to be transected are momentarily clamped and the conduit observed for few min-

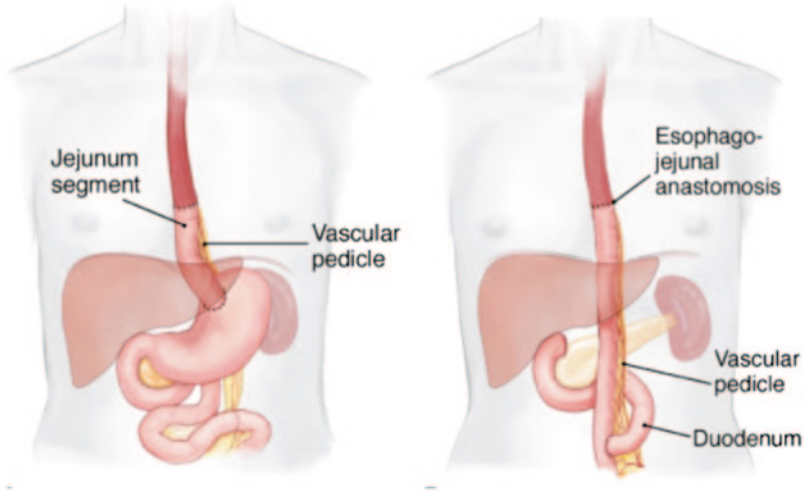

Fig. 8.2 Jejunum is then used to replace a portion of the esophagus as a free graft, pedicled graft, or Roux-en-Y replacement

utes for evidence of ischemia or congestion. A window in the transverse mesocolon is created to the left of the middle colic vessels for the jejunum and its mesentery to pass through. In cases of total gastrectomy, the proximal anastomosis is to distal esophagus in the upper abdomen. If distal esophagectomy is performed as for tumors of the cardia that extend to the gastroesophageal junction, the abdominal incision must be brought across the costal margin into the left sixth or seventh interspace.

A stapled or hand-sewn technique is used for the esophagojejunal anastomosis. We prefer a 33-mm EEA stapler. A pursestring suture is placed in the distal esophagus, and the shaft of the EEA stapler is introduced through the stapled end of the proximal jejunum. After removal of the EEA stapler, the jejunal end is closed with a TA 60-mm stapler. To prevent herniation of abdominal contents into the chest and minimize tension on the esophagojejunal anastomosis, the jejunum is tacked to the hiatus at several points with interrupted silk sutures. The defect in the colonic mesentery should be closed to prevent an internal hernia. The distal anastomosis can be hand sewn or performed by a side-to-side functional end-to-end stapled technique.

Pedicled Jejunal Interposition

This is best performed via a left thoracoabdominal incision along the left seventh interspace across the costal margin and the rectus muscle. The jejunum is transilluminated, and an appropriate length of jejunum is selected from a point 20 cm distal to the ligament of Treitz. A single large vessel is used as a feeding vessel for the conduit (Fig. 8.2). The jejunum is transected proximally and distally with a GIA stapler, and the mesentery is divided on each side. The remaining jejunum is reconnected by a side-to-side functional end-to-end standard stapled technique. The pedicled jejunum is tunneled through the mesocolon and brought into the left chest. The proximal anastomosis is then constructed in a similar fashion to the Roux-en-Y esophagojejunal anastomosis. The jejunogastric anastomosis is then hand sewn in two layers with interrupted 3.0 silk sutures.

Free Jejunal Interposition

In certain circumstances, a free jejunal graft may reach portions of the upper esophagus that pedicled grafts may not. There is a significant risk of life-threatening graft ischemia and necrosis. In addition, two anastomoses are required, increasing the morbidity risk of anastomotic leaks. A short segment of jejunum is harvested and a left cervical incision is made. The esophagus and carotid and jugular vessels are isolated. The jejunal vessels are dissected and isoplated and sharply divided. The artery and vein are flushed with heparinized saline. The proximal hand-sewn anastomosis is constructed first, an operating microscope and fine 9-0 or 10-0 suture are used to anastomose the jejunal vessels to the carotid and jugular vessels, and the distal anastomosis is then constructed. Finally the graft is covered with a meshed split-thickness skin graft to allow monitoring of graft viability in the postoperative period.

Summary

Various possible operative techniques for esophageal conduit replacement exist to treat patients with esophageal carcinoma in whom the stomach will not reach the neck due to disease or malignancy. The skilled esophageal surgeon should be a master of the anatomy of the neck, chest, and abdomen and prepared to use all routes and methods available. We have described our methods for alternative reconstruction in this chapter. The references below are included for further reading.

Key Points

1. The colon and jejunum are alternate conduits for the case where the stomach will not reach.
2. When using the colon, the left colon is preferred over the right, partly due to a better size

match with the esophagus. The posterior mediastinal route is preferred over the substernal route.

3. Careful assessment and preservation of the vascular supply, especially the marginal artery, to the colon must be performed when considering a colonic conduit.
4. A jejunal conduit can be used as a free graft or a pedicled graft. The vascular supply must be carefully assessed and preserved as well, similar to when using a colonic conduit.

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Injury to the Right Gastroepiploic Artery

9

Ravi Rajaram and Malcolm M. DeCamp

Introduction

The right gastroepiploic artery (RGEA) has played an important role clinically for the general and cardiothoracic surgeon for many years. While this vessel was frequently used in previous years for revascularization in cardiac surgery, its current significance stems primarily from its role as the principal blood supply to the gastric conduit in an esophagectomy. Consequently, careful dissection and preservation of this artery is paramount in ensuring adequate blood supply for alimentary reconstruction. This chapter is a review of the importance of technique and meticulous dissection of this vessel. Furthermore, we will describe important considerations in anticipating and avoiding injury to this artery, management options when an injury to RGEA is identified, and procedures to augment blood flow to the tenuous gastric conduit.

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Anatomy of the RGEA

The RGEA most often arises as a terminal branch of the gastroduodenal artery which itself is a branch of the common hepatic artery (Fig. 9.1). This vessel traverses from the patient's right to left along the greater curvature of the stomach and is encased within the greater omentum. Because the left gastric, short gastric, and left gastroepiploic arteries (LGEA) are ligated during a standard esophagectomy, the blood supply to the stomach relies primarily on the RGEA with some contribution from branches of the right gastric artery.

The gastric fundus is the region most distant from its arterial inflow and venous drainage and thus particularly susceptible to ischemia. Blood flow to the fundus was initially thought to rely on the RGEA communicating directly with the LGEA. However, studies on this topic differ and have suggested that a direct RGEA anastomosis with the LGEA only occurs approximately 23–70% of the time [1–5]. In a cadaver study by Liebermann-Meffert et al., the authors found that the RGEA contributed approximately 60% of the total blood supply to the gastric tube with the remaining portion distributed among collaterals from the LGEA (20%) as well as a smaller, submucosal network of collaterals (20%). Of note, they also reported that direct communication between the RGEA and LGEA is minute and that while the right gastric artery is often preserved in esophagectomy, its contribution to the vascularity of the gastric tube is negligible [6].

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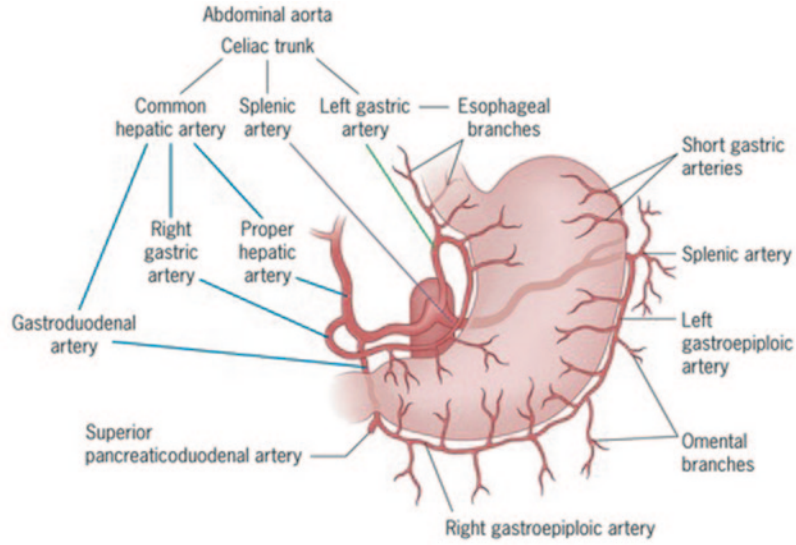

Fig. 9.1 Anatomy of the right gastroepiploic artery

These findings underscore the importance of the RGEA in the success of the gastric conduit during esophagectomy.

Vascular Considerations in Esophagectomy

Studies have demonstrated that use of a gastric conduit, as opposed to jejunal or colonic, for esophageal replacement following esophagectomy is associated with similar, if not lower, rates of ischemia. However, this highly morbid complication still occurs with use of stomach, with estimates ranging from 0.5% to 10.4% of cases [7–9]. Research has shown that mobilization of the gastric fundus during esophagectomy is associated with a greater than 50% decrease in gastric tissue oxygen tension and that this resulting degree of oxygenation is correlated with subsequent success of the esophagogastric anastomosis [10, 11]. Consequently, while some loss of tissue perfusion and oxygenation is unavoidable during this surgery, optimizing conditions for blood flow is critical for a successful anastomosis and good postoperative outcomes. These studies highlight the importance of careful, gentle manipulation and handling of the whole gastric conduit throughout the entirety of the operation to minimize local trauma, vascular torsion/kinking, or conduit tension or compression. From a physiologic perspective, it is also important to avoid worsening perioperative splanchnic hypoperfusion by minimizing the use of vasopressors and alpha agonists. Communication with the anesthesia team intraoperatively and critical care team postoperatively regarding the significance of avoiding these medications is key to maximizing oxygen tension in the newly mobilized gastric conduit.

Preoperative Evaluation of the RGEA

A detailed past medical and surgical history is critically important prior to esophagectomy. Known aorto-iliac occlusive disease or peripheral vascular disease, as well as any prior vascular intervention whether transabdominal or catheter-based, should raise concern for adequacy of gastric conduit perfusion after mobilization. An associated history of diabetes, given its known impact on both macro and microvascular disease, may also warrant a more focused evaluation. A dedicated computed tomography (CT) scan of the chest, abdomen, and pelvis is often part of the preoperative evaluation of the esophageal cancer patient. In addition to reviewing the tumor and nodal morphology and ruling out metastases, the surgeon should also evaluate the visceral aorta

for extensive calcification. In the setting of the aforementioned comorbid conditions, evaluation of celiac and mesenteric arterial integrity may be achieved through modalities such as CT or magnetic resonance (MR) angiography or aortography.

Currently, patients who have a planned esophagectomy, do not routinely undergo any form of preoperative screening to ensure an appropriate diameter or size of the RGEA. Evidence from cardiac surgery has shown that preoperative evaluation of this vessel in the form of transabdominal ultrasound or multidetector CT is feasible and may be worthwhile in operative planning for coronary artery bypass revascularization [12, 13]. For example, in a study by Minakawa et al., the authors used preoperative sonography to evaluate the RGEA and identify patients with a threshold artery diameter of 2 mm for subsequent revascularization. All individuals that met this criterion preoperatively were found intraoperatively to have arteries sizeable enough for subsequent anastomosis. Furthermore, comparison of preoperative ultrasound measurements with postoperative angiography of this vessel was highly correlated and confirmed acceptability of this screening approach. Unfortunately, data regarding the use of preoperative evaluation of the RGEA in esophagectomy are lacking. However, in patients who may have a history of foregut surgery, previous exploratory laparotomy, prior cardiac surgery with an unknown graft, or aberrant or incomplete anatomic visualization on routine preoperative imaging, the use of either of these modalities with special attention to the RGEA may prove useful in operative planning.

Preparation and Mobilization of the Gastric Conduit

Given the infrequency with which dedicated imaging of the RGEA is obtained preoperatively, it is important that soon after entering the peritoneal cavity and establishing exposure that the RGEA is identified. There is tremendous known variability in the celiac and hepatic arterial system and thus the location and path of the RGEA [14]. While this vessel reliably originates just inferior to the pylorus and traverses along the greater curvature, its relationship with the LGEA is subject to change as described above [1]. As such, to avoid accidental injury, it is advantageous to locate and establish the RGEA's anatomic relationship and path early upon entering the abdomen prior to proceeding further in the course of the operation. This is especially true during any abdominal reoperation as adhesions may distort or obscure the precise anatomy of the omentum, transverse colon, and greater curvature of the stomach.

During the preparation of the gastric conduit, the greater omentum is separated from the greater curvature of the stomach. At this point in the operation, the surgeon should be extremely mindful of the previously identified course of the RGEA. Accidental injury, or excessive manipulation, of this vessel during dissection of the omentum can cause irreparable vascular compromise and subsequently result in an inability to use the stomach as a conduit for esophageal replacement [15]. Consequently, it is recommended that a minimum of 2.0 cm clearance be given between the RGEA and the omentum to be divided to avoid accidental mechanical or thermal injury (Fig. 9.2) [16]. Additionally, particular attention should be given when the dissection approaches the pylorus as the RGEA courses deep and posterior to the duodenal bulb to its origin from the gastroduodenal artery. The gastrocolic ligament and omentum are often fused with the transverse mesocolon in this location. Careful separation of these planes

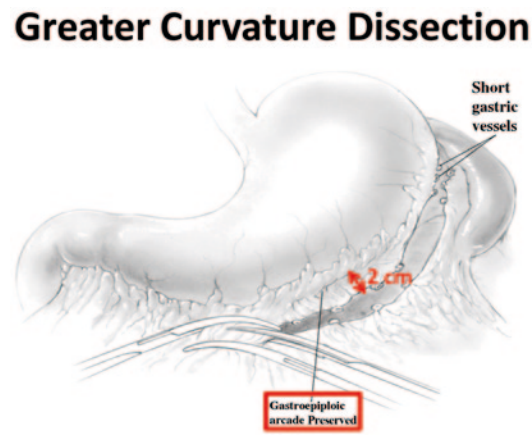

Fig. 9.2 Greater curvature dissection

is required to avoid traction injury to the RGEA or its accompanying veins. This dissection also promotes easier passage of the conduit cephalad while decreasing subsequent anastomotic tension.

Esophagectomy with the use of a gastric conduit involves a delicate balance of obtaining appropriate reach of the conduit while preserving vascularity to the esophagogastric anastomosis. Ensuring an appropriate length of conduit is key not only for achieving a tension-free anastomosis but also for minimizing reflux in the patient postoperatively [15]. Transferring of the conduit cephalad into the chest or neck is a critical step in the course of the operation. During this time, it is important to avoid excessive stretch, torqueing, or twisting that may result in stenosis, dissection, or a traction injury to the RGEA. Maintaining collinear movement of the conduit with its vascular pedicle will help to safeguard against inappropriate twisting or rotation during mobilization.

Additionally, after the tubularized stomach has been relocated to the chest, the surgeon should inspect the conduit to ensure that there is no excessive compression at the diaphragmatic hiatus. In recognition of this, we routinely open the hiatus anteriorly to the pericardial reflection, ligating the crossing phrenic veins. Omitting these safeguarding steps may result in significant vascular compromise to the conduit with identification after it is too late. Arterial compromise typically presents early postoperatively with acidosis and evidence of a systemic inflammatory response syndrome (SIRS) due to conduit necrosis. Venous compression is more insidious with full thickness necrosis often delayed until postoperative days 5–7.

Techniques for Improving Tissue Oxygenation

Tension-Free Anastomosis

Achieving appropriate length of the gastric conduit can often be an issue, especially for cervical anastomoses. The stretch placed on the stomach when attempting to reach the cervical esophagus may result in compromised blood flow, particularly in the relatively oxygen-deprived fundic region of the stomach. A generous Kocher maneuver and careful separation of the gastrocolic ligament from the transverse mesocolon aid in facilitating appropriate length.

Additionally, novel techniques have been described to address this issue of tension on the conduit and to allow for sufficient reach [17]. For example, noting the relative redundancy of the greater curvature in comparison with the strained lesser curvature, some authors have advocated for the use of a lengthening procedure termed "angleplasty." In this technique, the point of tension at the angle of the lesser curvature is divided transversely through the seromuscular layer for a distance of 4 cm exposing the submucosa. This is followed by a longitudinal incision for approximately 4 cm through the gastric wall with subsequent closure of the incision using vertical seromuscular Lembert sutures [18]. By lengthening the gastric tube, this procedure may allow for a tension-free anastomosis and as a result improved arterial flow and reduced venous congestion in the proximal portion of the stomach.

Finally, as long as a cancer-free esophageal resection margin can be achieved, another simple technical maneuver to reduce tension when conduit length is limited is to change the level of the planned anastomosis from cervical to intrathoracic. Multiple studies have consistently demonstrated lower anastomotic leak rates for intrathoracic reconstructions [19, 20]. Thus, although an unanticipated change in the operative plan is not ideal, it is often preferable to a dubious anastomosis.

During any esophagectomy, but particularly in the context of a tenuous RGEA, creating a tension-free anastomosis is critical to a successful patient outcome. Use of a generous Kocher maneuver, "angleplasty," and alterations to the anastomotic level are techniques the surgeon may employ to mitigate this concern as best as possible.

"Supercharging"

The territory most vulnerable to ischemia in the gastric conduit is the proximal portion of the

stomach in the area of the fundus. This is primarily attributed to the unfortunate fact that after mobilization and transposition of the stomach into the chest or cervical region, this portion of the conduit is farthest away from its nutrient arterial inflow and venous drainage. This area is also where the esophagogastric anastomosis occurs. Thus, a potentially ill-fated situation occurs, whereby the area most susceptible to ischemia is also the region most in need of a robust blood supply for healing.

With this in mind, a technique that has received considerable attention for patients requiring esophagectomy is "supercharging." The use of this method was first reported in 1947 and has increasingly been reported in the literature [15, 21]. "Supercharging" involves creating additional microvascular anastomoses to increase blood flow to the gastric conduit or, in some cases, the pedicled jejunal or colonic substitutes. While some surgeons may routinely use this procedure, more often it is selectively implemented to augment blood flow. In this context, the use of "supercharging" may prove invaluable as a salvage technique, particularly in the case of a tenuous conduit or compromised RGEA. The value of this procedure lies in its potential to not only increase arterial flow but also enhance venous drainage from the conduit. The latter is often a concern following esophagectomy, in particular when there is marked gastric distention at either the thoracic inlet or the diaphragmatic hiatus, or when the conduit is on tension or has a particularly long cephalad reach.

"Supercharging" has been described for many kinds of esophageal reconstructions including the use of gastric, jejunal, and colonic conduits. In a series reported by Sekido et al., 82 reconstructions of all types were performed with use of "supercharging" selectively in situations where the conduit appeared ischemic or had areas of poor perfusion. They most commonly used the superior thyroid artery in the neck and the internal thoracic artery in the chest as the recipient arteries. Venous drainage was achieved with use of the internal or external jugular veins in the neck or the internal thoracic vein in the chest. In the case of gastric conduits, the graft artery was the RGEA and the graft vein was a transferred gastroepiploic vein. The majority of patients had both an arterial and venous anastomosis performed. Of the 82 reconstructions, only two had leaks, none requiring reoperation, and only two patients had conduit necrosis with one requiring reoperation [22]. Of note, thrombosis in the anastomosis did occur in three patients intraoperatively, and in each case, redoing the anastomosis was successful.

In another series, nine patients had "supercharging" performed and seven of these involved a gastric conduit. In preparing the stomach, the LGEA was ligated proximally, close to its origin from the splenic artery. Subsequently, the LGEA was anastomosed to the transverse cervical artery in an end-to-end fashion using 9-0 nylon. Intraoperative blood flow measurements were taken at the fundus of the stomach and, in each case, flow increased after this microvascular anastomosis. None of the nine patients experienced a leak postoperatively [23].

In a study by Murakami and colleagues, they evaluated "supercharging" for use in total esophagectomy with pharyngogastrostomy. In this series of 11 patients, none experienced a leak or conduit necrosis postoperatively. Additionally, they found that performing only a venous anastomosis increased mean blood flow to the gastric fundus by 19% using laser Doppler flowmetry, whereas performing both an arterial and venous anastomosis resulted in a 43% increase in flow to this same region [24]. In a subsequent study, the authors found that performing a microvascular anastomosis procedure in subtotal esophagectomy was associated with a significantly lower likelihood of postoperative leak compared to a control group which did not have any microvascular anastomoses [25].

While the target and choice of recipient and graft vessels vary considerably in different descriptions of "supercharging," the basic tenets of augmenting blood flow to an area of relative ischemia remain consistent. Although these studies were all associated with increased operative times, serious consideration should be given to performing additional microvascular anastomoses in the presence of a questionably viable

RGEA. If an injury to the RGEA is sustained intraoperatively, or excessive stretch of this vessel is a concern, the use of "supercharging" as an adjunct may salvage use of the gastric conduit. It is worth noting that no studies have systematically looked at use of this technique in the context of a damaged or injured RGEA. Nevertheless, awareness and consideration of "supercharging" may prove timely when an injury does occur and few other options are available to supplement blood flow to the conduit.

Venous Drainage

The importance of alleviating stagnant venous drainage, as done in "supercharging, " has been addressed by other means as well. One example of this is by transient bloodletting from the short gastric vein. In one study, the authors found that 30 min of bloodletting after creation of the gastric tube resulted in a significant increase in tissue blood flow at the esophagogastric anastomosis shortly afterwards. Flow remained elevated from baseline after bloodletting ceased although this was not significant [26]. Nonetheless, in a patient with a compromised RGEA, it is necessary to attenuate venous congestion as much as possible and allow for appropriate inflow to the proximal region of the stomach. Transient venous bloodletting, while technically cumbersome, may help in achieving this and should be considered a tool in the surgeon's armamentarium during esophagectomy.

Conclusion

Esophageal reconstruction with use of the gastric conduit has become an established method of preserving alimentary continuity following esophagectomy. Although the risk of esophageal leak or necrosis is not insignificant following this surgery, techniques may be employed to improve postoperative success. These techniques center primarily upon preserving and augmenting the bloody supply the RGEA provides to the gastric tube. A detailed medical and surgical history with consideration of dedicated preoperative vascular imaging in high-risk patients is a necessary first step. Intraoperatively, early identification of this vessel with meticulous dissection is required to ensure that this vessel is kept intact. Transposition of the gastric conduit to the chest or neck should be done carefully with particular attention given to avoiding excessive twisting of this vessel and creating a tension-free reach. Finally, the surgeon should consider the use of novel procedures such as "angleplasty" or "supercharging" if there is persistent concern for a tenuous blood supply. With deliberate use of the steps outlined in this chapter, the likelihood of an injury to the RGEA is minimized and the resulting success of the operation optimized postoperatively.

Five Key Points: Avoiding Injury to the Right Gastroepiploic Artery

1. After gaining exposure, identify the right gastroepiploic artery early in the course of the operation and determine if any aberrant anatomy is present.
2. Ensure a buffer zone of **at least** 2.0 cm from the visible, palpable, or "dopplerable" right gastroepiploic artery when separating the greater omentum from the greater curvature of the stomach.
3. Ensure careful separation of the gastrocolic ligament, omentum, and transverse mesocolon as you approach the pylorus during the greater curvature dissection to avoid a proximal pedicle injury.
4. Delicate care should be taken when mobilizing or repositioning the gastric conduit into the chest or neck to prevent excessive longitudinal tension, kinking, or torsion on the right gastroepiploic arcade.
5. After mobilization, evaluate the right gastroepiploic artery at the diaphragmatic hiatus to assess for excessive impingement that may result in vascular compromise.

Five Key Points: Diagnosing and/or Managing the Complication Intraoperatively or Postoperatively

1. If concerned about vascular compromise, make liberal use of the Doppler to evaluate the pedicle and fundic region of the stomach to assess appropriate blood flow.
2. Consider additional intraoperative techniques in the conduit with a tenuous, but viable, right gastroepiploic arterial supply such as "angleplasty" to relieve tension or "supercharging" to improve inflow and/or venous drainage.
3. Consider revising the operative plan to allow a shorter conduit if oncologically feasible, e.g., an intrathoracic versus cervical anastomosis.
4. Consider converting to a pedicled jejunal or colonic interposition graft if irreparable damage has been done to the right gastroepiploic artery.
5. Avoid perioperative alpha agonists and vasopressors that may decrease splanchnic outflow in the setting of an already tenuous right gastroepiploic artery.

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Intra-Operative Solutions for Ischemic Gastric Conduit

10

Robert E. Merritt

Gastric Esophageal Replacement Conduit

The stomach has supplanted the colon and the small intestine as the esophageal replacement conduit of choice. The stomach has a constant blood supply, which includes the right and left gastroepiploic arteries and veins, the left and right gastric artery and veins, and the short gastric vessels. The stomach is easily be mobilized by dividing the gastro-colic, gastro-hepatic, and gastro-splenic ligaments (See Fig. 10.1). The stomach can easily be used to replace the esophagus for both transthoracic esophagectomy and transhiatal esophagectomy. The stomach can be constructed into a tubular conduit and an esophagogastric anastomosis can be performed in the upper thorax, which is typically done as part of an Ivor Lewis esophagectomy. The esophagogastric anastomosis should be performed at the level of the azygous vein or higher. The stomach can also be transposed into the neck for a cervical esophagogastric anastomosis as described in the transhiatal esophagectomy. There are four major factors to consider when mobilizing the gastric conduit, which have significant ramifications for gastric conduit ischemia or necrosis [1].

1. The right gastroepiploic artery is the main arterial blood supply to the gastric conduit and should be preserved in every case. The gastoepiploic vein is equally important and any direct manipulation of the gastroepiploic vascular arcade should be avoided. The adequacy of arterial blood flow within the artery can be tested with a Doppler probe intraoperatively if there are concerns about an injury to the arcade.
2. The intraoperative surgical margins on the gastric conduit should be assessed prior to the esophagogastric anastomosis. This can be a particular challenge for large GE (gastrointestinal junction) junction tumors that extend into the gastric fundus. The gastric conduit should not be narrower than 4 cm in diameter.
3. The gastric fundus should be maintained in order to provide adequate length of the gastric conduit. This principle becomes very important when the esophagogastric anastomosis needs to be performed in the cervical neck, where adequate length of the gastric conduit is essential to avoid tension on the anastomosis.
4. The shape and diameter of the conduit is an important consideration in terms of gastric emptying. The conduit should ideally be 4–5 cm in diameter. Large and patulous gastric conduits may not empty well, which results in delayed gastric emptying. Large and dilated gastric conduits may result in venous congestion and may possibly contribute to conduit ischemia.

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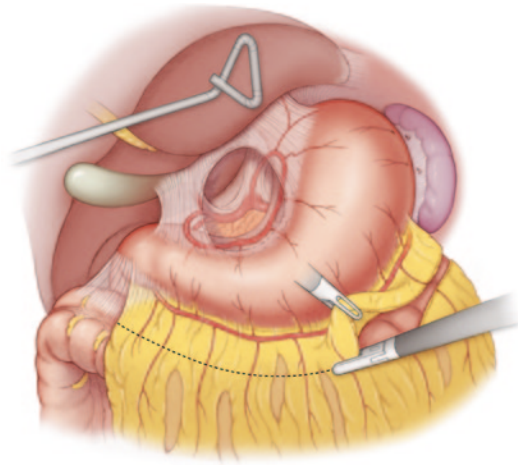

Fig. 10.1 The gastro-colic ligament is divided with a ligasure device along the greater curvature of the stomach. The right gastroepiploic arteriovenous arcade should be preserved during the dissection. Injury to the gastroepiploic arteriovenous arcade would result in immediate gastric conduit ischemia

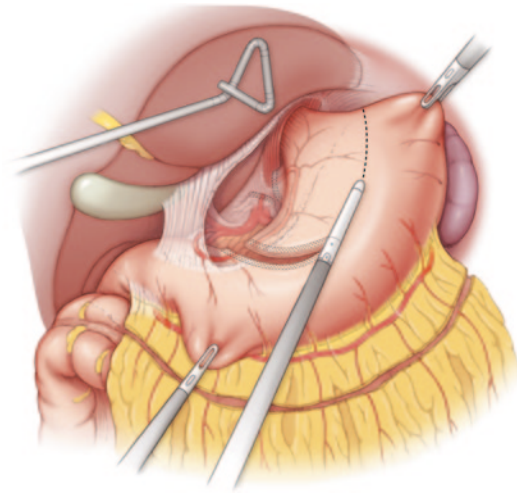

Fig. 10.2 The gastric conduit is created by dividing the stomach along the greater curvature with a linear endomechanical stapler. A tubular gastric conduit is created, which should measure 4–5 cm in diameter for maximal conduit perfusion and functional emptying

The preservation of the right gastroepiploic ateriovenous arcade is sufficient to sustain the gastric conduit after mobilization [2]. The left and right gastric artery arcades can be routinely divided without increased risk for ischemia because approximately 60% of the blood supply comes from the right gastroepiploic arteriovenous arcade [3]. The ideal width of the gastric conduit should be 4–5 cm in diameter. The gastric conduit is created by dividing the mobilized stomach along the lesser curvature with a linear endo-mechanical stapler (See Fig. 10.2). Gastric conduits that are too narrow can result in gastric tip necrosis due to the poor collateral circulation in the submucosa of the gastric fundus [4]. The gastric conduit is typically passed through the esophageal hiatus and the intrathoracic anastomosis is performed at the level of the azygous vein. The esophageal hiatus should be widened enough to avoid compression of the esophageal conduit and subsequent venous stasis.

The incidence of gastric conduit ischemia and necrosis depends largely on the technique that was used to mobilize the stomach. The occurrence of an anastomotic leak and/or stricture is largely related to the incidence of ischemia of the gastric conduit. The incidence of anastomotic complications varies in the reported studies with a range of 0–24% [5–8]. Kassis et al. recently reported an overall anastomotic leak rate of 12.3% for cervical anastomoses and 9.3% for intrathoracic anastomosis in a large series of 7595 esophageal resections from the Society of Thoracic Surgeons (STS) database [9]. Orringer et al. reported a large series of 1085 transhiatal esphagectomies, which reported an anastomotic leak rate of 13% and a gastric conduit necrosis rate of 2.6% [10]. The higher rate of gastric conduit ischemia/necrosis encountered with the cervical esophagogastric anastomosis is thought to be related to the possible compression from the mediastinum and/or the thoracic inlet. The overall incidence of gastric conduit necrosis ranges from 0.5 to 10.4% [10–15]. The reported series are summarized in Table 10.1.

The predisposing factors for gastric conduit necrosis include direct injury to the gastroepiploic ateriovenous arcade, external compression of the gastric conduit, low perioperative blood pressure, and excessive manipulation of the gastric conduit. The risk of gastric conduit necrosis can be minimized with meticulous operative technique

Table 10.1 Esophagectomy series reporting the incidence of esophageal conduit necrosis

Series	# Patients	Mortality (%)	Anastomosis leak (%)	Conduit ischemia (%)
Orringer [10]	1085	4	13	2.6
Peracchia [11]	242	0.8	5.8	1.2
Davis [12]	959	10.6	3.9	0.5
Shuchert [13]	222	1.4	–	3.2
Briel [14]	230	3.5	14.3	10.4
Moorehead [15]	760	3.8	–	1.0

for mobilization of the stomach and creation of the gastric tube. The gastroepiploic arcade should be identified intraoperatively with gentle palpation or by Doppler probing. The localization of the primary blood supply to the gastric conduit should minimize the risk of direct injury. In addition, the author recommends checking for twisting of the gastric conduit prior to the anastomosis and ensuring that the esophageal hiatus is not compressing the gastric conduit.

Diagnosis of Gastric Conduit Ischemia

The early recognition and diagnosis of gastric conduit necrosis is critical to minimizing the risk of perioperative mortality. The clinical signs and symptoms of gastric conduit necrosis depend on the degree of ischemia and the extent of the esophagogastric leak. Patients often develop tachycardia, leukocytosis, metabolic acidosis, and altered mental status. The patients can potentially develop florid sepsis and respiratory failure requiring intensive care unit (ICU) admission, mechanical ventilation, and vasopressor support. The contrast esophagogram should demonstrate extravasation of the contrast consistent with an anastomotic leak (See Fig. 10.3a, b). An upper endoscopy can be performed with minimal insufflation to assess the esophagogastric anastomosis and the mucosa of the gastric conduit can be evaluated for ischemia or frank necrosis. A computed tomography (CT) scan of the thorax can also be obtained to evaluate for the evidence of an anastomotic leak, such as pneumomediastinum, pleural effusion, or disruption of the esophagogastric anastomosis. For patients with cervical anastomoses, the neck incision can be opened directly to inspect for drainage from the anastomosis and assess the fundus for ischemia or necrosis.

The appropriate management and treatment of gastric conduit ischemia/necrosis is crucial to the survival of the patient. In cases in which the ischemia is mild and the manifestation is an anastomotic leak that is contained, the patients can be managed with bowel rest, intravenous antibiotics, and drainage. In patients with anastomotic leaks and associated mediastinitis and empyema, a reoperation is necessary to drain any purulent fluid and to debride the mediastinum and the intrathoracic cavity. The disrupted area of the esophagogastric anastomosis can be repaired primarily if the gastric conduit has adequate arteriovenous perfusion. The necrotic material of the edges of the esophagus and gastric conduit should be debrided before embarking on the primary repair. The author prefers to use interrupted nonabsorbable suture to re-approximate the anastomosis. A pleural flap or intercostal muscle flap can be used to cover the repaired anastomosis. In certain cases, the gastric conduit will be found to be severely ischemic, and there is a tissue necrosis present. In this situation, the gastric conduit cannot be preserved and an esophageal diversion should be performed. The gastric conduit should be dissected down to the esophageal hiatus and divided with a linear stapler. The staple-line should be over-sewn to minimize the risk of a bile leak into the thorax. The esophageal anastomosis is also resected and a cervical esophagostomy is fashioned below the level of the left clavicle. This location is better for the placement of an ostomy bag and for the concealment of the ostomy under clothing. The placement of a functioning

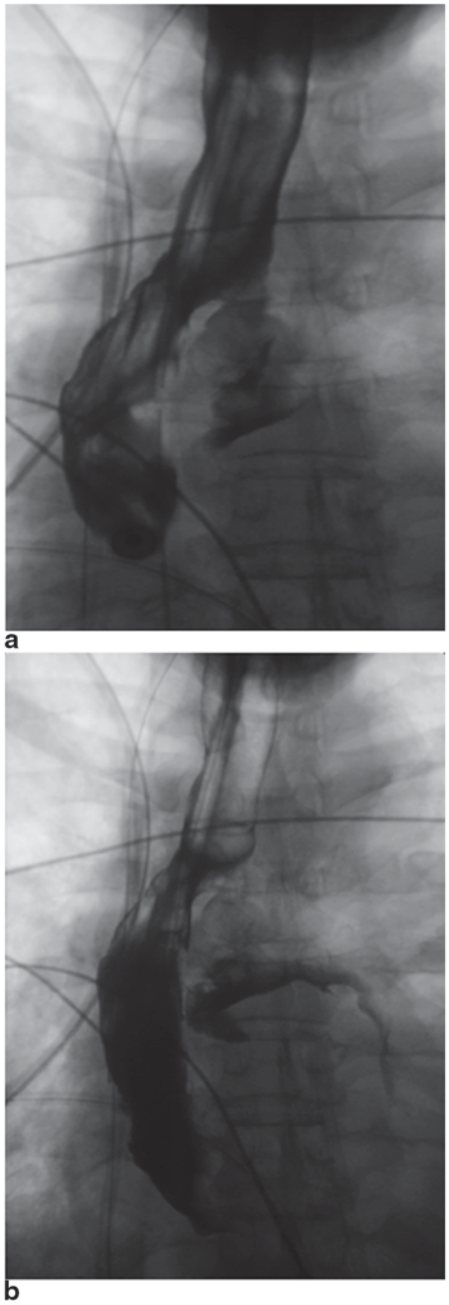

Fig. 10.3 **a** A contrast esophagogram demonstrates contrast extravasation consistent with an esophagogastric anastomotic leak. **b** A contrast esophagogram demonstrates contrast collecting in the mediastinum consistent with a large anastomotic leak

jejunostomy tube is essential for adequate enteral nutrition and hydration during the period of esophageal diversion. After the patient has recovered from the operation, a staged reconstruction can be planned for 3–6 months after esophageal diversion. The author prefers to utilize the supercharged pedicled jejunal interposition technique for reconstruction of the gastrointestinal tract [16]. During this procedure, a Roux-en-y limb of jejunum is harvested and passed through a substernal tunnel. The left clavicle head and hemi-manubrium are resected to provide space for the jejunal limb and avoid compression. The ateriovenous pedicle of the jejunal limb is then anastomosed to the left internal mammary vein and artery to provide "super-charged" perfusion. A two layer hand-sewn esophago-jejunostomy is performed to restore gastrointestinal continuity. Blackmon et al. reported a series of 60 patients who underwent super-charged pedicled jejunal interposition for esophageal replacement in which 83 % of the patients were able to achieve a return to a regular diet [16].

There have been a number of techniques that were proposed for the prevention of gastric tube ischemia/necrosis. Urschel hypothesized that ischemic conditioning of the gastric fundus could be achieved by dividing the left gastric arteriovenous pedicle prior to a planned esophagectomy [17]. Patients would undergo a staging laparoscopy 1–4 weeks prior to the esophagectomy. The left gastric pedicle would be divided at the time of laparoscopy to "pre-condition" the gastric fundus for ischemia. This concept has not been proven to be effective in preventing gastric conduit necrosis. Similarly, Sekido et al. reported the results of performing microsvascular augmentation for the gastric conduits that appeared ischemic immediately after the gastric mobilization [18]. Two patients underwent a venous—venous anastomosis and one patient underwent an arterial augmentation with improved gastric conduit outcome.

Summary

The occurrence of gastric conduit ischemia/necrosis after esophagectomy remains the most challenging postoperative complication to manage. The incidence of this complication is relatively low; however, the impact on perioperative mortality is significant when the gastric conduit necrosis occurs. In the postoperative period, surgeons should be attuned to recognizing the early clinical signs of conduit necrosis, such as new onset tachycardia, respiratory failure, or mental status changes. The diagnosis can be determined with contrast esophagography and/or direct inspection of the gastric mucosa with endoscopy. In cases of frank gastric conduit necrosis, a takedown of the esophagogastric anastomosis and resection of the ischemic gastric conduit is indicated. The esophageal diversion procedure is completed by creating a cervical esophagostomy. Patients can be reconstructed with either a jejunal interposition graft or a colonic interposition graft after 3–6 month recovery period. The best strategy to minimize the risk of the gastric conduit necrosis is prevention. Meticulous dissection of gastric conduit and preservation of the right gastroepiploic arteriovenous arcade will help ensure excellent conduit function and healing. In addition, careful patient selection is important to avoid postoperative cardiopulmonary dysfunction that directly impacts the vascular perfusion to the gastric conduit during the postoperative period. Clearly, more research needs to be conducted to better predict which patients are at high risk for the gastric conduit ischemia/necrosis and to improve intraoperative assessment of the gastric conduit perfusion.

Key Points for Avoiding Gastric Conduit Necrosis

- Avoid direct injury to the gastroepiploic ateriovenous arcade.
- Ensure that there is no external compression of the gastric conduit as it passes through the esophageal hiatus.
- The diameter of the gastric conduit should be 4–5 cm.
- Preserve the gastric fundus for maximal gastric conduit length.
- Avoid perioperative hypotension and hypoxemia to minimize decreased arteriovenous perfusion to the gastric conduit.

Key Points for Managing Gastric Conduit Necrosis Postoperatively

- Recognize the early signs of conduit necrosis, such as tachycardia, hypotension, leukocytosis, respiratory dysfunction, and altered mental status.
- Patients with gastric conduit necrosis and anastomotic dehiscence require an esophageal diversion with formation of an esophagostomy.
- A functional jejunostomy tube is essential for nutritional support and hydration after esophageal diversion.
- A supercharged jejunal interposition or colon interposition can be used for esophageal reconstruction after the esophageal diversion.
- Ischemic preconditioning or vascular augmentation have limited evidence of efficacy in the prevention of gastric conduit necrosis.

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Jejunal Feeding Tube Complications

11

Sidhu P. Gangadharan

Introduction

Adequate nutrition in patients undergoing treatment for esophageal pathology is crucial. Dysphagia and odynophagia may lead to malnutrition at presentation. Treatment, whether chemoradiation or surgery, may also lead to impaired ability to take adequate nutrition. While this is typically temporally limited, at times it may be more chronic. Malnutrition increases the risk of postoperative complications in patients undergoing surgery for esophageal cancer [1–4]. Intensive nutritional support has been found to improve outcomes of esophagectomy, particularly in patients who undergo neoadjuvant chemoradiation [5]. Weight gain is improved and the incidence of severe postoperative complications is decreased in patients in whom nutrition is optimized. A randomized trial of nutritional supplementation noted that patients who received preoperative supplementation and patients who received both preoperative plus postoperative supplementation with a formula enriched with arginine, omega-3 fatty acids, and RNA revealed similar levels of significant improvement when compared with a control group with no supplemental nutrition [6].

However, in some patients, oral intake is not sufficient to realize these benefits, and tube feeding must be used to supplement or replace food by mouth. In cases where this might be thought to be transient, a nasally placed enteric tube may suffice. However, for longer-term use, a feeding tube that accesses the bowel directly may be preferable, especially with a high rate of dislodgement of a nasally-placed tube [7]. At esophagectomy, the standard practice is to place a feeding tube to allow more rapid resumption of enteric nutrition if a pre-esophagectomy tube had not already been placed. Recent studies have questioned whether this routine practice is necessary, noting that a benefit with regard to length of stay, infectious complications, or anastomotic leak has not been definitively demonstrated [8]. Nevertheless, given the minimal additional time needed to place feeding jejunostomy tubes, and the hedge against future issues such as anastomotic stricture or delayed gastric conduit emptying leading to poor oral intake, most surgeons still believe in this practice. Dependence on tube feeding outside of the initial postoperative period (>3 weeks) has been reported in over 10 % of patients undergoing esophagectomy [9].

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Technique for Placement

Open Surgical Jejunostomy Tubes

The history of the development of jejunal access spans over 150 years with Bush in 1858 who created a jejunostomy for feeding in a patient with unresectable gastric cancer [10]. The use of a tube placed directly into the jejunum for feeding dates back to 1878 and Surmay de Havre. Further surgical technical modification is most notable for Witzel's description in 1891 of the imbrication of bowel longitudinally over the tube [11]. In 1973, Delany described the technique of needle catheter jejunostomy, utilizing a thinner catheter and a subserosal tunnel [12]. With the advent of percutaneous endoscopic gastrostomy, technical modifications were soon made to allow both transgastric jejunal tube placement and direct percutaneous endoscopic jejunostomy tube placement [13–15]. As laparoscopy became established in the early 1990s, this technique was adopted for jejunostomy tube placement [16–19]. Radiologists have since developed a technique for direct percutaneous access of the jejunum without endoscopic guidance [20].

A standard surgical jejunostomy tube may be accomplished via three different techniques: Stamm jejunostomy, Witzel jejunostomy, or needle catheter jejunostomy [11]. The location for placement is similar in all cases, usually between 20 and 30 cm from the ligament of Treitz. Orientation of the jejunum is assured so that the tube will eventually pass in an antegrade direction so as to avoid the reflux of tube feeds into the stomach or esophagus. Latex or silicone rubber catheters have been used for these feeding tubes, with sizes ranging from 8 to 18 Fr, generally. A Witzel jejunostomy is created by placing a purse-string suture in partial-thickness fashion on the antimesenteric aspect of the jejunum. An enterotomy is created in the middle of the purse string, and the tube is directed into the lumen, and the suture is tied without occluding the tube lumen, but snugly enough to avoid leakage. A "Witzel tunnel" is then created by imbricating the seromuscular jejunal wall over the tube with interrupted sutures. This is done retrograde from the initial enterotomy over a distance of 3–4 cm. The tube is externalized through the abdominal wall and the jejunum is tacked to the peritoneum broadly to avoid volvulus. The jejunostomy tube is also secured to the skin with an additional suture or commercially available wafer-style tube holder. Additional modifications of the technique include the use of Foley catheters with the balloon inflated or T-tubes, both of which allow the bowel to be pulled flush against the peritoneum by slight traction on the tube, similar to the technique utilized for percutaneous endoscopic gastrostomy tubes.

The needle catheter jejunostomy is classically performed by passing a 14G needle in an subserosal fashion for ~5 cm before entering the jejunal lumen [21]. A 16G catheter is then threaded through the needle and passed distally within the lumen of the bowel for 25 cm. Similarly to the Witzel jejunostomy, the external site of tube entry into the antimesenteric jejunum is then tacked to the peritoneum, and the tube is then externalized through the abdominal wall and secured.

The Stamm jejunostomy utilizes two concentric purse-string sutures to seal the jejunal antimesenteric entry site around the tube. No tunnel is created.

Laparoscopic Jejunostomy Tubes

Laparoscopic jejunostomy tube placement may be accomplished via similar technique to open surgery [16–19]. Commercially available kits may be utilized to assist in the passing of the catheter through the abdominal wall (peel-away sheaths) or to facilitate tacking of the jejunum to the peritoneum (T-shape fasteners), though standard suturing and instrumentation allow the same solutions to be achieved [22]. The laparoscopic working ports are in the right mid- and upper abdomen, with an umbilical port being used for the camera.

Complications

Overall, the complication rates for feeding jejunostomy placed at the time of elective surgery have been reported to be as high as 45% [9, 23–27]. However, significant complications appear to be a much more event. In a large series of over 1100 patients undergoing needle catheter jejunostomy at the completion of esophagectomy, the rate of complication leading to repeat laparotomy was only 1.1% [25].

Bowel Necrosis

Diarrhea, nausea, crampy abdominal pain, and distention, accompanied by high nasogastric tube outputs, may occur in about 40% of patients fed by jejunostomy[28]. However, despite these common potentially alarming signs and symptoms, small bowel necrosis is thought only to occur in between 0.14 and 3.5% of patients [29]. The diagnosis does carry a very high rate of mortality [30]. The true etiology of small bowel necrosis in the setting of jejunal tube feeding is not entirely clear, but it does occur in a patchy distribution similar to necrotizing enterocolitis found in neonates, and segments of bowel which are not exposed to the flow of tube feeds appear to be spared [31].

If suspicion for this complication exists, computed tomography may suggest bowel ischemia or perforation, but a surgical re-exploration is often the incisive and timely way to diagnose and then remediate the problem. Bowel resection, bowel rest, and resiting or removal of the tube all may be necessary.

Pneumatosis intestinalis also, has been reported in patients with jejunostomy tubes [32, 33]. (Fig. 11.1) However, not all pneumatosis intestinalis is necessarily a sign of necrosis or other significant morbidity, especially when incidentally detected radiographically. In the absence of bloody diarrhea, acute abdomen, obstruction, portal venous gas, or other signs and symptoms of bowel ischemia, it may be possible to simply observe patients with pneumatosis closely [34–37]. Data regarding the mechanism of formation of benign pneumatosis in patients with jejunostomy tubes are scant. It is theorized that

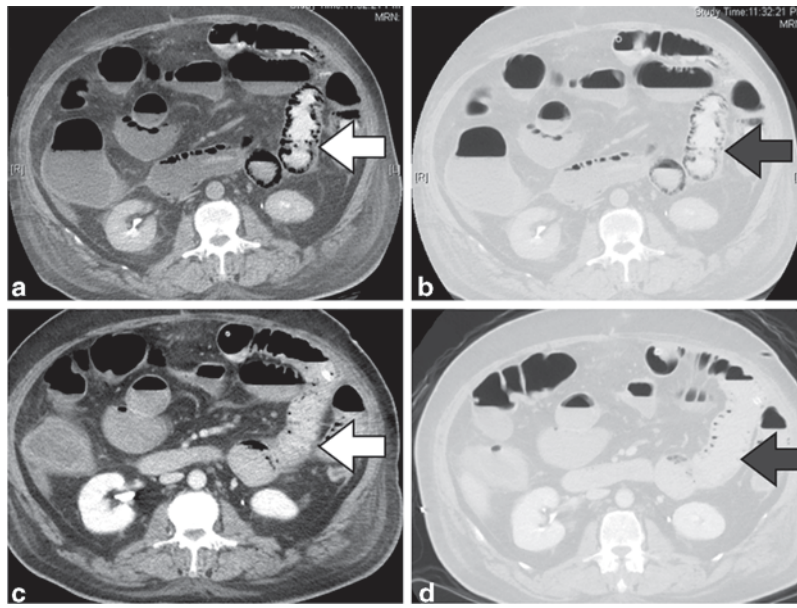

Fig. 11.1 Benign pneumatosis intestinalis around a jejunostomy tube. **a** and **b** Abdominal CT scan (soft tissue and lung windows); *arrow* points to loop of jejunum with pneumatosis (jejunostomy tube in that bowel loop is not visualized on these images). **c** and **d** Five days later the degree of pneumatosis has decreased considerably

a mechanical breach in the mucosa from the tube coupled with increased intraluminal gas/pressure from fermentation, ileus, or hypoosmolar feeds is responsible for the air [38, 39].

Bowel Obstruction

While ileus may result from any intraabdominal operation, bowel obstruction is a complication that may require more aggressive intervention or reoperation. The entry site of the feeding tube into the bowel lumen is a potential site of obstruction. A Witzel jejunostomy that gathers up too much seromuscular tunnel will result in decreased cross-sectional area at that site. Tube feeding may be tolerated, as the tip of the tube is distal to the site of bowel narrowing, but the patient may have vomiting, conduit distention, or increased nasogastric tube output as the bowel transit upstream of the Witzel tunnel is impeded. A recent report on 153 patients who underwent a Witzel jejunostomy tube noted a 7% incidence of bowel obstruction [40]. However, this publication suffers from a lack of definition of obstruction, and no mention was made of whether these patients necessitated intervention beyond bowel rest for this condition. In addition, it is unclear what the duration of follow-up is. Far more prevalent in the literature are reports that detail minimal or no episodes of bowel obstruction in the short-term, which reflects avoidance of technical error during the placement of the feeding tube [9, 41, 42].

Volvulus around the jejunostomy tube or through an internal hernia has been described as etiologies of bowel obstruction [43, 44] (Fig. 11.2). Despite the single-tacking site of percutaneous endoscopic jejunostomy or direct percutaneous jejunostomy tubes placed with fluoroscopic or ultrasound guidance, the reporting of volvulus with those techniques is still quite rare [45–47]. Other obstructive events include obstruction from the catheter balloon, which may be obviated by choice of tube or avoidance of balloon over-inflation [48]. Intussusception at the site of direct percutaneous endoscopic jejunostomy tubes has been described by multiple groups [49–51]. Despite the usual technique of multiple tacking sites with a Witzel jejunostomy tube, it has been described with that technique as well [52].

In cases of obstruction, an exploratory laparotomy or laparoscopy may be employed. A partial obstruction may be observed at times. Edema at the Witzel tunnel may reduce in time with conservative measures and allow free passage of enteric contents. If there is a balloon catheter responsible for the obstruction, this may be diagnosed with contrast studies or simple examination of the tube and balloon apparatus and remediated by balloon deflation.

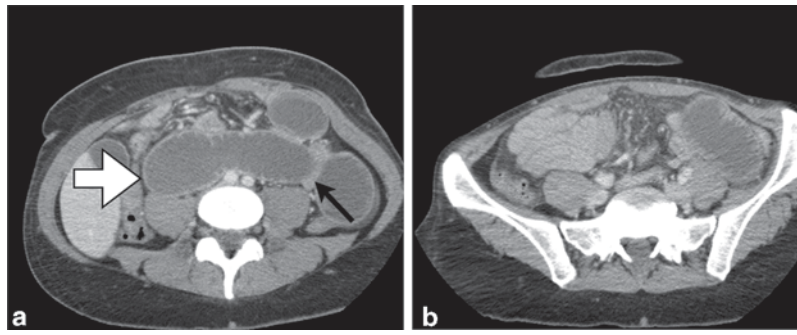

Fig. 11.2 Small bowel obstruction secondary to internal herniation and volvulus around jejunostomy tube site. **a** Abdominal CT depicting dilated loops of small bowel (*white arrow*) as well as a decompressed loop of small bowel tacking along the previous jejunostomy tube site (*black arrow*). **b** Decompressed small bowel in the right lower quadrant; dilated loop of small bowel in the left lower quadrant

Tube Dysfunction

Overall rates of tube dysfunction have been reported as high as 45% in a mixed series of gastrostomy and jejunostomy tubes. These complications—clogging, knotting of the tube [53], dislodgement, or breakage of the connectors—may be considered minor; however, they may lead to the interruption of nutrition delivery or additional invasive procedures. Clogging of the tube is a very common problem, reported in 0.5–6% of prospectively collected series of patients undergoing a Witzel jejunostomy tube at the time of esophagectomy or gastric surgery [41, 54]. Needle catheter jejunostomy has been reported to have similar propensity for clogging as Witzel jejunostomy [55]. Best practices for feeding tube maintenance include adherence to a flushing regimen and avoidance of introducing any solid material into the tube (e.g., crushed pills). In addition, checking of residuals via a jejunostomy tube is not recommended, both due to technical limitations and inaccuracy of the measurement and due to concerns that this might hasten clogging. Meat tenderizer, pancreatic enzymes, and soda have all been utilized to help dissolve the inspissated tube feed substance from clogged jejunostomy tubes [56]. Of these agents, pancreatic enzyme appears to have the greatest efficacy in resolving the obstruction, with 96% restoration of tube patency in one series [57]. Some researchers have suggested that a pancreatic enzyme "lock" similar to a heparin lock for vascular catheters may be utilized as prophylaxis against inspissated tube feeds obstructing the feeding tube [58]. The mechanical remedy for a clogged tube is steady or oscillating pressure via a syringe filled with saline or water. Reconstitution of patency has also been achieved with a vascular embolectomy catheter [59]. Of note, in the series quoted above with a 6% incidence of tube obstruction, all feeding tubes were able to be recanalized with local measures, without need for replacement of the tube [41].

Similar to any externalized tube or drain, jejunostomy tubes are subject to dislodgement. While this data point may be under-reported in the largely retrospective reviews of jejunostomy tube complication (as simple replacement of the tube may occur without any documentation), a prospective trial of nasoduodenal tubes versus jejunostomy tubes reported a 6% incidence of tube dislodgement [7]. Dislodgement of jejunostomy tubes that required a reoperation to address the problem occurred in 1.2% of patients in another series [54]. In one particularly notable case report, a patient with a jejunostomy tube that had been placed for enteral access in the setting of unresectable gastric cancer presented with "disappearance of the tube and abdominal pain" and was found to have the entirety of the tube within the bowel [60]. Peristalsis eventually allowed the tube to pass per rectum without any surgical intervention.

For chronically indwelling surgically placed tubes, the tract may not close completely for 2–3 days, though the optimal timing for direct replacement of a jejunostomy tube is as soon as possible after it falls out. If there is an undue resistance in passing a lubricated tube of the same size as that which was dislodged, the procedure should be aborted. A contrast study via the tube should confirm a correct placement prior to use.

If a surgical tract is no longer directly accessible, ultrasound or fluoroscopy may facilitate tube replacement at the site of the previously tacked jejunum. In one series, successful jejunostomy tube replacement at the site of a previous surgical jejunostomy was achieved in 26 of 28 attempts (92%) [61]. While the mean time from surgical jejunostomy tube removal to direct percutaneous placement averaged 278 days, the range included sites as early as 3 days from removal. Some surgeons will mark the tube entry site into the bowel with metallic clips to facilitate direct fluoroscopic-assisted percutaneous access if necessary [62]. However, as a caveat, metal clips may not always correspond to the exact site of accessible bowel over time [63].

To help mitigate accidental tube dislodgement, the device or sutures used to secure the tube to the abdominal skin should be inspected routinely and replaced as necessary.

Infectious Complications

In a prospective trial, leakage around a feeding tube was detected in 4%, though only one patient of 79 ended up needing a re-laparotomy for complication [7]. (Fig. 11.3) Often, a small amount of succus entericus may stain the dressing around the jejunostomy tube. When this occurs in notable amounts, local measures may be employed to keep the skin from becoming excoriated. Vigilance for signs of superficial or deeper infection must be maintained.

Infection at the tube entry site occurred in 0.5% of patients in a series of over 400 patients undergoing a Witzel jejunostomy tube [54]. In Han-Geurts's report of a randomized trial of needle catheter jejunostomy versus nasoduodenal tubes, the rate of site infection was 16% [7]. With direct percutaneous endoscopic jejunostomy tubes, a 6% site infection rate has been reported, with all of these being treated successfully with antibiotics alone [45]. In this same series, a single patient (0.6% incidence) did suffer an abdominal wall abscess in the setting of peri-tube leakage; this required operative debridement. Occasionally, with minor cellulitis and no significant abscess collection, opening the tract more widely around the tube and passing a wick into the space may help. Occasionally, the leakage associated with the infection is too persistent and re-siting or upsizing of the tube may be necessary. Necrotizing fasciitis is a rare sequela of a tube infection, but has been described in percutaneous and surgical jejunostomy tubes alike [64, 65].

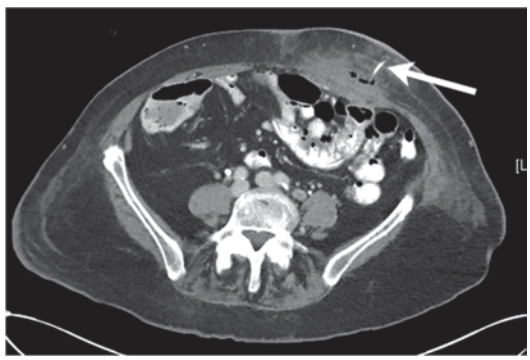

Fig. 11.3 Abdominal wall abscess secondary to leaking of succus entericus and tube feeds around jejunostomy tube. *Arrow* points to jejunostomy tube

Aspiration

The rate of aspiration events with jejunostomy tube feeding is a controversial subject. Many groups believe that there is a decreased rate of aspiration with jejunostomy tubes as compared with gastrostomy tube feeding [66, 67]. In the early experience with percutaneous endoscopic jejunostomy tubes, a very high aspiration rate (67%) was reported [68]. However, more mature results from the same group were more promising, with the mean number of aspiration pneumonia events per month decreasing from 3.39 to 0.42 after the placement of the percutaneous jejunostomy tube [69].

In a counter-argument, one group reported no difference in the rate of aspiration pneumonia with surgically placed gastrostomy and jejunostomy tubes [70]. Moreover, a prospective randomized trial of nasally placed gastric or jejunal tubes demonstrated no difference in the aspiration rate [71]. Jejunal tube feed infusion itself was detected to induce gastroesophageal reflux, even in the absence of gastric distention [72].

The key point around the issues of aspiration is to individualize the treatment to the patient. For example, some patient populations (e.g., elderly stroke patients) laparoscopic enteral access may not obliterate the risks of aspiration and pneumonia, and their overall mortality rate may be quite high [73]. The same might be taken into account in the elderly aspirating population, where jejunostomy feeding in and of itself does not protect against aspiration pneumonia in patients known to aspirate [74].

Conclusion

Jejunostomy tube feeding remains an important adjunct to major esophageal surgery. While it may not be necessary to perform a jejunostomy tube in every case as nutritional support may be able to proceed uneventfully by mouth, the

reasonably low rate of complication and the ease of discontinuation of the tube argue that prophylactic placement is a valid strategy. Complications of jejunostomy tubes may be reduced with careful attention to the technical details of surgical placement. In addition, early signs of complication must be followed closely so that salvage might occur should a highly morbid process begin to unfold.

Key Points

1. Jejunostomy tubes are often placed at the time of esophagectomy and/or gastrectomy in order to optimize nutritional status. Their utility is debated.
2. Jejunostomy tubes can be placed surgically with three different techniques: Stamm, Witzel, or needle-catheter. Endoscopic and percutaneous techniques can be utilized on a selective basis as well.
3. Complications after jejunostomy tube placement include bowel necrosis and perforation, obstruction, volvulus, tube-feeding intolerance, infection, aspiration, and tube dysfunction. Careful attention to the technical details of tube placement and tube choice are needed to minimize these complications.
4. Technical pearls include avoiding obstruction of the bowel lumen with either too large of a tube size or over-zealous imbrication while performing a Witzel technique. Broad-based fixation of the bowel to the abdominal wall should be employed to avoid obstruction and volvulus.

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Part II
Gastric Surgery

Bile Reflux and Gastroparesis

12

Robert E. Roses and Douglas L. Fraker

Gastroparesis

Etiology

Postoperative gastroparesis is most often associated with upper abdominal surgery but may develop after lower abdominal surgery as well. In the early postoperative period following pancreaticoduodenectomy, gastroparesis has been reported in up to 50 % of patients [1, 2]. In this context, the syndrome of upper gastrointestinal tract dysfunction (i.e., nausea and vomiting) has been termed delayed gastric emptying (DGE). In many cases, this heralds the evolution of a pancreatic fistula or other infectious complication. There is also some suggestion that operative factors contribute to this problem. Some but not all series have suggested a higher incidence of DGE after a pylorus-preserving operation (PPPD) compared to pancreaticoduodenectomy with antrectomy [3]. Likewise, retrocolic compared to antecolic duodenojejunostomy following PPPD has been associated with an increased incidence of DGE [1].

More persistent gastroparesis following pancreaticoduodenectomy occurs in upwards of 5 % of patients. A similar rate of gastroparesis has been reported after gastric resection. Patients with risk factors for underlying gastric dysmotility (e.g., diabetes mellitus) are at increased risk [2]. Although the era of frequent surgery for peptic ulcer disease has passed, that experience provided substantial insight into the etiology of gastroparesis after gastric resection. Not surprisingly, antrectomy with truncal vagotomy was associated with an increased incidence of postoperative gastroparesis, compared to highly selective vagotomy, implicating gastric denervation as an important contributing factor [4, 5]. Roux-en-y reconstruction was also variably linked to a greater incidence of gastroparesis than either Billroth I or Bilroth II reconstruction pointing to an additional contribution of disruption of intestinal innervation.

Clinical Presentation and Evaluation

Postoperative nausea and vomiting in the presence of lower gastrointestinal tract function often herald gastric dysmotility. The aforementioned concept of DGE has been variably defined in the literature and this inconsistency has complicated the interpretation of studies on the subject [6]. In an often referenced 1993 trial of erythromycin

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after pancreaticoduodenectomy, Yeo and associates defined DGE as either (1) nasogastric tube requirement for 10 or more days plus one of the following: (a) emesis after nasogastric tube removal, (b) postoperative use of prokinetic agents after postoperative day 10, (c) reinsertion of a nasogastric tube, or (d) failure to progress with diet; or (2) nasogastric tube requirement fewer than 10 days plus two of (a) through (d) above [7]. The 10-day cutoff for nasogastric tube requirement has been adopted in some, but certainly not all subsequent studies.

In practice, DGE or postoperative gastroparesis are often diagnoses of exclusion. Anastomotic leak (particularly an evolving pancreatic fistula after pancreatoduodenectomy) may present with proximal ileus and be accompanied by leukocytosis, tachycardia, or turbid output from a postoperative drain. Mechanical obstruction can likewise be difficult to differentiate from gastroparesis on clinical grounds alone. A CT scan with enteric contrast is often an appropriate first imaging modality and can identify undrained fluid collections, extraluminal air, or transition points between enhanced and collapsed viscera. A dynamic upper GI contrast study may be more sensitive in identifying partial mechanical obstruction. The experienced gastrointestinal radiologist will often identify delayed transit time as contrast traverses the stomach and proximal bowel. The use of barium for these studies may further enhance sensitivity but should be reserved for those cases in which the index of suspicion for an enteric leak or high-grade mechanical obstruction is low, as barium extravasation into the peritoneal cavity or retained barium can be problematic in these settings, respectively. Furthermore, retained barium can limit interpretation of subsequent CT scans.

Gastric emptying scintigraphy provides perhaps the most nuanced assessment of gastric emptying; however, the role of this study in evaluating the postoperative patient remains poorly defined and standardized definitions of normal scintigraphic findings after gastric resection remain elusive. In general, there is delay in the emptying of solids and accelerated emptying of liquids after partial gastrectomy [8]. After Roux-en-y reconstruction, there is often retention of solids in both gastric remnant and the Roux limb [9]. Scintigraphy does allow assessment of regional emptying of the fundic and antral regions and can be helpful in explaining dyspeptic symptoms, particularly when global gastric emptying values are normal [10]. For example, nausea, early satiety, and abdominal distention have been associated with proximal gastric retention; in contrast, vomiting is more often associated with delayed distal GE.

Management

In the early postoperative period, gastroparesis often necessitates prolonged NG tube decompression. Early dysmotility often improves with time, and a deliberate management approach is justified. Correction of hyperglycemia, electrolyte abnormalities, and the reduction of narcotic use are recommended. While waiting for recovery, nutritional support is requisite, in the form of either enteral feeding (if the patient has a jejunostomy feeding tube) or parenteral nutrition. Depending on the severity of symptoms and the scope of the initial operation, placement of a jejunostomy feeding tube or a decompressive gastrostomy tube may expedite recovery.

The use of promotility agents is sometimes helpful and fairly safe although convincing evidence of efficacy in the postoperative setting is lacking. Macrolide antibiotics (e.g., erythromycin) agonize the motilin receptor. In patients with diabetes mellitus and delayed gastric emptying, intravenous administration of erythromycin 200 mg before a test meal has been shown to normalize gastric emptying of liquids and solids [11]. The clinical efficacy of oral erythromycin, however, has not been consistently demonstrated. In a randomized placebo controlled trial, intravenous erythromycin after pancreaticoduodenectomy did not significantly reduce delayed gastric emptying as defined by the authors; though, fewer patients required reinsertion of a nasogastric tube or retained liquids by scintigraphy in the treatment group [7]. Even in those patients who do appear to respond favorably, a tolerance phenomenon is

frequently observed and drug interactions with agents that are metabolized by CYP3A4 further limit utility.

Metoclopramide is a dopamine-2 (D2) antagonist with apparent efficacy in a subset of patients with gastroparesis. Sedative effects can limit utility and extrapyramidal side effects, though not as frequent as with older antipsychotic drugs (e.g., haloperidol and chlorpromazine), can be irreversible. A majority of cases of tardive dyskinesia occur with longer-term use, and limiting metoclopramide use to less than 3 months is prudent.

Pyloroplasty when applicable has also been proposed, and botulinum toxin injections may transiently improve gastric emptying in a subset of patients. In the majority of postsurgical patients who have undergone either gastric or pancreatic resection, these approaches are not relevant. Historically, completion or subtotal gastrectomy was offered to patients with refractory gastroparesis. A number of reports from single institutions support the efficacy of such an approach [12, 13]. Importantly, these should represent options of last resort considered only after exhausting all more conservative measures. In most cases, enteral access with a jejunostomy feeding tube with or without a decompressive gastrostomy and dietary modification affords prompter improvement in the quality of life than does near-total gastrectomy. Placement of a percutaneous endoscopic gastrostomy (PEG) tube with jejunostomy tube extension represents a useful alternative to traditional enteral access procedures in selected patients requiring gastric decompression and distal enteral access for nutrition support.

More recent experiences with gastric electrical stimulation (GES) suggest an alternative therapeutic option. Initial studies in dogs demonstrated increased peristaltic pressure waves and the gastric emptying rate with electrical stimulation [14]. A series of small trials using implantable electronic devices in patients with diabetic gastroparesis followed. Recently, patients with refractory postsurgical gastroparesis were reported to achieve symptomatic improvement with GES [15, 16]. Interestingly, the stimulation impulses used (5 mA, duration 330 ms) are too weak to excite gastric smooth muscles (hence the term "gastric pacemaker" is a misnomer). Moreover, objective measurements of gastric emptying have not consistently demonstrated effect [17].

Bile Reflux

Etiology

Pancreaticobiliary reflux into the stomach is obligate after resection or ablation of the pylorus (e.g., pyloroplasty or Billroth I) or loop reconstruction to a gastric remnant (e.g., gastrojejunostomy or Billroth II). Only a subset of patients, however, develop bile reflux gastritis or esophagitis as a result. Billroth II reconstruction to a small gastric pouch may anticipate particularly severe bile esophagitis and should be avoided (Fig. 12.1). Resection of greater than 60 % of the distal stomach should be reconstructed with a Roux-en-Y gastrojejunostomy to prevent this complication. The syndrome of bile reflux has also been recognized after cholecystectomy. In this setting, it has been attributed to loss of gallbladder reservoir function and continuous passage of biliary

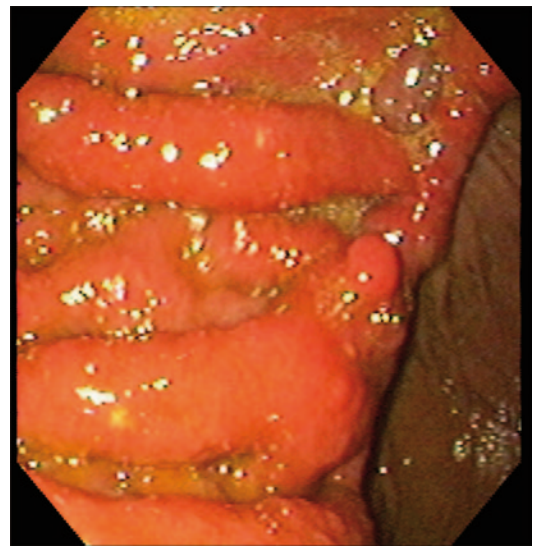

Fig. 12.1 Enlarged hyperemic folds in gastric remnant, after Billroth II reconstruction. (Image courtesy of Gregory Ginsberg, MD)

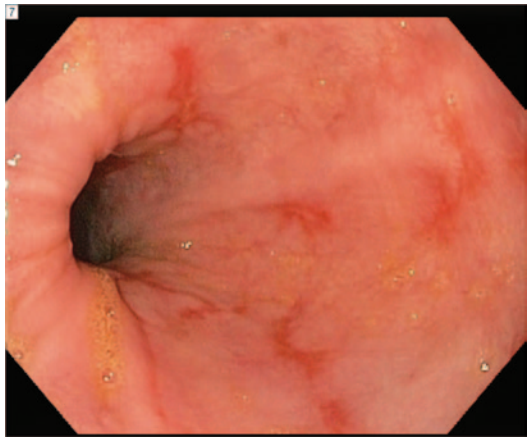

Fig. 12.2 Erosive alkaline reflux esophagitis. (Image courtesy of Gregory Ginsberg, MD)

secretions, more of which reflux into the stomach than would otherwise be the case (Fig. 12.2). Delayed gastric emptying or gastric stasis may be contributory in many cases as well, and the denervating procedures of the past era of peptic ulcer disease surgery (i.e., truncal vagotomy) yielded an experience that informs the current understanding of this clinical syndrome. In the presence of gastric stasis, exposure of gastric mucosa to duodenal fluids is increased. A higher gastric pH may allow bacterial overgrowth and subsequent conversion of bile salts to unconjugated bile acids, which are particularly noxious to the gastric mucosa. Pathological changes in the gastric mucosa develop over time and include foveolar hyperplasia, glandular cystic degeneration, edema of the lamina propria, and vasocongestion of the mucosal capillaries [18].

Clinical Presentation and Evaluation

The occasional patient complains of profound reflux pain in the early postoperative period. More often, symptoms evolve a year or more after the index operation. A symptom complex of nausea, pain, and bilious emesis is characteristic but, by no means, specific to bile reflux. As with gastroparesis, other more common etiologies must be excluded. Cross-sectional imaging or dynamic upper gastrointestinal contrast studies are useful for excluding mechanical obstruction. The former can rule out fluid collections as well, more relevant in the early postoperative period. Upper endoscopy may identify marginal ulceration or mucosal irritation. Scintigraphy (bile reflux scan or HIDA scan) may be useful, particularly in determining a role for remedial surgery. An abnormal study is not that informative. A normal study, however, anticipates a poor response to surgical management.

Management

A variety of pharmacologic agents have been utilized in the treatment of bile reflux; none are consistently effective. Sucralfate may buffer the stomach or gastric remnant and provide symptomatic relief and is often a good first choice. Cholestyramine has been advocated but is probably of little utility [19]. Promotility agents (e.g., metaclopromide) may have a role, particularly if a contribution of gastroparesis is suspected. Persistent symptoms over months despite pharmacologic intervention in the face of an abnormal bile reflux scan point to a role for remedial surgery.

In the patient with severe symptoms, objective signs of bile reflux (e.g., endoscopic evidence of gastritis, scintigraphy confirming duodenal reflux into the stomach) surgery can be considered. A variety of operative approaches can be utilized for the remediation of bile reflex. The most commonly chosen and most familiar is Roux-en Y gastrojejunostomy; however, Braun entero-enterostomy and the Henley procedure (antiperistaltic jejunal interposition) are reasonable alternatives (Fig. 12.3). If Roux-en Y reconstruction is selected, a limb in excess of 40 cm (some have advocated >60 cm) should be constructed to maximize isolation of the stomach from duodenal secretions. Longer limbs (>80 cm) should be avoided to decrease the risk of malabsorption and Roux stasis. Assuming careful patient selection, a high rate of success can be expected.

The major disadvantage of Roux-en Y reconstruction is an incidence of "Roux stasis syndrome," generally attributed to small bowel denervation and diminished prograde peristalsis

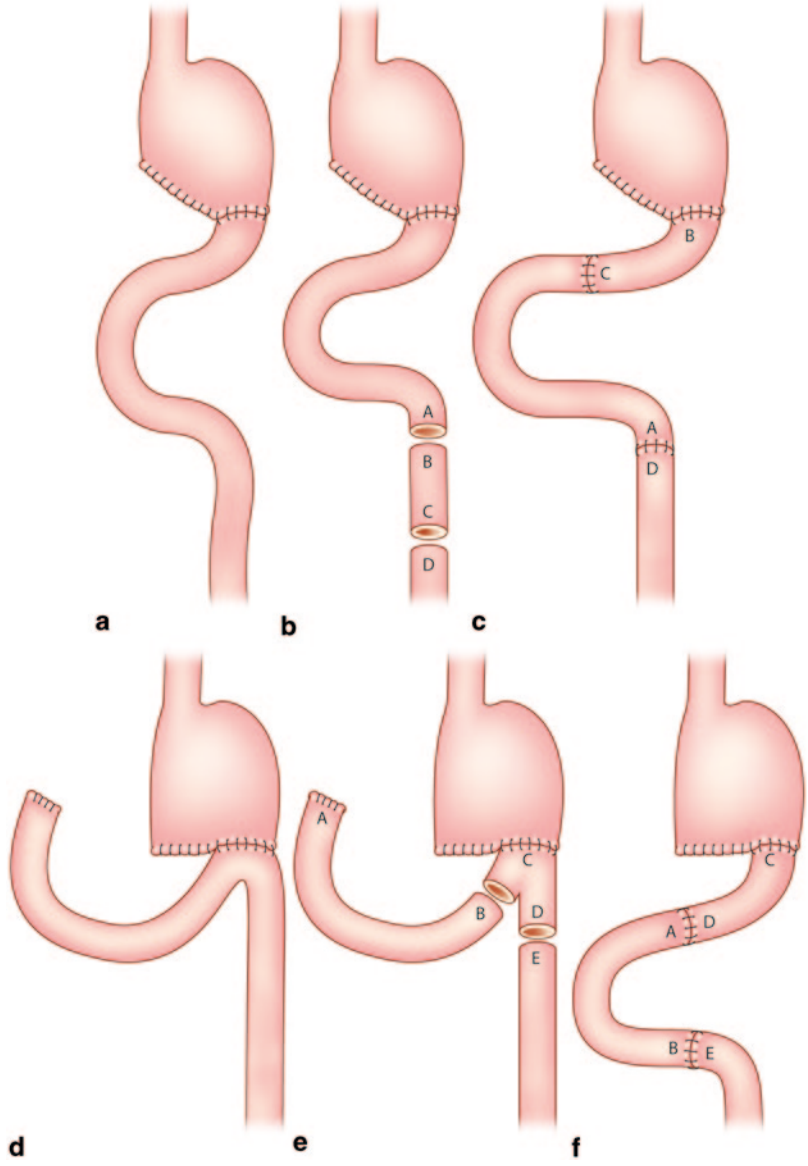

Fig. 12.3 Isoperistaltic jejunal loop interposition. (Henley procedure)

in the Roux limb. Bacterial overgrowth, diarrhea, jejunal ulceration, and impaired protein digestion may result. Abdominal pain and vomiting are typical symptoms and there is often overlap with gastroparesis, as this syndrome is observed with greater frequency in patients with larger gastric remnants. These concerns may necessitate completion antrectomy or even subtotal gastrectomy, and truncal vagotomy at the time of remediation in the appropriate clinical setting.

While bilious emesis is mitigated by Roux-en Y reconstruction, a number of larger published experiences suggested recurrent symptoms in approximately 30 % of patients long term [20]. This substantial rate of long-term morbidity justifies consideration of other remedial approaches. Perhaps the simplest of these is creation of a *Braun* enteroenterostomy. This is most applicable in the setting of prior Billroth II construction and is achieved by side-to-side anastomosis of the af-

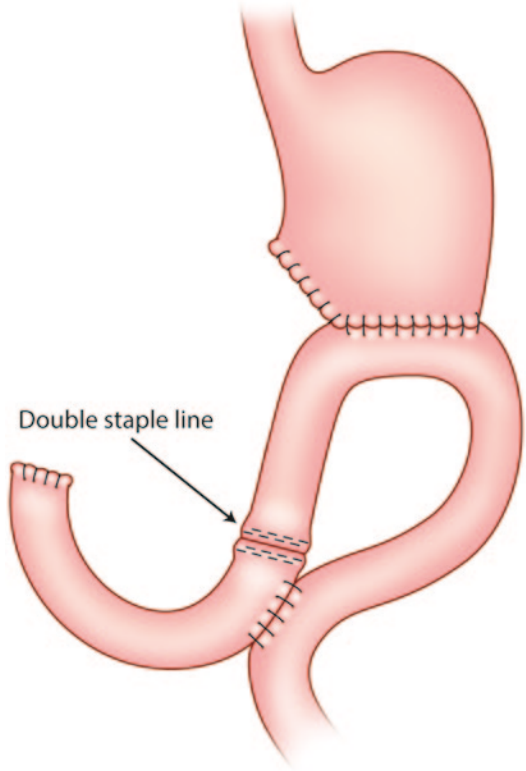

Fig. 12.4 "Uncut Roux" reconstruction

ferent limb to the jejunum at least 40 cm distal to the gastrojejunostomy. Diminution of duodenal fluid into the stomach or gastric remnant can be achieved with the application of a staple line across the afferent limb just proximal to the gastrojejunostomy. Use of a thoracoabdominal (TA) stapler facilitates the creation of a partition without transection, and may, therefore, preserve prograde peristalsis through the small bowel. Importantly, this partition is temporary in most cases (recanalization is a likelihood over time). For this reason, this so-called uncut Roux may not be the best option in a younger patient for whom effective long-term remediation is necessary (Fig. 12.4).

Interposition of an isoperistaltic segment of small bowel between the gastric remnant and duodenum was advocated by Henley in the 1950s for the management of dumping syndrome. The Henley procedure has been used with reported success for the treatment of Bile reflux. In the setting of prior Billroth II reconstruction, the afferent limb just proximal to the gastrojejunostomy is divided. The jejunum is divided 20–45 cm distal to the anastomosis at a point that allows for convenient anastomosis to the proximal duodenum. Jejuno-duodenstomy and downstream jejunojejunostomy are performed to restore continuity. This configuration has been associated with effective amelioration of biliopancreatic reflux on scintigraphic examination [21] and may result in less of the long-term morbidity associated with Roux reconstruction.

Conclusion

Gastroparesis and bile reflux after foregut surgery remain distinct clinical challenges. Both diagnoses require exclusion of other correctable surgical complications, particularly mechanical obstruction or undrained infection. Scintigraphic studies can be used to confirm either diagnosis. Even when the diagnosis has been secured, a trial of conservative management is almost always in order during which time attention to nutritional status, correction of metabolic disturbances, and reduction of narcotic exposure are critical. Pharmacologic therapies are associated with only modest benefit, but may be helpful in selected cases and are relatively safe. In the setting of persistent severe refractory symptoms, remedial surgery should be considered. In the case of gastroparesis, distal enteral feeding access with gastric decompression may be an appropriate intermediate step before subtotal gastrectomy. A role for gastric electrical stimulation is evolving. A variety of remedial operations for bile reflux have been used with moderate success including conversion to Roux-en Y reconstruction, Braun enteroenterostomy, and Henley jejunal interposition.

Key Points (Prevention)

1. Although definitive data are lacking, antecolic reconstruction after pylorus-preserving pancreaticoduodenectomy may be associated

with a lower rate of delayed gastric emptying compared to retrocolic reconstruction.
2. Gastric and intestinal denervation may contribute to the incidence of gastroparesis after gastric resection favoring Billroth II over Roux-en Y in appropriate circumstances.
3. Correction of hyperglycemia and electrolyte abnormalities and the reduction of narcotic use are self-recommending after abdominal surgery and may decrease the incidence of postoperative gastrointestinal dysmotility.
4. Loop reconstruction to a small gastric pouch may anticipate particularly severe bile esophagitis and should be avoided.

Key Points (Management)

1. Initial priorities in the management of postoperative gastroparesis include decompression and treatment of postsurgical infection.
2. Bile reflux is most often a late complication and must be distinguished from mechanical obstruction.
3. Nutritional repletion is critical in the initial management of gastroparesis or bile reflux. When appropriate, surgical or percutaneous enteral access should be obtained early.
4. Remedial surgery for gastroparesis or bile reflux should be reserved for refractory cases after exclusion of reversible etiologies, nutritional repletion, and confirmatory scintigraphic studies.

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Dealing with Dumping Syndrome

13

Kyung Ho Pak and Sung Hoon Noh

Introduction

Although gastric surgery for ulcer disease has decreased, gastric cancer surgery and bariatric surgery are still frequently performed worldwide. Accordingly, the number of patients suffering from dumping syndrome has increased. In particular, in Korea and Japan, early gastric cancer (EGC) comprises up to 60–70 % of gastric cancer; therefore, the life expectancy of patients with gastric cancer is quite high. Surgeons, therefore, must better understand dumping syndrome and be familiar with its management. Previously, there was a greater focus on finding a radical cure rather than on improving quality of life to increase the survival rate for gastric cancer; in contrast, concerns regarding the development of postgastrectomy syndromes such as dumping syndrome or reflux disease are now increasing.

Dumping syndrome is one of the most common complications after gastric surgery. Approximately 25–50 % of patients develop some manifestation of dumping syndrome. Among them, 5–10 % have clinically significant symptoms, and 1–2 % are debilitated by them. [1] Mallory et al.[2] reported that the incidence of dumping syndrome after gastric bypass was as high as 75 % in the early postoperative period, and most symptoms disappeared 15–18 months after surgery. However, many patients exhibit symptoms throughout life. Dumping syndrome has also been reported after Nissen fundoplication in children and adults [3–5], and in pediatric and adult patients receiving gastrostomy feeding with a persistent vegetative state [6, 7]. In recent years, bariatric surgery has become the principal cause of postoperative dumping syndrome [8].

The symptoms of early and late dumping syndrome are believed to have distinct underlying pathophysiologies (Fig. 13.1). Early dumping, typically starting 20–30 min after a meal, usually causes both vasomotor and gastrointestinal complaints such as sweating, palpitation, weakness and faintness, abdominal bloating, cramping, and profound diarrhea. These symptoms, in severe cases, can occur during meals, but usually happen after meals. Although these symptoms can occur after any type of gastrointestinal surgery, Billroth-II reconstruction after gastrectomy is the leading cause of dumping syndrome. The probability of occurrence increases when a greater amount of stomach is resected. Early dumping appears to be caused by the excessive secretion of gastrointestinal hormones after the rapid flow of a hypertonic diet into the small intestine, which shifts intravascular fluid into the

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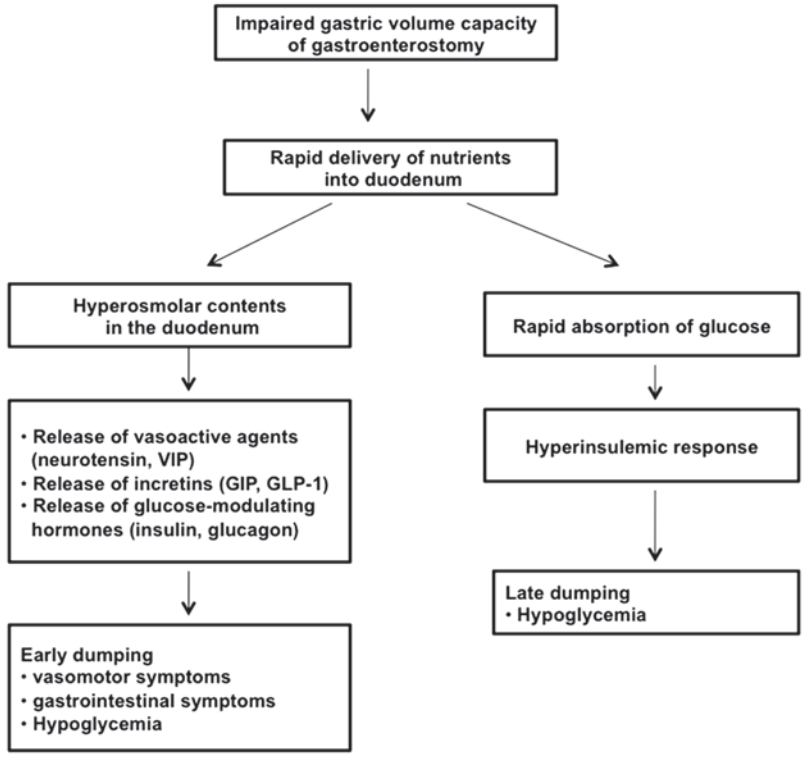

Fig. 13.1 Pathophysiology of dumping syndrome

small intestine [9]. It causes the abrupt expansion of the small bowel, which causes increased frequency and amplitude of bowel contractility. Up to 25 % of the blood circulation can be utilized in this process.

Late dumping, often occurring 2–3 h postprandially, involves mainly vasomotor complaints characterized by perspiration, palpitation, mental confusion, and sometimes syncope. Rapid delivery of a meal to the small intestine leads to an initial higher concentration of carbohydrates in the proximal small bowel, followed by rapid absorption of glucose into the blood. This is countered by the excessive release of insulin, the so-called "hyperinsulinemic response," responsible for the subsequent reactive hypoglycemia [10]. The majority of patients exhibit early dumping, approximately 25 % of them exhibit late dumping, and only a minority of patients have symptoms of both [11].

Diagnosis

Dumping syndrome is diagnosed based on a group of symptoms in patients who have undergone gastric surgery, or by the dumping provocation test. In 1970, Sigstad [12] proposed a scoring system based on the occurrence of different symptoms of dumping syndrome, to calculate a diagnostic index (Table 13.1). A diagnostic index >7 is suggestive of dumping syndrome. This system is simple to use, but its disadvantage is that it is difficult to distinguish other postprandial symptoms from dumping. The score index is helpful in clinical practice to assess response to therapy.

A provocative test for assessing dumping syndrome can be used to confirm clinical suspicions. This test is a modification of the oral glucose tolerance test (OGTT) and involves the ingestion of 50 or 75 g glucose in solution after an overnight fast. Immediately before and up to

Table 13.1 Sigstad score. Weighting factors allocated to the symptoms and signs of dumping syndrome

	Sigstad score
Preshock, shock	5
Almost fainting, syncope, loss of consciousness	4
Desire to lie or sit down	3
Breathlessness, dyspnea	3
Weakness, exhaustion	3
Sleepiness, drowsiness, yawning, apathy, falling asleep	3
Palpitation	3
Restlessness	2
Dizziness	2
Headache	1
Feeling of warmth, sweating, pallor, clammy skin	1
Nausea	1
Fullness in the abdomen, meteorism	1
Borborygmus	1
Eructation	−1
Vomiting	−4

180 min after ingestion of this solution, the blood glucose concentration, hematocrit, pulse rate, and blood pressure are measured at 30 min intervals. The provocative test is considered positive if late (120–180 min) hypoglycemia occurs, or if an early (30 min) increase in hematocrit of more than 3% occurs. The best predictor of dumping syndrome seems to be a rise in pulse rate of more than 10 bpm (beat per min) after 30 min [13]. Assessments of the speed of gastric emptying might show that this process occurs rapidly in patients with dumping syndrome—especially for liquid nutrients—but this test does not seem to have good diagnostic sensitivity or specificity, probably because rapid emptying occurs early after meal ingestion, a phase that is not analyzed closely or separately in most protocols that test gastric emptying [10, 13, 14].

Prevention

Prevention, rather than treatment, is recommended for dumping syndrome. The introduction of proton pump inhibitors and *Helicobacter pylori* eradication decrease the need for elective surgery in peptic ulcer disease. In addition, highly selective gastric vagotomy, which causes minimal disturbance of the gastric emptying mechanism, results in a lower incidence of dumping syndrome [15]. If more extensive surgery is necessary, a Roux-en-Y gastrojejunostomy (RYGJ) is preferable because of its decreased rate of dumping, when compared with pyloroplasty or loop gastrojejunostomy [16–18].

The choice of reconstructional method after distal gastrectomy is still controversial. The use of the Billroth I procedure after distal gastrectomy is preferred in Japan, whereas Billroth II is more common in Korea because it facilitates wider dissection and less anastomotic tension. There are some advantages in Billroth I compared to Billroth II, as follows: a more natural route for food passage, potentially less operative time due to one anastomosis, no risk of duodenal stump leakage, and less incidence of postoperative weight loss, anemia, and dumping syndrome. The disadvantage of Billroth I, however, is that the dissection area can be limited in order to facilitate a tension-free anastomosis. Therefore, the Billroth I procedure is commonly used for benign disease or distally located EGC in Korea. However, Kim et al. [19] compared results from 122 gastric carcinoma patients undergoing Billroth I and Billroth II gastrectomy. They evaluated postgastrectomy syndrome with a survey of abdominal symptoms, and dumping syndrome was measured using the Sigstad dumping score. According to their results, the occurrence of abdominal

symptoms and dumping syndrome was lower in the Billroth I group than in the Billroth II group. Furthermore, pylorus-preserving gastrectomy (PPG) is a kind of reduced-gastric operation that preserves the distal portion (1.5 cm) of the gastric antrum and reduces postoperative complications such as dumping syndrome and reflux esophagitis [20]. However, a limitation of this operation is that complete lymph node (LN) dissection of the suprapyloric LN is undesirable for the preservation of the pyloric branch of the vagus nerve. Nowadays, some reports state that this procedure may be applicable in EGC confined to the mucosa and located at the gastric mid-body [21].

According to a recent Japanese large-scale investigation into dumping syndrome after gastrectomy for gastric cancer, [22] many more patients suffer from early dumping syndrome (67.6%) than from late dumping syndrome (38.4%) after gastrectomy. This study revealed that patients suffering from at least one symptom of early dumping syndrome were significantly more likely to also experience symptoms of late dumping syndrome. The study also demonstrated that two clinical factors, the surgical procedures used and the amount of weight loss, were significantly associated with the occurrence of both early and late dumping syndromes. Consistent with previous reports, [23, 24] patients who underwent PPG showed the lowest incidence of dumping syndrome. In addition, patients who underwent PG (proximal gastrectomy with jejunal interposition) showed the second highest incidence of early dumping syndrome. Patients who underwent RYGJ showed a lower incidence of dumping syndrome symptoms relative to Billroth I patients. Taken together, RYGJ or Billroth I is less associated with dumping syndrome after distal gastrectomy than Billroth II.

Management of Dumping Syndrome

The first step in treating dumping syndrome is the introduction of dietary modification. If this approach is insufficient, medical therapy and, in some cases, surgery might be considered (Fig. 13.2).

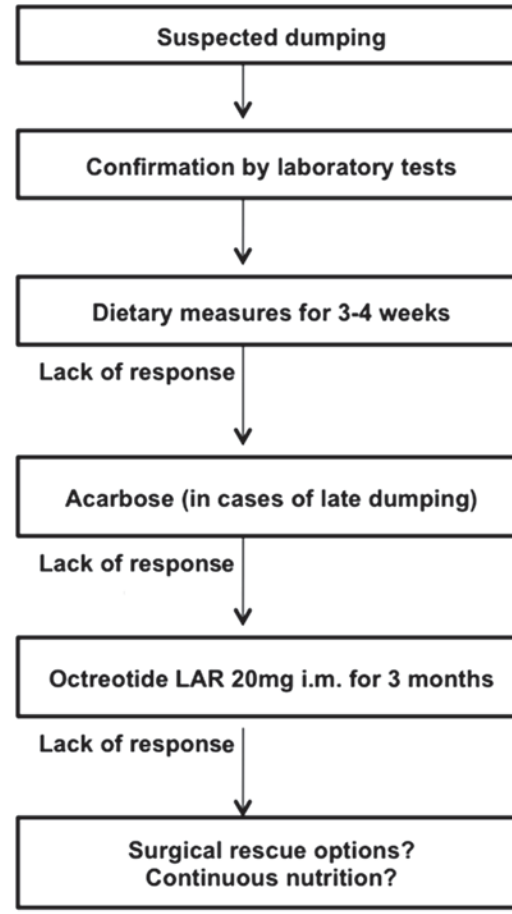

Fig.13.2 Proposed treatment algorithm for dumping syndrome

Diet

The resolution of dumping symptoms is achieved in most cases by dietary modification, in particular by the reduction of carbohydrate intake, and lifestyle adjustment.

Dietary measures include advising patients to consume smaller amounts at one time by dividing the recommended daily energy intake between six meals. Dietary prohibitions are very important. Fluid intake during meals should be restricted. Drinking liquids should be avoided for at least one half-hour after a meal. Complex carbohydrates (e.g., unsweetened cereals, pasta, potatoes, fresh fruit, and vegetables) are preferred. All rapidly absorbable carbohydrates (e.g., all

sweet or sweetened foods) should be eliminated from the diet to prevent late dumping symptoms. Protein (e.g., meat, fish, chicken, eggs) and fat intake should be increased to meet daily caloric needs because of the restricted intake of carbohydrates. Many patients modify their diet according to their personal experiences with food tolerance.

Most individuals with relatively mild symptoms will respond to dietary changes. For patients with severe vasomotor symptoms (postprandial hypotension), lying supine for 30 min after meals may minimize the chance of syncope by delaying gastric emptying and improving venous return. Supplementation of dietary fibers (bran, methylcellulose) with meals has been proven effective in the treatment of hypoglycemic episodes. Increasing the viscosity of food, which slows down gastric emptying, is another approach to improve dumping symptoms. Fifteen grams of guar gum or 5 g of pectin with each meal has been tested with good results, especially in the pediatric population [25, 26]. However, the palatability and tolerability of these supplements is poor. Moreover, these substances are usually not readily available as pharmaceutical products at sufficiently high doses.

Pharmacologic Therapy

In approximately 3–5% of patients, severe dumping will continue despite dietary modifications. This results in marked weight loss, fear of eating and outdoor activities, or even an inability to maintain full-time employment. Drug therapy plays an important role in patients who failed dietary changes.

Acarbose

Acarbose is an α-glucosidase inhibitor that interferes with carbohydrate absorption in the small intestine. It is a generic drug sold in Europe and Asia as Glucobay (Bayer AG), in North America as Precose (Bayer Pharmaceuticals), and in Canada as Prandase (Bayer AG). Acarbose significantly blunts the postprandial rise of glucose and insulin by delaying carbohydrate digestion. Because of the reversible nature of the inhibitor–enzyme interaction, the conversion of complex carbohydrates (starch and sucrose) to monosaccharides is delayed rather than completely blocked. This mechanism is responsible for the effectiveness of acarbose in late dumping. The positive effects of acarbose have been documented after a test meal in a few studies (Table 13.2). In a double-blinded study of nine patients after gastric surgery, acarbose given at a dose of 50 mg following a normal carbohydrate-rich meal has been shown to reduce the symptoms of postprandial hypoglycemia, especially in combination with pectin [27]. A higher dose of acarbose (100 mg) has not been found to have any beneficial effect.

This treatment approach, however, affects only the symptoms of late dumping, owing to the mode of action of acarbose. In addition, acarbose treatment often results in bloating, flatulence, and diarrhea, as the unabsorbed carbohydrates undergo bacterial fermentation in the small intestine; despite the decrease in these symptoms with time, these adverse effects might hamper treatment compliance.

Somatostatin Analogs

Somatostatin and its analog octreotide (Sandostatin®) [28] cause decreases in several GI peptides (insulin, glucagon, VIP, GIP, neurotensin, etc.) that usually increase after meals. In addition, these compounds directly decrease gastric emptying and bowel motility, leading to decreased nutritional absorption and blood flow in the bowel [29]. As such, these analogs show a broad range of activity against the full spectrum of symptoms of dumping syndrome. Both fast-acting and delayed-release somatostatin analogs have been used in the treatment of dumping syndrome. Fast-acting or long-acting repeatable (LAR) formulations of octreotide are the agents that have been most commonly studied [14, 28, 30–35].

Table13.2 Summary of studies that evaluated the effect of acarbose in dumping syndrome

Study	No. of patients	Treatment	Result
McLoughlin et al. (1979)	10	Acarbose 100 mg; single administration before OGTT	Improved symptoms and glycemia during OGTT; reduced rise in plasma levels of GIP and insulin
Gerard et al. (1983)	24	Acarbose 100 mg; single administration before OGTT	Improved glycemia during OGTT; reduced increase in plasma insulin level; inhibition of glucose-induced glucagon suppression
Lyons et al. (1985)	13	Acarbose 50 mg; single administration before standard breakfast	Significant attenuation of hyperglycemia; reduced rise in plasma levels of GIP, enteroglucagon, and insulin; no influence on plasma levels of VIP and somatostatin; no significant effect on symptoms
Hasegawa et al. (1998)	6	Acarbose 50–100 mg; 3 times daily before meals for a month	Attenuation of glucose fluctuations and improvement of dumping symptoms (uncontrolled)

GIP glucose-dependent insulinotropic polypeptide (also known as gastric inhibitory polypeptide), *OGTT* oral glucose tolerance test, *VIP* vasoactive intestinal peptide

Studies of the Fast-Acting Somatostatin Analog Octreotide

The results of several short-term studies of subcutaneously administered octreotide have shown efficacy in improving symptoms, improving glycemia, and slowing gastric emptying (Table 13.3) [30–33]. However, the need for 3–4 daily injections is potentially a major limitation for the long-term application of fast-acting somatostatin analogs. Three studies have evaluated the long-term use of subcutaneously administered octreotide in the treatment of dumping syndrome. Geer et al. found that long-term octreotide therapy (15 months on average) provided sustained symptom control [32]. Out of ten patients, eight received three daily injections of 100 μg octreotide, which resulted in good symptom control; seven individuals were able to resume work. Similarly, Vecht et al. evaluated the long-term effect of three daily doses of 25–200 μg octreotide in 20 patients with a mean follow-up of 37 months [36]. All patients had an initial positive response; at 3 months, 80% continued this positive response. After 10 years, however, 11 of the 20 patients had discontinued therapy for a variety of reasons, including a lack of effect at 3 months ($n=4$), diarrhea ($n=4$), painful injections ($n=1$), reversible alopecia ($n=1$), and weight loss ($n=1$). Similar data were obtained in a larger group of patients, in whom long-term effects seemed less favorable than short-term effects, although 41% of the cohort continued octreotide therapy after the follow-up period of 93 ± 15 months [34].

Studies of Long-Acting Octreotide LAR

Slow-release preparations of somatostatin analogs, which require only monthly intramuscular injections, are an attractive alternative to multiple daily injections of fast-acting formulations. Two studies have investigated the efficacy of a slow-release preparation of octreotide in dumping syndrome. Penning et al. compared the efficacy of monthly octreotide LAR (10 mg) to subcutaneous octreotide and found both formulations to be effective at improving symptoms [35]. The long-acting form seemed superior at increasing body weight and improving quality of life. The 10 mg dose is only available in a limited number of countries; the 20 mg dose is the usual standard dose for LAR octreotide.

A multicenter study in Belgium confirmed the efficacy of monthly LAR octreotide (20 mg) in the treatment of dumping syndrome that was refractory to dietary measures and acarbose treatment [14]. The study compared the control of symptoms and underlying pathophysiological mechanisms after 3 days of subcutaneous treatment with octreotide (50 μg, 3 times daily) with 3 months of treatment with octreotide LAR

Table13.3 Summary of studies that evaluated the effect of octreotide in dumping syndrome

Study	No. of patients	Treatment	Result
Hopman et al. (1988)	12	Octreotide 50 mg vs. placebo before OGTT	Improved dumping symptoms and suppression of postprandial rise in pulse rate; reduced peak insulin and increased nadir glycemia; slowing of gastrointestinal transit
Primrose and Johnson[28]	10	Octreotide 50 mg vs. 100 mg vs. placebo before OGTT	Reduced early dumping and abolished late dumping symptoms; suppression of early dumping-associated changes in hematocrit and pulse rate; inhibition of hypoglycemia
Tuiassay et al. (1989)	10	Octreotide 50 mg vs. placebo before OGTT	Suppression of rise in pulse rate and hematocrit; suppression of rise in plasma levels of VIP; inhibition of postprandial hypoglycemia; inhibition of rise in plasma levels of insulin and GIP
Geer et al. [32]	10	Octreotide 100 mg vs. placebo before a dumping-provocative meal	Prevention of development of dumping symptoms and diarrhea; prevention of late hypoglycemia and of the rise in plasma levels of glucose, glucagon, pancreatic polypeptide, neurotensin and insulin; delayed gastric emptying and intestinal transit
Richards et al. [33]	6	Octreotide 100 mg vs. placebo before a dumping-provocative meal	Prevention of dumping symptoms; induction of migrating motor complex phase III in the small intestine; decreased postprandial intestinal motor activity
Gray et al. (1991)	9	Octreotide 100 mg vs. placebo before a dumping-provocative meal	Suppression of rise in pulse rate; inhibition of insulin release; prevention of hypoglycemia; inhibition of dumping symptoms
Hasler et al. (1996)	8	Octerotide 50 mg vs. placebo before OGTT	Suppression of rise in pulse rate; inhibition of dumping symptoms and diarrhea; no influence on change in hematocrit; inhibition of insulin release; prevention of hypoglycemia; no influence on gastric emptying rate
Arts et al. [14]	30	Octreotide 50 mg before OGTT	Suppression of rise in pulse rate and hematocrit; inhibition of postprandial hypoglycemia; inhibition of rise in plasma levels of insulin; improvement of early and late dumping symptoms

GIP glucose-dependent insulinotropic polypeptide (also known as gastric inhibitory polypeptide), *OGTT* oral glucose tolerance test, *VIP* vasoactive intestinal peptide

at 20 mg. Both the fast-acting and long-acting formulations had a favorable effect on dumping symptoms, glycemia, and pulse rate during provocative testing for dumping. The fast-acting form showed greater efficacy than the long-acting form in improving hypoglycemia. However, treatment with the long-acting formulation was associated with a significant improvement in patients' quality of life and was markedly preferred by recipients over the fast-acting preparation [14].

Adverse Effects of Somatostatin Analogs

The main adverse events related to the use of somatostatin analogs are pain at the site of injection, gallstone formation, and the occurrence of steatorrhea. The latter symptom is usually mild, and the long-term use of somatostatin analogs is usually associated with weight gain of approximately 1 % in spite of the occurrence of steatorrhea. Gallstone formation is not an uncommon complication of the long-term use of somatostatin analogs and should be taken into account when considering treatment options for dumping syndrome [37, 38]. Another disadvantage of somatostatin analogs is their considerable cost. For this and the aforementioned reasons, treatment with somatostatin analogs is not the first-line treatment option for patients with dumping syndrome. However, dumping syndrome is associated with significant impairment of quality of life, and the improvement in this parameter with somatostatin analogs is impressive. The development of an oral or nasal formulation should further improve the application of octreotide in the treatment of dumping syndrome [14, 32].

Surgical Treatment

Conservative management is always preferred because most patients will exhibit improvement in dumping over time, and surgery may not be curative. Postgastrectomy syndromes often abate with time. Therefore, medical, dietary, and behavioral therapy should be given at least a 1-year trial. If these nonoperative measures fail, corrective surgery may be considered.

Conversion of Billroth II to Billroth I Anastomosis

This procedure restores the physiological delivery of the meal to the duodenum without creating the risk of gastric outlet obstruction. Woodward et al. reported an improvement in dumping syndrome in 75 % of patients [39]. The procedure has a low rate of complications and is relatively simple.

Roux-en-Y Conversion

A conversion to a Roux-en-Y gastrojejunostomy is preferred as a remedial operation [40]. RYGJ is useful in patients with dumping because it slows down gastric emptying and the transit of chyme through the Roux limb. The mechanisms responsible for the effectiveness of this surgery in dumping are not well known. However, the interruption of the migration motor complex and diminished jejunal contractions may play a major role. Favorable outcomes have been reported after this operation in 85–90 % of patients with Billroth I and II gastrectomy [16, 17]. Vogel et al. [18] reported excellent results in 19 of 22 patients with this operation. This procedure is easier to perform and has fewer long-term complications (e.g., Roux stasis syndrome) [41].

Overall, surgery has a limited role in the treatment of dumping. Selection of the appropriate surgical procedure is very important. In terms of remedial operations for patients following pyloroplasty, pyloric reconstruction should be the initial corrective operation. Roux-en-Y reconstruction appears to be the most effective option for patients with Billroth I and Billroth II gastrectomies. For those patients who already have a Roux-en-Y reconstruction, an antiperistaltic jejunal segment can be interposed.

Continuous Enteral Feeding

A final approach to the treatment of patients with refractory dumping syndrome is the creation of a feeding jejunostomy, through which a continuous background flow of nutrients can be provided. This is a rather invasive intervention, with a major effect on daily life, but it appears to be effective in avoiding symptoms that are triggered by meal ingestion [42].

Conclusion

Dumping syndrome is a common complication after gastric surgery. Clinically significant dumping can result in serious distress and considerable morbidity in patients. The diagnosis of dumping syndrome is based on clinical presentation, and if needed, it can be confirmed by a provocation test

with oral glucose. With regard to gastric surgery, Billroth I or R-Y gastrojejunostomy after distal gastrectomy is better than Billroth II for the prevention of dumping syndrome. The majority of patients respond to dietary modifications. Therapy with octreotide is an effective alternative prior to considering surgical correction. Close attention must be given to the patient's nutritional status. If medical therapy fails to provide symptom relief, surgical revision should be offered, with the understanding that even this intervention may not be successful.

Key Points

1. Dumping syndrome is a common complication of esophageal and gastric (including bariatric) surgery.
2. Symptoms include early (gastrointestinal and vasomotor) and late (hypoglycemia) symptoms.
3. Diagnosis is based on a suggestive symptom pattern in patients with the appropriate surgical history; a modified oral glucose tolerance test might help to establish the diagnosis.
4. To prevent dumping syndrome, Billoth I or R-Y gastrojejunostomy after distal gastrectomy is preferred over Billroth II.
5. Initial therapy should focus on dietary measures.
6. In patients who have not responded to initial therapy (slow-release), somatostatin analogs are the treatment of choice.
7. In patients with treatment-refractory dumping syndrome, surgical reintervention or continuous enteral feeding can be considered, but the outcomes of such approaches are variable.

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Afferent Loop Syndrome

14

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Introduction

Afferent loop syndrome (ALS) is a constellation of signs and symptoms caused by mechanical obstruction of the afferent loop following surgical construction of a double-barrel gastrojejunostomy (Fig. 14.1a). The afferent loop consists of the segment of duodenum and/or proximal jejunum upstream of a double-barrel gastrojejunostomy anastomosis. Accumulation of enteric secretions in the obstructed afferent loop causes increased intraluminal pressure leading to symptoms of abdominal pain and distension. ALS can be classified into acute and chronic forms. Acute ALS is due to complete obstruction of the afferent loop, usually occurring within 1 week after surgery. Chronic ALS is due to partial obstruction of the afferent loop, usually occurring several months or years after surgery. McNealy first described acute ALS as a cause of early postoperative duodenal stump leak in 1942 [1]. In 1948, Lake first described chronic ALS as obstruction of free passage of duodenal contents across the anastomosis leading to "afferent loop stasis" [2]. In 1950, Roux coined the terms "afferent loop syndrome" when describing the condition in partially gastrectomized patients [3]. Because the symptoms associated with ALS are nonspecific, these conditions can be difficult to diagnose. However, if unrecognized, ALS can lead to significant morbidity and mortality and consequently requires a high index of suspicion and prompt treatment.

Epidemiology

In 1955, Jordan initially reported an incidence of 0.3% of afferent loop syndrome complicating partial gastrectomies [4]. Historically, ALS was associated with gastrectomy with Billroth II reconstruction, with an incidence of up to 20% [5]. At that time, many of these operations were performed for peptic ulcer disease. However, given the precipitous decline in elective operations for complications of ulcer disease, [6],, the contemporary incidence of ALS is unclear. More recently, Aoki retrospectively reviewed the cases of 1908 patients who underwent open distal gastrectomy between 1999 and 2008. He found that 0.2% of these patients developed ALS. Pannala reported that the incidence of ALS in a cohort of 186 pancreatic cancer patients after pancreaticoduodenectomy was as high as 13% [7]. Kim retrospectively reviewed a surgical database of 396 patients who underwent laparoscopic distal gastrectomy with Billroth II reconstruction between 2004 and 2011 and found an incidence of ALS of 1.01% [8]. Therefore, the estimated current inci-

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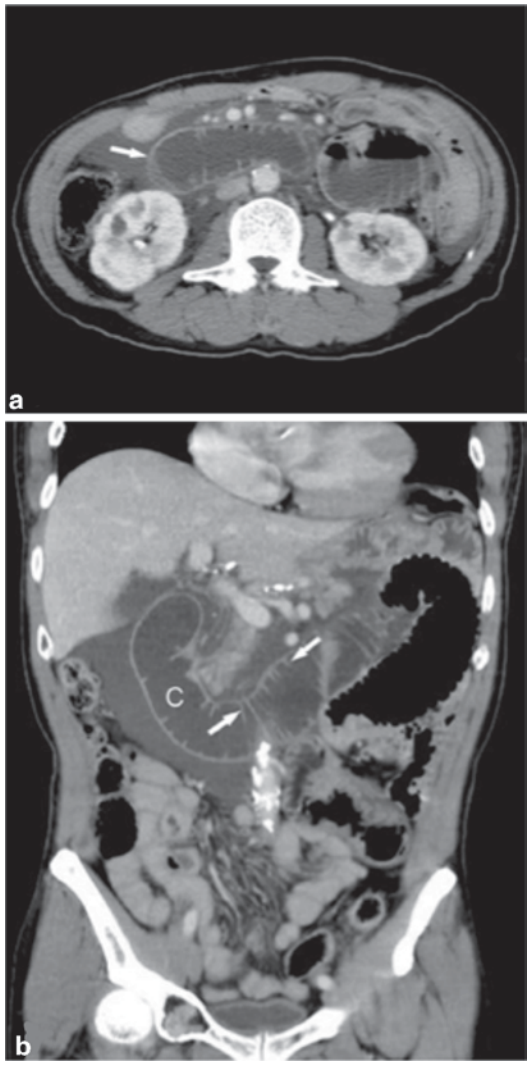

Fig. 14.1 Afferent loop obstruction in a 62-year-old man after Roux-en-Y gastroenterotomy. **a** Axial plane of MDCT shows a dilated fluid-filled afferent loop (*arrow*) located at the mid-abdomen and crossing between the aorta and superior mesenteric artery. **b** Coronal plane of MDCT reveals the configuration of the afferent loop to be of a "C" character. **c** Keyboard sign (*arrows*) is also clearly demonstrated. Focal bowel thickening at the anastomotic region is present, suggesting local recurrence. Endoscopic biopsy confirmed the MDCT diagnosis of local recurrence. (With permission from [28] © Copyright: Yonsei University College of Medicine 2011; Creative Commons Public License: http://creativecommons.org/licenses/by-nc/3.0/legalcode. Used without modification)

dence is between 0.2 and 13%, with a guestimate incidence of 1–2%. Mortality from ALS is typically the result of a delay in diagnosis leading to bowel necrosis and perforation. This occurs because typically the surgeon is not considering ALS in the differential diagnosis. The mortality rate reported before the development of CT or ultrasound was as high as 30–60% [9].

Etiology

The likelihood of developing ALS is influenced by both surgical technique and postoperative complications. The syndrome generally occurs when the afferent limb is longer than 30–40 cm and has been anastomosed to the gastric remnant in an antecolic fashion [10]. A variety of factors can contribute to the development of ALS, including kinking and angulation of the afferent limb, internal herniation behind the efferent limb, stenosis of the gastrojejunal anastomosis, redundant twisting of the afferent limb with resultant volvulus, or adhesions involving the afferent limb. ALS can also result from a failure to close mesocolic defects following construction of retrocolic gastrojejunostomy.

Several conditions following gastrojejunostomy can lead to ALS. Presentations of ALS with enterolith tend to be rare and late onset [11]. Several case reports have documented cases of chronic ALS related to large duodenal stones as late as 24 years postsurgery [12, 13]. Hui et al. reported a case of a 10-year presentation of ALS postgastric surgery with a large duodenal phytobezoar [14]. Other postoperative causes of ALS following gastrojejunostomy include scarring due to anastomotic ulcers [15], internal hernia [16], and intestinal volvulus [17]. Cancer recurrence near the site of anastomosis causing ALS, often termed malignant ALS, has been reported frequently in patients with pancreatic cancer with widespread carcinomatosis resulting in twisting or obstruction of the afferent limb [18].

Pathophysiology

Complete or partial obstruction of the afferent limb as a technical issue at the time of surgery causes acute ALS and potentially chronic ALS.

Complete or partial obstruction along the jejunal portion of the efferent loop results in entry of gastric chyme into the afferent loop, triggering the release of enteric hormones. Accumulation of bile, water, pancreatic secretions, and bicarbonate in the afferent loop causes abdominal distension and increased intraluminal pressure. Postoperative ascending cholangitis [19], obstructive jaundice [20], and pancreatitis [21] may ensue. Bile acid malabsorption may occur due to bacterial overgrowth and result in accompanying iron-deficiency anemia, megaloblastic anemia due to B12 deficiency, bleeding due to vitamin K deficiency, and Wernicke syndrome due to deficits in vitamin B1 [22]. Intestinal stasis resulting in bacterial overgrowth and steatorrhea, vitamin B12, folic acid, and iron deficiency is often termed "blind loop syndrome."

Clinical History

Patients with acute ALS frequently present with sudden onset right upper quadrant abdominal pain, nausea, and nonbilious vomiting. Acute ALS is considered a surgical emergency and typically occurs in the early postoperative period but has also been reported to occur 30 years after surgery. The risk of intestinal perforation/infarction and disruption of the duodenal stump necessitates prompt decompression of the afferent loop.

Patients with chronic ALS typically experience postprandial epigastric pain and abdominal distension lasting from several minutes to an hour. Bilious projectile vomiting is a common manifestation of chronic ALS and provides rapid symptom relief. Intestinal stasis during chronic ALS can be complicated by diarrhea and steatorrhea. Subsequent bacteria-mediated deconjugation of bile salts can result in vitamin B12 deficiency and/or iron-deficiency anemia. Patients often stop eating to avoid postprandial pain and may experience severe weight loss.

Physical Findings

The most common physical finding in ALS is epigastric/right upper quadrant abdominal tenderness. Approximately one-third of patients with acute ALS have a palpable right upper quadrant abdominal mass. Patients may present with obstructive jaundice or abdominal pain radiating to the back or flank indicative of pancreatitis. If bowel perforation has occurred, patients may present with a rigid abdomen and guarding indicative of peritonitis.

Differential Diagnosis

Because the physical findings associated with ALS are nonspecific, there are a number of other etiologies that must be considered. Among the differential diagnosis for ALS are abdominal abscess, hernia, acute mesenteric ischemia, anemia, bacterial overgrowth syndrome, bile duct strictures, bile reflux gastritis, biliary colic, bowel obstruction, carcinoma of the ampulla of Vater, choledochal cysts, choledocholithiasis, gastric outlet obstruction, gastric sarcoma, gastric ulcer, volvulus, gastritis, intestinal perforation, mesenteric thrombosis, mesenteric cyst, omental torsion, pancreatic pseudocyst, and tumors (gastric, bile duct, small intestine, mesenteric). Given the broad differential diagnosis, a detailed surgical history and high clinical suspicion are imperative to making an accurate diagnosis.

Diagnosis

Laboratory studies may aid in the diagnosis of ALS; however, a confirmatory diagnosis necessitates imaging studies. Increased intraluminal pressure accompanying ALS may be transmitted to the biliary tract and cause ascending cholangitis, obstructive jaundice, or pancreatitis [23, 24]. A check for elevated levels of alkaline phosphatase, alanine/aspartate aminotransferases, amylase, lipase, and serum bilirubin may aid the diagnostician in this regard. Given the possible presence of anemias related to ALS (vitamin B12

deficiency, iron deficiency), a check for hemoglobin, hematocrit, mean corpuscular volume, cell size, iron content, and WBC count may also aid in the diagnosis of chronic ALS. In suspected ALS patients, a serum electrolyte panel should also be obtained to check for possible hyponatremia, hypokalemia, hypochloremia, and metabolic alkalosis due to vomiting and diarrhea that may accompany ALS. Finally, a carbon 14 xylose breath test may detect bacterial overgrowth due to intestinal stasis related to ALS.

Noninvasive Imaging Studies

Abdominal CT is considered the radiographic study of choice in the diagnosis of ALS [25]. CT scanning can directly visualize the obstructed intestinal segment. Other structures such as the pancreas and biliary tree that may be impacted by the obstruction can also be examined. ALS typically presents as a fluid-filled tubular structure crossing the abdominal midline between the aorta and super mesenteric artery, and the radiographic appearance was first described in 1980 by Kuwabara et al. [26]. CT scanning has also proven useful in predicting the pathology underlying ALS. Kim et al. found that CT scanning helped correctly predict internal herniation, adhesions, and recurrent gastric cancer as the underlying etiology for ALS in all 18 patients examined [27]. Juan assessed the multidetector computed tomography (MDCT) findings of ALS in a retrospective study of 1100 patients who underwent gastroenterostomy reconstruction between 2004 and 2008. Of the 2% of patients diagnosed with ALS, 100% had a fluid-filled C-shaped afferent loop and 98% had valvulae conniventes projecting into the lumen (keyboard sign) on MDCT (Fig. 14.1) [28].

In patients with ALS, abdominal ultrasound may reveal a fluid-filled mass in the right upper quadrant or a peripancreatic cystic mass. Derchi et al. identified the distended afferent limb as a fluid-filled structure in four patients with ALS caused by tumor recurrence at or near a Billroth II gastrojejunostomy [29]. Lee et al. reported similar findings in a study of seven ALS patients, observing the obstructed afferent limb as a dilated, fluid-filled structure crossing the midline in the upper abdomen [30].

In patients in whom ultrasound and endoscopy are nondiagnostic, hepatobiliary scintigraphy may prove useful in diagnosing chronic ALS. Sivelli et al. used technetium-99 m hepatoaminodiacetic acid scanning in 50 patients and found that hepatobiliary scanning is useful in diagnosing ALS [31]. Despite other studies showing success using mebrofenin and hepatoaminodiacetic acid scanning [17, 32], scintigraphic studies should be reserved for cases where abdominal CT and ultrasound are nondiagnostic.

Invasive studies such as esophagogastroduodenoscopy allow for direct visualization of the gastrojejunostomy and detection of possible modes of obstruction (i.e., volvulus, herniation, ulceration, etc.). In addition to identifying possible masses in the region of the gastrojejunostomy, esophagogastroduodenoscopy can be helpful in distinguishing between alkaline reflux gastritis and ALS [10].

Treatment

Medical Treatment

Acute ALS requires immediate diagnosis and corrective surgery. Indeed, the major pitfall associated with ALS is a delay in diagnosis due to risk of intestinal perforation and sepsis [33]. Patients with chronic ALS may develop malnutrition or anemia [22, 34], and may derive benefit from nutritional therapy or transfusion prior to surgery.

Endoscopic/Interventional Radiology

Although surgical conversions have been the treatment of choice, percutaneous tube drainage or stent placement has been performed as a palliative treatment for patients who cannot tolerate a surgical procedure. Metallic stents have been used for the relief of afferent loop syndrome due to number of etiologies [35–37]. In a 77-year-

old patient with afferent loop obstruction due to recurrent cancer, a double-pigtail catheter placed beyond the ampulla of Vater resolved symptoms [36]. Two cases of refractory ALS were successfully treated by transhepatic biliary catheterization coupled with transcholecystic cholangiography, both showed clinical improvement with no complications [37]. More recently, Lee et al. described the successful endoscopic treatment of near-complete obstruction of the efferent loop with insertion of a double-pigtail stent (Fig. 14.2a–e) [38]. A study by Morita and colleagues indicated that percutaneous transhepatic catheter drainage for obstructed afferent loop may be risky due to the development of septic shock [39]. In such cases, the authors suggested an additional drainage catheter of the bile duct might be needed when biliary stasis is present.

Han retrospectively analyzed the clinical effectiveness of placement of dual stents in 13 consecutive patients who underwent operations for gastric cancer, cholangiocarcioma, or pancreatic adenocarcinoma and subsequently developed afferent loop syndrome due to disease progression. Twelve of the 13 patients experienced normalization of their abnormal biliary laboratory findings and decompression of the dilated bowel loop following dual stent placement [40].

Kim et al. found that percutaneous tube enterostomy is an effective palliative treatment in ALS presenting as obstructive jaundice [41]. Radiographically guided interventional techniques with metallic stents have been used to effectively palliate ALS caused by a number of different etiologies. Successful palliation of biliary obstruction was achieved using transhepatic metallic stents across duodenal and biliary strictures for the treatment of malignant ALS caused by inoperable carcinoma of the head of the pancreas [35]. Percutaneous transhepatic metallic stent insertion for malignant afferent loop obstruction following pancreaticoduodenectomy for carcinoma of the ampulla of Vater is an option [42]. Percutaneous transhepatic insertion of metal stents was also successfully used to treat ALS due to distal gastrectomy [36]. A study by Song et al. looked at the use of metallic stents in 39 patients with recurrent cancer after gastrojejunostomy and found that placement of expandable metallic stents was successful in 90% of patients, but did require accurate knowledge of surgical procedure and tumor recurrence pattern for effective stent placement [43].

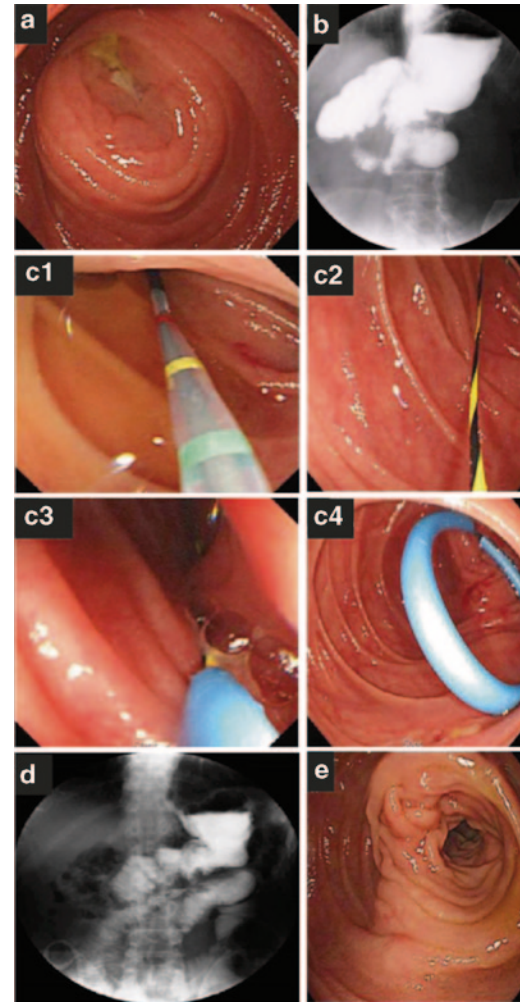

Fig. 14.2 Endoscopic finding revealed a narrowed and swollen entrance of the efferent loop (**a**). Gastrografin study showed nearly complete obstruction of the efferent loop (**b**). Endoscopic stent procedure was performed that double-pigtail stent was inserted through efferent loop stenosis and over the guide wire using double-channel endoscope under endoscopic view (**c**). Follow-up gastrografin and endoscopic study showed free flow of contrast and recovery of narrowed, swollen orifice of the efferent loop (**d**, **e**). (With permission from [38] Baishideng Publishing Group Co., Limited)

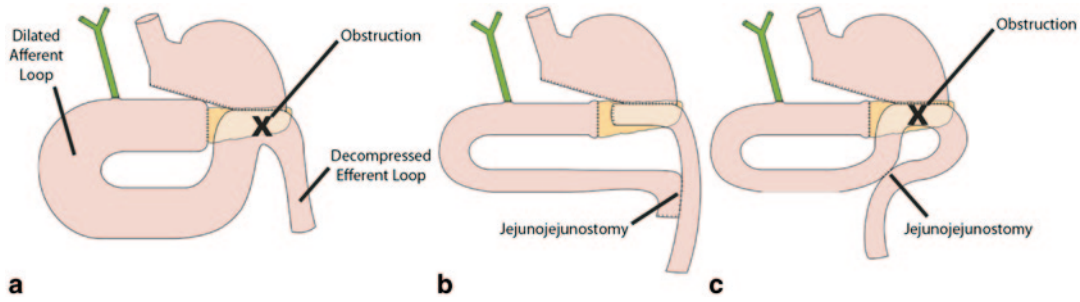

Fig. 14.3 Afferent loop syndrome (*ALS*) is caused by mechanical obstruction of the afferent loop of a double-barrel gastrojejunostomy (**a**). ALS may be surgically corrected by deconstructing the Billroth II gastrojejunostomy and restoring gastrointestinal continuity with a Roux-en-Y gastrojejunostomy (**b**). Alternatively, entero-anastomosis between the afferent and efferent loops may be performed to bypass the obstruction (**c**)

Surgical Intervention

Surgical treatment of chronic ALS, unlike acute ALS, is an elective procedure. Surgical interventions ranging from simple operations to major resections have been used to effectively treat afferent loop obstruction. In some cases, suture fixation to reduce angulations and kinks have been reported to successfully alleviate afferent loop obstruction [44]. In a study of 79 patients in 1951, Capper and Butler recommended suspension of the afferent jejunal loop to the posterior peritoneum and hepatic omentum to promote drainage of the efferent loop [45].

The most widely used procedure for the surgical correction of ALS involves deconstruction of the Billroth II gastrojejunostomy followed by restoration of gastrointestinal continuity with a Roux-en-Y gastrojejunostomy (Fig. 14.3a–c).

Theodor Billroth performed the first gastroduodenostomy in 1881 following partial gastrectomy on a patient with carcinoma of the stomach [46]. A Bilroth I gastroduodenostomy creates an anastomosis between duodenum and stomach. However, the use of this procedure should be avoided in patients with duodenal scarring or previous subtotal gastrectomy due to the risk of excessive tension on the anastomosis. Gastroduodenostomy itself can cause ALS, among other postgastrectomy syndromes, and for this reason the technique of Roux-en-Y anastomosis was developed by Wolfer in 1883. Cesar Roux of Lausanne later popularized the procedure in 1887 [47].

The Roux-en-Y gastrojejunostomy involves dividing the jejunum distal to the ligament of Treitz and anastomosis of the stomach to the proximal portion of the distal jejunal segment. The distal proximal jejunal segment is anastomosed to the distal end of the Roux limb [47]. Possible complications of the Roux-en-Y gastroejejunostomy include proximal blind loop, duodenal stump blowout, and bile reflux gastritis [48]. A variant of this operation, termed the "uncut" Roux-en-Y gastroejejunostomy, involves occlusion via stapling rather than complete division of the jejunum and is intended to avoid Roux stasis syndrome [49]. However, risk of staple line dehiscence stands in the way of widespread adoption of this procedure.

Alternatively, resection of the redundant segment of the afferent jejunal loop, entero-anastomosis (Fig. 14.3c), or revision of the gastrojejunostomy may be performed. Entero-anastomoses between afferent and efferent loops are complicated by possible marginal ulceration and should be avoided unless vagotomy or gastric resection is performed.

Summary

Although ALS is a rare complication following gastric surgery, early diagnosis and treatment of the obstruction are critical given the risk of bowel perforation and subsequent sepsis. In the case of chronic manifestations of the syndrome, proper treatment is dependent upon a thorough

understanding of patient-specific etiology, anatomy, and associated complications.

Key Points for Avoiding

1. Avoid Billroth II gastrojejunostomy whenever possible
2. Make an afferent limb shorter than 30–40 cm
3. Avoid an antecolic anastomosis to the gastric remnant
4. Close mesocolic defects following gastrojejunostomy
5. Early diagnosis is critical to avoiding intestinal perforation and sepsis

Key Points for Diagnosing/Managing

1. Physical exam and laboratory findings are generally nonspecific
2. Abdominal CT is the noninvasive imaging study of choice in the diagnosis
3. Upper endoscopy allows for direct visualization of the anastomosis and obstruction
4. Surgical correction of the mechanical obstruction is the most common management
5. Percutaneous drainage or endoscopic stent placement may also be performed in patients who cannot tolerate an operation.

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Duodenal Stump Blowout

15

Paul J. Speicher, Andrew S. Barbas, George Z. Li and Douglas S. Tyler

Introduction

In 1885, Billroth and von Hacker performed the first gastrojejunostomy reconstruction after partial gastrectomy in a patient with a pyloric cancer [1]. The procedure, now known as the Billroth II, was one of the crucial innovations in the late nineteenth century that ushered in a new era of gastric surgery. While many patients did well following gastric resection, surgeons also began to realize the devastating complications that could occur. In particular, the Billroth II requires closure of the proximal end of the duodenum, which creates potential for leakage, or "blowout," from this stump.

Today, duodenal stump blowout remains one of the most feared complications of a Billroth II or Roux-en-Y reconstruction after gastric resection, as spillage of enteric contents from the duodenal staple line can lead to overwhelming sepsis and death. Stump blowout can also lead to duodenal fistulas that cause significant morbidity and are difficult to manage [2]. The incidence of duodenal stump blowout is reported to be 1–6 % after gastric surgery, with an associated mortality rate of 3–5 % [3, 4]. Factors associated with it include inflamed or scarred duodenal tissue in the setting of an ulcer, which makes duodenal closure difficult, and distal obstruction of an afferent limb, which exerts excess pressure on the duodenal staple line [5].

Even in the modern era, there exists controversy over how to best prevent and treat this devastating complication, as much of the literature describing this complication comprises of studies from the 1950s to 1990s. During this period, gastric cancer was the most common cancer worldwide, and gastric and duodenal resections were still commonly being performed for peptic ulcer disease. Since the discovery of effective medical management of peptic ulcers and the declining incidence of gastric cancer, the number of gastrectomies has decreased [6, 7]. Nevertheless, prevention and management of stump blowout remains a clinically important consideration for the general surgeon and surgical oncologist performing gastrointestinal (GI) surgery.

Clinical Presentation of Blowout

Duodenal stump blowout typically presents between postoperative days 3 and 10. There have been case reports describing blowout occurring as

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early as postoperative day 1, but this is extremely rare and should raise suspicion of a technical failure during duodenal closure, such as stapler malfunction [8]. Early diagnosis of a duodenal stump blowout is essential to reducing the associated morbidity and mortality, as these patients often require emergent reoperation. Fortunately, the clinical diagnosis is usually difficult to miss so long as there is adequate clinical suspicion, as the onset of symptoms is typically sudden, severe, and appropriately termed a "blowout."

Classically, patients who are initially doing well postoperatively acutely develop fever, tachycardia, and marked right upper quadrant abdominal pain. There may also be peritoneal signs on abdominal examination. Patients can progress rapidly to hemodynamic instability and septic shock from overwhelming intraabdominal infection in a matter of hours from initial onset of symptoms. Laboratory studies often reveal leukocytosis, and involvement of the adjacent pancreas in the inflammatory reaction may cause elevations in amylase and lipase as well [9]. Computed tomography (CT) imaging may reveal a subphrenic or subhepatic fluid collection suggestive of abscess formation. Other clues to the diagnosis of stump blowout can be found by observing surgical drain output. Abdominal drains left in the resection bed may begin outputting bilious fluid leaking from the duodenal stump. In some cases, the erosive duodenal content can damage adjacent mesenteric vessels to cause hemorrhage, which manifests as sanguineous drain output.

Mechanisms Contributing to Blowout

Breakdown and rupture of the duodenal stump is usually the result of numerous factors working in concert and leading to potentially catastrophic results. While a multitude of specific causes likely exist, these factors include broadly the following: staple line failure, distal obstruction, malnutrition, and the "difficult duodenum" or an underlying duodenal problem that makes closure more tenuous and complex.

Staple Line Failure

Staple line failure, or more generally, technical failure of the duodenal stump closure, constitutes probably the most basic and obvious cause of stump blowout. Prior to the widespread use of standardized surgical stapling devices, hand-sewn two-layered closure without tension was the technique of choice [10]. With the introduction of surgical staplers, hand-sewn closure of the duodenal stump has lost popularity, but the underlying mechanisms of failure remain unchanged; namely, ischemia and/or incomplete closure. With a hand-sewn closure, the most common technical error is not incomplete closure with resultant leakage, but rather overaggressive use of suture, which results in ischemia at the line of closure. The ischemic tissue at the site of aggressive suturing can eventually necrose, with catastrophic results. Starting in the 1970s and 1980s, surgical staplers began to replace sutured techniques for closing the duodenal stump. While providing a simple, efficient, and watertight closure, staples were not a panacea for stump blowout. When using a surgical stapler device, improper selection of staple size and failure to appreciate tissue thickness and edema can lead to excessive compression at the staple line similar to sewn closures, with subsequent ischemic breakdown. Furthermore, flawed stapler technique and aggressive dissection and devascularization can contribute to inadequate closure and increase the risk of staple line failure.

Distal Obstruction

Managing the intraluminal pressure in the duodenal stump has gained renewed attention as an important factor in reducing the risk of stump blowout. Distal obstruction, regardless of etiology, will eventually lead to high enough stump pressures to disrupt even the most secure and technically sound closure. While much work has been done studying intact gastrointestinal tract both anatomically and functionally, scant literature has focused on the behavior of the surgically

modified upper GI tract following distal gastrectomy. Recent advances in measurement techniques and computer simulation, however, have allowed for more rigorous and detailed investigations into the underlying mechanical stresses involved with stump blowout.

While it seems fairly obvious that higher intraluminal pressures in the duodenal stump would lead to higher likelihood of leakage and blowout, why such elevated pressures develop remains less clear. Recent work using computerized manometry and mathematical models has demonstrated that the length of the afferent duodenal section associated with the duodenal stump has important implications for pressure distribution, food mixing, and appropriate transport [11]. Longer duodenal sections, while reducing the risk of retrograde food mixing in the direction of the stump, also led to higher stump pressures, with maximal pressure at the point of duodenal closure. Because of this, the position of gastrojejunal anastomosis should be chosen such that the afferent segment is long enough to minimize reflux and patient symptoms, but short enough to reduce the risk of stump blowout.

In addition to the nuances of afferent duodenal section length, another more general cause of elevated intraluminal pressure at the stump is nonspecific distal obstruction. Postoperative ileus and early postoperative obstruction case both lead to more proximal elevations in intraluminal pressure and dilatation, increasing the risk of catastrophic blowout. Management and prevention of this situation, by careful consideration of postoperative patient symptoms, thoughtful clinical examinations, and appropriate use of nasogastric decompression when indicated can help prevent and/or alleviate this pressure buildup.

Malnutrition

The importance of perioperative nutrition is often neglected, both in practice and in the literature. While a full discussion of the topic is clearly beyond the scope of this chapter, nutrition plays a key role in duodenal healing and prevention of stump blowout. Numerous growth factors and hormones, including insulinlike growth factor, TGF-beta, VEGF, fibroblast growth factor, epidermal growth factor, and PDGF are essential in the progression of anastomotic healing [12]. Malnutrition, by way of inadequate substrate availability and decoupling of this tightly controlled axis of growth hormone regulation, can impede wound healing and contribute to stump breakdown and blowout.

In cases of elective gastric resection and duodenal stump creation, it is imperative that the patient's nutritional status be assessed both by physical examination and biochemically prior to surgery. When substantial preoperative malnutrition exists, a delay in surgery, even of the order of days to weeks, should be considered to allow for nutritional optimization either enterally or parenterally. This is particularly important in cases of gastric resection, where the resulting duodenal bypass can worsen malnutrition postoperatively.

The Difficult Duodenum

The "difficult duodenum," or the classical description of situations where underlying duodenal pathology makes proper closure particularly tedious and difficult, requires thoughtful consideration and distinctive approaches. In cases where the duodenum is inflamed, scarred from chronic ulcer disease, or otherwise abnormal, the risk of subsequent complications is considerable. While advances in acid-reducing medical therapy for ulcer disease have made cases of the difficult duodenum substantially less common than in the past, such situations continue to arise, and in such circumstances, the risk of duodenal stump blowout remains.

Techniques for Reducing the Risk of Blowout

Management of the Difficult Duodenum

Techniques for managing the difficult duodenum have been described since the first half of the twentieth century, but little data exist on the

modern state of duodenal closure. While advances in surgical technology and perioperative management have been remarkable since then, the basic approaches first described by Nissen and Bancroft have remained largely unchanged over the decades. These closure techniques, along with the relatively more recent tube duodenostomy, remain essential tools in the general surgeon's armamentarium when attempting to prevent stump blowout following particularly difficult duodenal closures.

General Principles of Closure

In the setting of chronic duodenal ulcer disease, dissection of the difficult duodenum should be carefully carried beyond the site of ulceration in the duodenal wall. When a primary gastroduodenostomy following distal gastrectomy is not an appropriate option in these situations, the duodenum must be closed, either by stapling if circumstances will allow or by two-layered suture closure in more difficult situations. When such an approach is necessary, the anterior and posterior walls of the duodenum should be closed with full-thickness 3-0 silk sutures with attempts to incorporate a portion of the mucosa. A second layer of interrupted Lembert sutures should then be placed to secure the closure.

Nissen Technique

Nissen's closure is best suited in situations where a large ulcer has eroded through the entire posterior wall of the duodenum, and the ulcer is not formally resected (see Fig. 15.1). In such situations where the closed duodenum must be sewn to the ulcer bed itself, the anterior duodenal wall should be approximated to the posterior wall with full-thickness bites at the margin of the ulcer bed in order to exclude the crater. Following this, two additional layers of sutures should be used to then approximate the anterior wall onto the ulcer bed itself (see Fig. 15.2). In order to ensure a tension-free closure, a Kocher maneuver is often performed prior to creation of the additional suture lines. If, following repair, concern exists regarding the integrity of the closure, or if the stump cannot be completely approximated using this strategy, alternative closure techniques or tube duodenostomy must be employed.

Bancroft Technique

Bancroft's closure, first described in 1932, begins with a submuscular dissection starting in the distal antrum and progressing toward the duodenum [13]. The stomach is then divided, and dissection is carried down around the circumference of the antrum distally. Once the antral mucosa and submucosa have been dissected in their entirety to the duodenal junction, a frozen section confirms the presence of duodenal mucosa and this is then closed. Following mucosal approximation, the excess antral muscle tissue is trimmed and closure is completed with a running nonabsorbable suture line (see Fig. 15.3). While Bancroft's closure can be a useful strategy in the management of a difficult duodenum during distal gastrectomy, this approach must be planned for early in the operation. As the technique relies on viable tissue around the distal antrum, the right gastric and gastroepiploic arteries, which are typically ligated at the beginning of the dissection, must instead be preserved.

Tube Duodenostomy and Drainage

Drainage of the duodenal stump by way of catheterization has long been championed as a potential means of reducing the risk of blowout, albeit with some controversy. As early as the late 1880s, both Billroth and von Langenbuch had reported on the use of indwelling duodenal catheters for the purpose of postoperative feeding. Not until more than 20 years later, however, did Neumann describe catheter duodenostomy for stump decompression [14]. In the 1950s, tube duodenostomy was revisited by Welch, and by the 1970s had gained traction as an acceptable and established approach in managing the difficult duodenum [15–17].

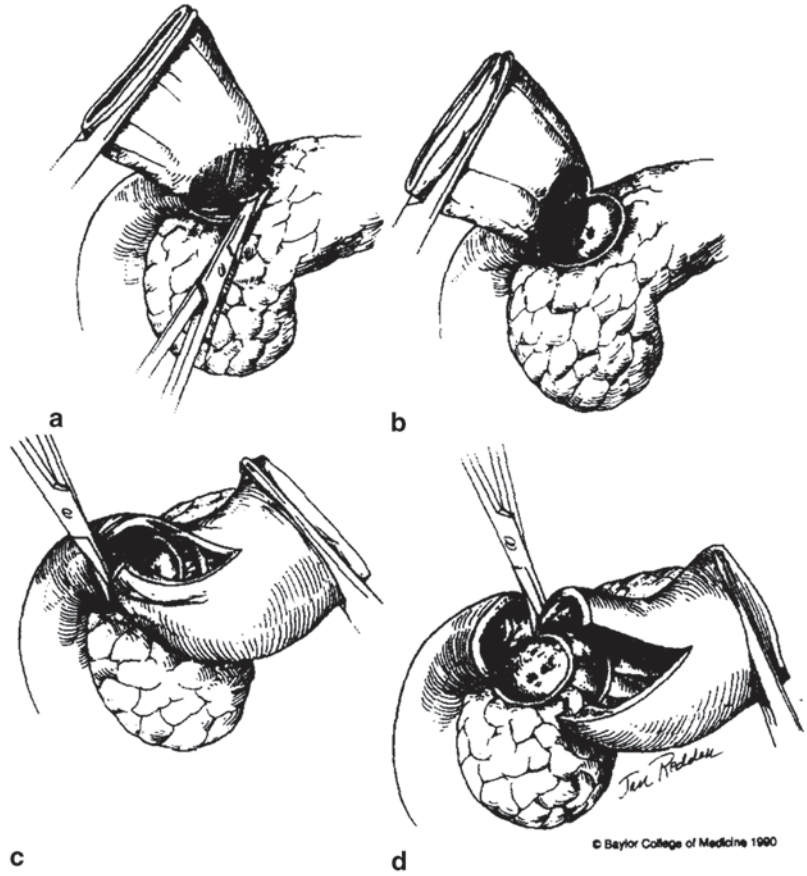

Fig.15.1 Initial dissection required for Nissen's closure. (Source: [13]. Reprinted with permission from Elsevier. © Elsevier 1991)

Early experiences using tube duodenostomy were plagued with reports of leakage and no improvement in patient outcomes, and the technique was initially met with skepticism. Over time, results improved, but the technique was nonetheless slow to gain considerable popularity. To this day, there remains considerable controversy regarding whether tube duodenostomy is an appropriate and helpful procedure, and we advocate for selective use based on surgeon preference and individual circumstances.

While lateral T-tube catheter drainage of the duodenal stump has been described and used with success [10], contemporary approaches to tube duodenostomy typically involve introduction of a Foley, Pezzer, or straight catheter via the stump of the duodenum to approximately 5 cm (see Fig. 15.4) [18]. The open end of the duodenum is then gently secured in place around the tube using a pursestring 3-0 absorbable suture, taking care to slightly invaginate the suture into the lumen of the duodenum (see Fig. 15.5). The seal around the catheter should then be tested by injecting 30–60 ml of sterile saline into the duodenum via the tube and observing for leaks. Once an adequate seal has been established, an omental pedicle is brought into place at the point of tube entry and secured in place. The distal end of the tube is then brought through the abdominal wall, minimizing the length of the intraabdominal portion of the tube.

Fig.15.2 Technique of Nissen's closure for the difficult duodenum. (Source: [13]. Reprinted with permission from Elsevier. © Elsevier 1991)

Management of Stump Blowout

The management of a patient with a duodenal stump leak is one of the most challenging clinical scenarios faced by gastrointestinal surgeons. Historically, duodenal stump leak has been characterized by significant morbidity and mortality. While this has improved over time, even in the current era this condition can be associated with substantial mortality. Successful management of duodenal stump leak requires a comprehensive approach that incorporates optimal medical management, judicious employment of percutaneous radiologic procedures, and sound clinical decision-making regarding the need for reoperation, timing, and surgical approach.

Medical Management

Optimizing medical therapy greatly enhances the likelihood of successful treatment of duodenal stump leak. A thorough evaluation of the patient's clinical condition is a critical first step. Clinicians must recognize that these patients may decompensate rapidly, and patients who display signs of hemodynamic instability or sepsis should be transferred to an intensive care setting. Appropriate intravenous access should be ensured. Patients will frequently require central line placement for the administration of vasoactive agents, monitoring of central venous pressure, and administration of total parenteral nutrition (TPN). Adjuncts such as arterial line placement may also be necessary for close hemodynamic monitoring. Along with these basic steps to resuscitate

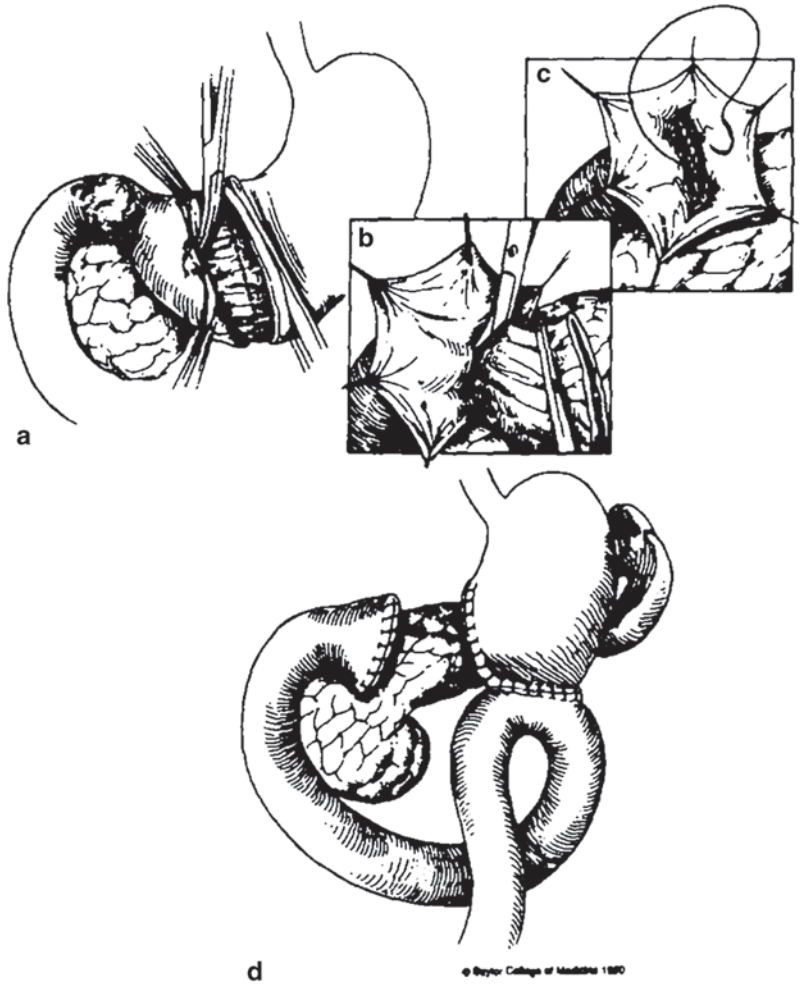

Fig.15.3 Bancroft's closure. (Source: [13]. Reprinted with permission from Elsevier. © Elsevier 1991)

the patient and restore euvolemia, the initiation of broad-spectrum antibiotics is required. Initial antibiotic selection is generally broad spectrum and includes coverage of Gram-negative and anaerobic organisms. Antifungal coverage may be necessary in patients who display signs of sepsis in the context of previous treatment with a prolonged course of antibiotics.

Another important consideration for successful management is optimization of nutritional status. Patients with duodenal stump leak are commonly malnourished and require additional caloric intake secondary to the considerable physiologic stress associated with this condition. Due to the compromised state of the upper gastrointestinal tract, oral feeding is generally not possible. If enteral access is available in the form of a feeding jejunostomy tube, enteral nutrition is preferred, but this is commonly not the case. Thus, for most patients, initiation of TPN is common to provide adequate nutrition in this setting. Nutritional parameters including prealbumin, transferrin, and albumin should be monitored at least weekly, and adjustments to TPN administration made accordingly.

Other adjunctive medical therapies are also commonly administered in patients with duodenal stump leak. Gastrointestinal prophylaxis with proton pump inhibitors or histamine blockers may combat stress gastritis. Additionally,

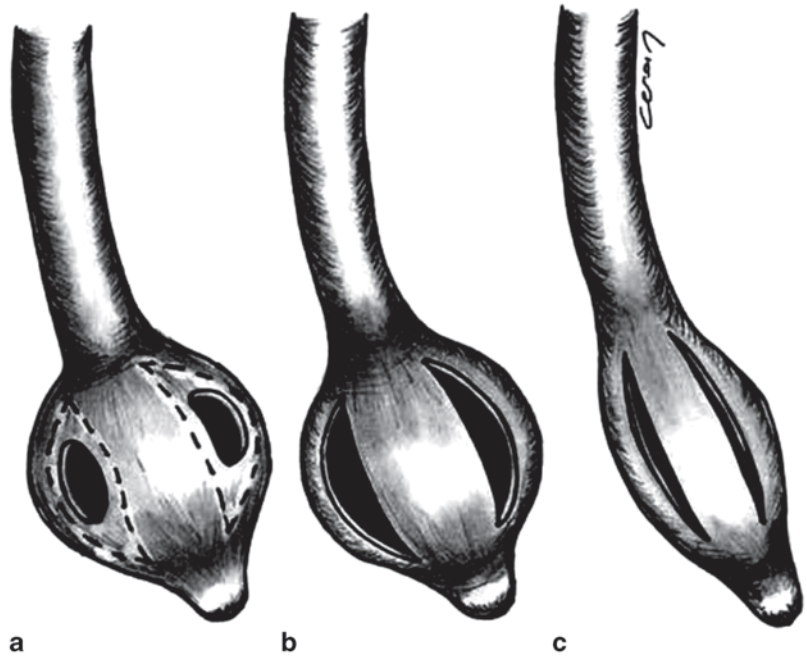

Fig.15.4 Modification of a standard Pezzer-type catheter for use in tube duodenostomy: **a** Original appearance of the tube. **b** Final appearance before inserting into the duodenum. **c** Appearance of the tube while removing. Note less traumatic effect of the tube to the duodenal stump. (Source: [18]. Reprinted with permission from Springer. © Springer Science and Business Media 2007)

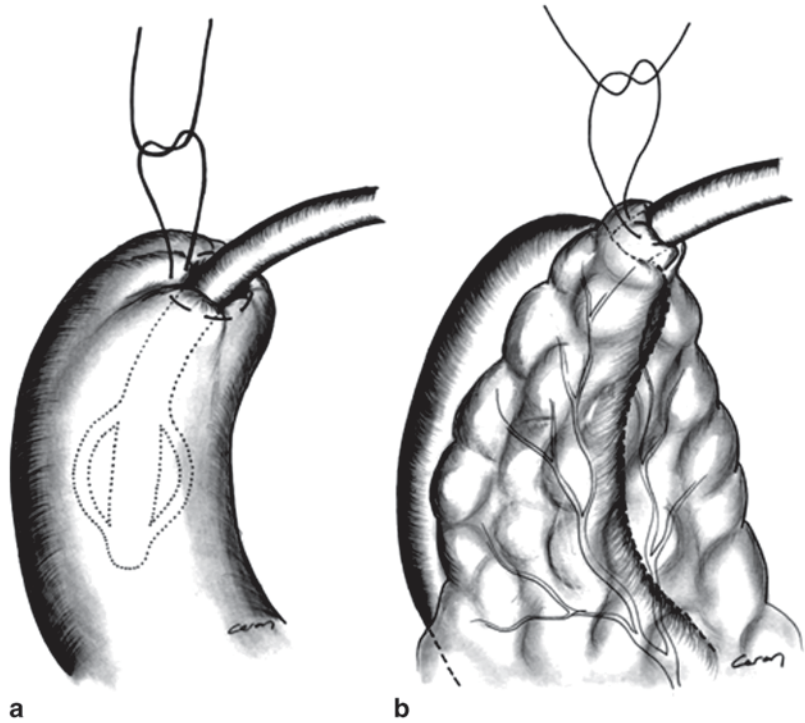

Fig.15.5 **a** Tube duodenostomy through the duodenal stump. **b** The duodenal stump with Pezzer drain in it has been protected by surrounding omentum. (Source: [18]. Reprinted with permission from Springer. © Springer Science and Business Media 2007)

administration of the somatostatin analogue octreotide may be employed in an effort to reduce the volume of effluent from the duodenal stump and promote fistula closure.

Percutaneous Radiologic Techniques

With significant advances in imaging technology and greater sophistication of image-guided percutaneous techniques in the current era, radiologic intervention has become the mainstay of therapy for duodenal stump leak. The first requirement of successful management is establishing control of abdominal sepsis. This can frequently be achieved by percutaneous drainage of intraabdominal fluid collections with catheter placement to allow ongoing evacuation of fluid. The goal of this intervention is to completely drain intraabdominal fluid and convert the duodenal leak into a stable duodenal fistula. This may require an aggressive approach with placement of multiple catheters and frequent trips to radiology suite for catheter repositioning and upsizing to gain optimal control of intraabdominal fluid.

After initial control of abdominal sepsis and successful establishment of a duodenal fistula, treatment strategies shift to interventions with the goal of achieving closure of the duodenal fistula. A common technique employed to decrease fistula output is biliary diversion by percutaneous transhepatic biliary drainage. The goal of this procedure is to divert the majority of bile flow away from the duodenum and thus significantly reduce the volume of effluent from the duodenal stump. In a small study by Zarzour and colleagues, percutaneous biliary drainage significantly reduce fistula volume from a mean value to 775 ml to less than 50 ml and lead to fistula closure in five of six patients [19]. Some centers have expanded on this technique by adding placement of a biliary occlusion balloon in addition to percutaneous biliary drainage in order to completely divert all bile flow [20].

Another percutaneous strategy for managing duodenal stump leak is percutaneous placement of tube duodenostomy. In a recent report, Oh and colleagues describe a staged approach for establishing tube duodenostomy using a Foley catheter [21]. In the initial phase of this technique, a percutaneous pigtail catheter is placed to drain duodenal stump effluent and establish a fistulous tract. After establishment of a fistulous tract, the Foley catheter is then advanced through the tract directly into the duodenum and confirmed via fluoroscopy.

The Decision to Operate and Surgical Approach

Decision-making regarding the need for reoperation and timing of such intervention in patients with duodenal stump leak is complex and requires mature surgical judgment. In the first 2–4 weeks following the index procedure, there is a great degree of inflammation in the dissection field, making reoperative surgery difficult and potentially hazardous. In light of these considerations, many surgeons prefer an initial trial of percutaneous management as described above to temporize the situation, control abdominal sepsis, and allow patient stabilization.

However, in settings where sophisticated interventional radiology support is not available, or if patients fail to respond to these measures, surgical intervention will be necessary. There are a variety of surgical approaches that have been employed in the management of duodenal stump leak. Considerable judgment is required to select the appropriate intervention at the optimal time. A clear goal for reoperation should be established (controlling abdominal sepsis, providing drainage, definitive closure, etc.). Factors that impact this decision include patient stability, nutritional status, and the volume and duration of duodenal stump leak.

The most commonly employed operative technique for managing duodenal stump leak is placement of a duodenostomy tube. The benefit of this strategy is that it reliably controls duodenal leakage and promotes the formation of a stable fistulous tract, yet is a smaller-scale procedure and better tolerated by patients who are physiologically compromised. The duodenostomy tube can be placed though the defect in the staple line at the end of the duodenal stump, or alternatively through intact duodenal wall a few

centimeters downstream of the staple line [18]. This procedure is commonly combined with the placement of large-bore surgical drains to establish control of abdominal sepsis.

Larger-scale operations are generally reserved for the nonhealing chronic duodenal fistula. These operations are generally best performed in the semielective setting, after patients have been medically stabilized and nutritionally optimized. Preoperative studies to rule out common reasons for persistence of duodenal fistula should be performed. In particular, small bowel follow-through should be performed to rule out downstream obstruction. One approach for definitive closure is performance of a roux-en-Y duodenojejunostomy, in which a roux limb is connected to the duodenal stump to provide drainage. As previously stated, reoperative surgery after duodenal stump leak can be highly challenging given the significant inflammatory changes in the field of dissection. Meticulous technique in dissection and adhesiolysis is required to prevent the occurrence of inadvertent enterotomies or damage to the biliary system and pancreas. Another definitive procedure for chronic duodenal fistula is pancreaticoduodenectomy, in which the entire duodenum and head of the pancreas is resected with reconstruction consisting of pancreaticojejunostomy, choledochojejunostomy, and gastrojejunstomy.

Summary of Management

The management of duodenal stump leak is challenging and requires a comprehensive approach. Key steps in management include stabilization of the patient, optimization of medical status and nutrition, and selection of percutaneous strategies to control abdominal sepsis and promote fistula closure. Reoperation should be reserved for the failure of these strategies and may require roux-en-Y duodenojejunostomy or pancreaticoduodenectomy.

Ramifications of Blowout

The substantial morbidity and mortality associated with duodenal stump blowout have been known for decades, with literature describing the risks and natural history of this feared complication dating back to the 1950s and 1960s. Namely, while blowout in that era was fairly uncommon, with an incidence of only 1.5–3.5% following Billroth II resection, subsequent mortality was striking at 50–80% [22–24]. Put another way, duodenal stump blowout was estimated to account for roughly half of all deaths following Billroth II gastric resection in that era [25].

Unquestionably, perioperative management and surgical technique have evolved and improved over the past half century. In the decades since those early descriptions, the mortality associated with stump blowout has been estimated to be more on the order of less than 10%, with recent studies even suggesting that this can be reduced even further [2–4, 13, 26]. Much of this improvement in patient outcomes can likely be attributed to advances in critical care, a better understanding of the importance of perioperative nutrition, accumulating experience in the duodenal trauma literature, and the evolution of image-guided interventions.

Furthermore, a decline in the incidence of gastric cancer and the remarkable changes over the past few decades in the treatment of peptic ulcer disease, shifting first to vagotomy and drainage and more recently away from surgery altogether, has markedly changed the landscape of gastric resections. A once rare complication of a common operation has become a rare complication of an uncommon operation. Despite this, duodenal stump blowout will continue to be a disastrous potential complication following gastric resection. The resulting morbidity associated with fistula formation or abdominal sepsis can have substantial effects on length of hospitalization, reinterventions, and overall patient quality of life.

Conclusions

Duodenal stump blowout, while much less common than in previous decades due to a marked reduction in the number of gastrectomies performed, continues to be one of the most dreaded complications following gastric resection. While mortality following stump blowout has improved substantially since the dismal rates of the 1950s, taking steps to prevent this devastating complication remains a contemporary concern. In situations where stump blowout nonetheless occurs, rapid diagnosis and intervention are essential in minimizing associated morbidity for the patient.

Key Points: Avoiding Duodenal Stump Blowout

1. The position of the gastrojejunal anastomosis should be chosen such that the afferent segment is long enough to minimize reflux and patient symptoms, but short enough to reduce the risk of stump blowout.
2. Management and prevention of postoperative ileus and obstruction can help prevent proximal elevations in intraluminal pressure and subsequent stump blowout.
3. In cases of elective gastric resection and duodenal stump creation, it is imperative that the patient's nutritional status be assessed both by physical exam and biochemically prior to surgery.
4. The "difficult duodenum," or cases where the duodenum is inflamed, scarred from chronic ulcer disease, or otherwise abnormal, requires thoughtful consideration and distinctive approaches, including Nissen's and Bancroft's closures.
5. Tube duodenostomy can reduce the risk of blowout in appropriate situations, based on surgeon preference and individual circumstances.

Key Points: Diagnosing and Managing Stump Blowout

1. In the appropriate postoperative setting, acute development of fever, tachycardia, marked right upper quadrant abdominal pain, and hemodynamic instability should be considered duodenal stump blowout until proven otherwise.
2. Computed tomography (CT) imaging is the preferred diagnostic study in cases of uncertainty and may reveal a subphrenic or subhepatic fluid collection suggestive of abscess formation.
3. Optimizing medical therapy with fluid resuscitation, antibiotics, and nutritional support greatly enhances the likelihood of successful treatment of duodenal stump leak.
4. With significant advances in imaging technology and greater sophistication of image-guided percutaneous techniques in the current era, radiologic intervention has become the mainstay of therapy for duodenal stump leak.
5. Surgical reoperation should be reserved for the failure of more conservative strategies and may require roux-en-Y duodenojejunostomy or pancreaticoduodenectomy.

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Postoperative Complications After Surgery for Gastric Cancer: Anastomotic Leakage

16

Han J. Bonenkamp

Introduction

Anastomotic leakage after gastric resection is a feared complication. Unfortunately, it is not a rare one, although the reported incidence differs substantially depending on country of surgery, experience of the surgical team, and type of resection. Leakage invariably leads to prolonged hospital stay, and it dramatically increases the risk of dying. Infectious complications after gastrectomy also increase the risk of cancer recurrence [1].

The clinically most important leakages are seen at the esophagojejunal or the gastrojejunal anastomosis. Management of these follows the same principles and these will be discussed here. Leakage from the duodenal stump is a separate and even more dangerous condition, which will be discussed separately.

Incidence

The incidence of anastomotic leakage is probably underestimated. Patients in clinical studies are usually healthier and are being followed more critically than nonstudy patients and anastomotic leakage is expected to be seen less often. On the other hand, prospective series with high incidence rates of leakage are more likely to be subject to publication bias. There are not many data from nationwide, nonclinical surveys, although prospective registration and national clinical audits are being developed in many countries [2].

There are two large, prospective studies with detailed surgical information. Anastomotic leakage occurred in 7% of the patients entered in the Dutch D1–D2 study (1988–1990), 5% after D1 dissection and 9% after D2 dissection [3]. In the British Medical Research Council (MRC) study of D1 and D2 dissection, anastomotic leaks were reported in 6% after D1 surgery and 13% after D2 surgery [4]. In that same time period, anastomotic leaks were seen in 5% of the patients operated in the National Cancer Center Hospital in Tokyo [3]. Hospital mortality was seen in 6.6% in the Dutch study and in 10% in the British study [3, 4]. Most of the patients that died after surgery suffered from complicated intraabdominal abscesses and the majority of these were caused by anastomotic leakage.

A recent (2012) comparison of risk factors after gastrectomy showed that mortality rates in the Netherlands, Britain, Sweden, and Denmark were 6.9, 5.9, 3.5 and 4.3%, respectively [5]. Although details of the hospital courses of these patients were not provided, we may assume that anastomotic leakage was the leading cause of hospital mortality. It seems that the incidence has not decreased much in the past decades. Even the introduction of laparoscopic surgery has not reduced leakage rates. After laparoscopic total

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gastrectomy, complications occurred in 22% of the patients, and 24% (6%) of these were anastomotic leaks [6]. It appears that even in the hands of experienced surgeons and with the help of modern minimally invasive approaches and stapling techniques, anastomotic leakage is still a frequently seen complication. It is not expected that with the increasing age and comorbidities of the average gastric cancer patient, this will change in the near future.

Prospective Factors

Anastomotic leakage is usually an early postoperative event, occurring during the first 7 days after surgery. Directly after surgery, the anastomosis is weaker than the intact surrounding tissues and its strength solely depends on the sutures. This weakness is related to the inflammation taking place as a normal step in wound healing. As soon as proliferation and collagen accumulation starts, the strength of the anastomosis increases, and after 7 days matrix deposition and collagen accumulation restore the initial strength. Even in the absence of known risk factors as diabetes and immunosuppressive medication, this healing process may be impaired by a variety of other factors, although many of these do not stand out as independent prospective factors. Most series on risk factors of anastomotic leak focus on clinical and surgical data, rarely on postoperative medication. Older age, longer operation time, and the amount of blood loss are generally accepted risk factors for anastomotic leakage [7]. Given the impact on inflammation, it is not surprising that common medication as nonsteroidal antiinflammatory drugs (NSAIDs) may impair the healing of an anastomosis as well [8].

Because of the weakness of the anastomosis in the early postoperative phase, many methods for reinforcement have been tried, but neither double-layer manual suturing nor stapling devices with three rows of staples reduce the leakage rate. Sealants (fibrin glue or fibrin-coated patches) are increasingly used to reinforce the anastomosis in the early healing phase. In experimental studies, however, they also do not prevent anastomotic leakage but they actually may increase the risk of developing ileus [9]. Results of large prospective studies on this subject are still awaited.

Detection

Anastomotic leakage may be difficult to detect. In most centers, patients will have a standard X-ray on days 5–7, using gastrografin or a comparable water-soluble contrast agent. The likelihood of detecting a nonclinically apparent leak is low however, and pseudoleaks may occur [10]. Treatment of these "subclinical" leakages is conservative, with cessation of oral intake and intravenous (IV) infusion. Antibiotics are only required if blood cultures become positive, but at that time, the patient has usually become symptomatic.

"Clinical" leakage is associated with typical signs of infection (fever, increasing C-reactive protein (CRP), leukocytosis) and abdominal pain, although leakage of an esophagojejunostomy may cause pulmonary symptoms (shortness of breath, tachycardia, pleural effusion) rather than abdominal pain. In this situation, multislice computed tomography (CT) scan with oral and IV contrast is more sensitive to detect anastomotic leakage than a contrast swallow study. Endoscopic confirmation may be useful for cases where radiological studies are inconclusive and especially if endoscopic treatment is considered. Due to the often poor condition of the patient with a leak and the lack of experience to conduct endoscopy in this setting, this step is often postponed wrongfully.

Clinical signs of anastomotic leakage vary. Fever and leukocytosis from days 3 to 5 are suggestive, but CRP >150 on day 3 may be a more sensitive parameter than leukocytosis [11]. Tachycardia or newly developed atrial fibrillation also suggests an emerging infection, and excluding underlying anastomotic leakage is essential, even in the absence of other signs of infection. Abdominal pain or tenderness may be absent in the early phase, because the anastomosis is usually covered by the liver and the omentum. In any case, leakage with clinical signs is an abdominal emergency and swift management is required.

Differential Diagnosis

Using only clinical parameters and physical examination, it may be difficult to differentiate between an abdominal source and a pulmonary source of infection after gastrectomy. With the widespread use of CT scanning, the site of infection (above or below the diaphragm) is nowadays rarely misdiagnosed. There are, however, many intraabdominal sources for an infection. Especially after total gastrectomy, with clearance of lymph nodes alongside the pancreas, there are at least three anastomoses at risk for leakage, pancreatitis may occur, and even leakage from a feeding jejunostomy site or accidental small intestinal injury may be the source of infection. In most cases, CT scan will accurately detect the cause of the infection and guide further treatment. Diagnostic laparoscopy is rarely needed apart for the treatment of an anastomotic leak after minimally invasive gastrectomy.

General Management

As soon as an abdominal infection is suspected, swift action is required to prevent a fulminant peritonitis. The infection should be managed generally with antibiotics and hemodynamic support. Furthermore, adequate calorie intake should be guaranteed.

Use of antibiotics depends on the local antibiotic guidelines. In our hospital, perioperative antibiotic use is limited to the time of surgery. The most common pathogens in foregut surgery are enteric Gram-negative bacilli and Gram-positive cocci, but anaerobes may be present as well, especially in case of obstruction or tumor invasion of the colon. We use cephazolin and metronidazol prophylaxis 15–30 min prior to incision, and this is stopped after surgery. If a postoperative infection emerges, blood cultures or cultures from a drained abscess guide further antibiotic treatment.

Patients with a severe peritonitis require intensive care support, but in case of a developing infection, this is not necessary. By using an emergency scoring system with a cutoff value for intensive care support (MEWS, modified early warning system), hemodynamic support, and oxygen can usually be provided to the ward.

In abdominal emergencies, enteral feeding is associated with less infectious complications and possibly less mortality than parenteral feeding [12]. We use a percutaneous jejunostomy for early postoperative feeding after total gastrectomy and esophagectomy in all our patients. Alternatively, a nasojejunal tube may be inserted at endoscopy. Parenteral feeding should be reserved for those patients were enteral options fail.

External Drainage

Although anastomotic leaks invariably cause prolonged hospital stay and increase the risk of mortality, the associated morbidity has been diminished substantially because of improved ways of imaging leaks and the increased availability of interventional radiologists. CT imaging can accurately detect leaks or abscesses, and interventional radiologists can drain almost any intraabdominal abscess without the need for general anesthesia. As a consequence, many surgeons have little experience with open drainage procedures. Unfortunately, leakage of an esophagojejunostomy or a subsequent subphrenic abscess is often difficult to drain percutaneously because of interposition of the liver or pleura. In such cases, surgical drainage is still mandatory. The gastrojejunal or the esophagojejunal anastomosis is easily reached through the upper midline incision, because they after situated just beneath the liver edge. After inspection of the anastomosis and nettoyage, a drain can be placed accurately. Since a subhepatic abscess is rarely seen if the falciform hepatic ligament is intact, we prefer to place the drain through the left subphrenic space.

Surgical drainage of a subphrenic abscess or leakage is more difficult and often requires resection of the left 12th rib and opening of the perirenal fatty layer.

Treatment of the Leakage Site

Although abscess drainage may be sufficient treatment in cases where communication with the gastrointestinal tract is minimal, in most patients, this creates an enterocutaneous fistula and the leakage of enteric fluid should be stopped as well. After gastric surgery, leakage of saliva and gastric juice can usually be prevented by nasogastric or nasoesophageal drainage. Only in rare cases cervical esophageal diversion is needed.

Attempts to repair the leakage site during surgery are usually ineffective and may actually increase the risk of postoperative complications. Small leaks do not require repair, and large leaks are often caused by ischemia. In these patients, complete resection of the anastomosis and creation of a new conduit should be postponed until later.

There is increasing expertise with endoscopic treatment of upper gastrointestinal (GI) leakage. Endoscopic clips, fibrin glues, and stents are used frequently, and often successfully [13, 14]. There are, however, no comparative studies of conservative or endoscopic management of esophagojejunal leakage, and there are no clear recommendations for either treatment [15]. Stent placement in a hemodynamically unstable patient may be difficult, although there seems to be no additional perforation risk [16]. Smaller leaks are usually covered easily, but these leaks probably heal with conservative measures as well. In case of a large leak, the stent may not cover all leakage, although additional stent-in-stent procedures have been described. There seems to be no difference between self-expanding wall stents and plastic stents, and the choice for these depends on local availability and expertise [15]. Stent dislocation is a rare but threatening event, and stents need to be removed after 4–6 weeks in order to prevent ischemia and necrosis.

In cases where leakage is confirmed by CT, we will always evaluate the endoscopic options. Small leaks (arbitrarily less than 2 cm) are usually treated conservatively with nasogastric suction, but for larger leaks without signs of ischemia stent placement is first choice. Fibrin glue and endoscopic clips are only used in patients where conservative management was unsuccessful.

Duodenal Stump Leakage

Blowout of the duodenal stump after total gastrectomy is a serious complication. Bile leakage into the peritoneum causes ascites because of a chemical peritonitis. If bacterial contamination is present, this will soon develop into an infectious peritonitis with severe sepsis. Furthermore, bile will activate pancreatic trypsin, which is even more irritating to the peritoneum. Apart from leukocytosis, elevated bilirubin with mildly elevated alkaline phosphotase is a prominent laboratory finding. Ascites and the infiltration of the duodenal stump will be recognized on CT, and as soon as duodenal stump leakage is diagnosed, general treatment of peritonitis with broad spectrum antibiotics and fluid replacement would be started. Because of the irritation of the peritoneum, percutaneous drainage alone is often not sufficient to treat the peritonitis. Furthermore, drainage of the leakage site alone will result in a long-lasting enterocutaneous fistula. Surgical irrigation and drainage should be considered in all patients that fail to improve after initial percutaneous drainage. During surgery, the aboral jejunojejunal anastomosis can be checked for stenosis, since that might be the reason for the blowout of the duodenal stump. Decompression of the duodenum can be achieved by a retrogade drain from the jejunum into the duodenal stump, fixed with Witzel's sutures for easy removal after 4–6 weeks. Together with a drain at the failed stump, this will result in a much quicker healing process.

Summary

Treatment of an anastomotic leakage after gastrectomy requires swift action with antibiotics and hemodynamic support. Detection of the leakage site by multislice CT is reliable, and it guides immediate percutaneous drainage. Surgical drainage is only needed if radiological drainage

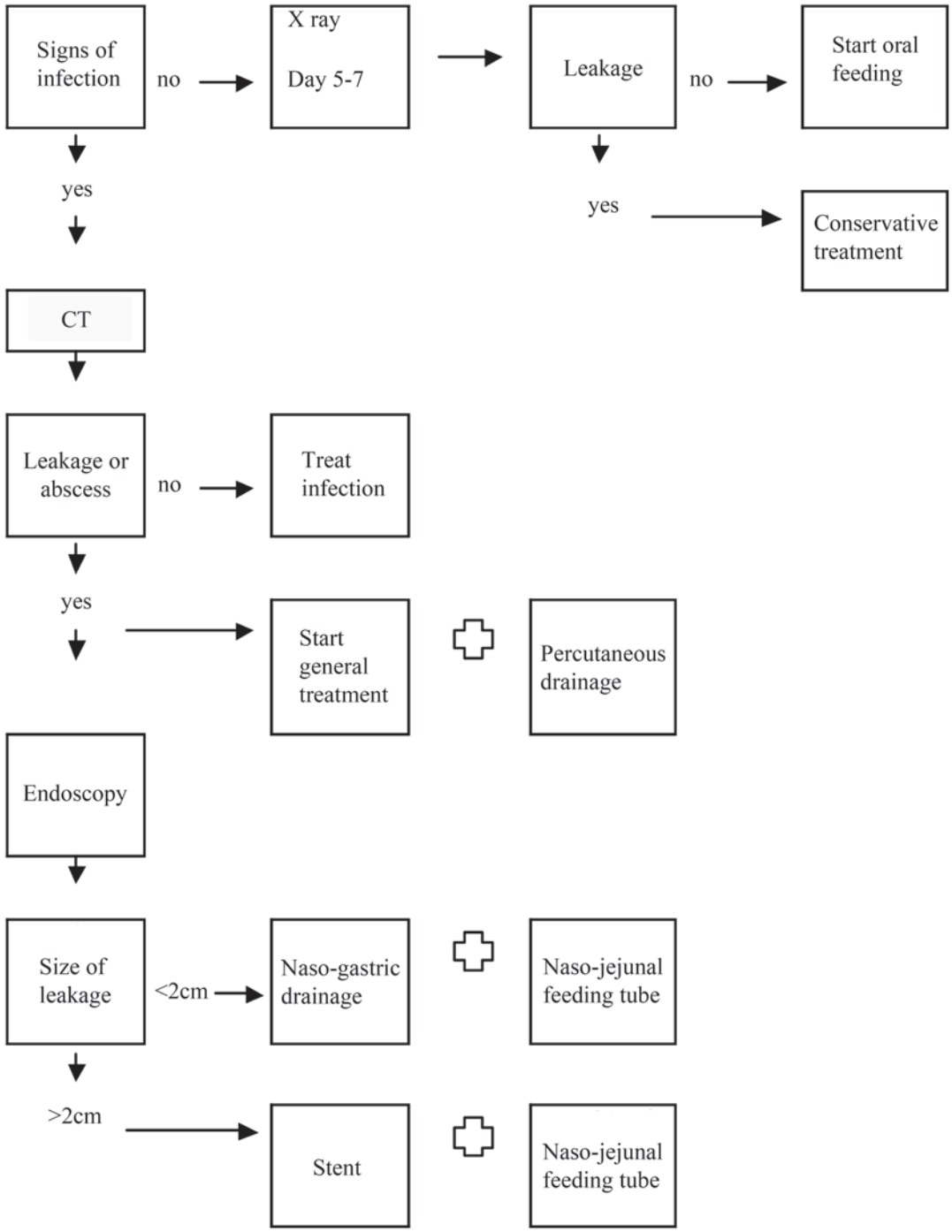

Fig.16.1 Treatment algorithm

is declined due to interposition of other organs. Small leaks may be managed with nasogastric drainage. For larger leaks, temporary endoscopic stent placement is a viable option. A treatment algorithm is shown in Fig. 16.1.

Five Key Points to Avoid Anastomotic Leakage

- Optimize pre- and postoperative calorie intake.
- Correct co-morbidities.
- Make a tension-free anastomosis with vital tissue.
- If the anastomosis is not perfect, redo.
- Avoid postoperative NSAIDs.

Five Key Points to Diagnose and Manage Leakage

- If signs of abdominal infection are seen postoperatively, start general treatment with antibiotics and hemodynamic support and order CT scan with the possibility to drain any leakage or abscess.
- Percutaneous drainage is preferable if technically feasible.
- Duodenal stump leakage requires surgical drainage, abdominal irrigation, and decompression of the duodenum.
- Small anastomotic leaks can be managed with percutaneous drainage and nasoesophageal decompression.
- Large anastomotic leaks may require endoscopic stent placement.

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Part III
Hepatobiliary and Pancreatic Surgery

Postoperative Hepatic Insufficiency

17

Junichi Shindoh and Jean-Nicolas Vauthey

Introduction

With advances in hepatobiliary surgery and perioperative care, the number of patients undergoing major or extended hepatectomy is increasing. In patients for whom these procedures are being considered, the risk of postoperative hepatic insufficiency (PHI) should be carefully assessed. PHI is closely associated with a small future liver remnant (FLR) and the quality of the underlying liver. Consequences of PHI include nonobstructive jaundice, ascites, coagulopathy, and increased susceptibility to complications. Patients with PHI are at high risk of death from liver failure and require prolonged hospitalization. Therefore, assessment of the risk of PHI and prevention of PHI are critical for safe performance of major or extended hepatic resection.

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Definition of PHI

At present, there is no standardized definition of postoperative severe liver dysfunction. The International Study Group of Liver Surgery defined posthepatectomy liver failure as "a postoperative acquired deterioration in the ability of the liver to maintain its synthetic, excretory and detoxifying functions, which are characterized by an increased international normalized ratio and concomitant hyperbilirubinemia on or after postoperative day 5" (Table 17.1) [1]. However, these criteria are complex, partly subjective, and difficult to quantify.

In addition, PHI should sensitively predict postoperative mortality from liver failure. Therefore, the definition of PHI should not include clinical outcomes or ongoing treatment. Among the various definitions of PHI reported in the previous studies, the so-called 50–50 criteria [2] (prothrombin time $<50\%$ and serum bilirubin level >50 μmol/L on postoperative day 5) and our definition of PHI [3] (peak postoperative total bilirubin level >7 mg/dL) are simple and promising objective criteria based on studies including large numbers of patients.

In a multiinstitutional study of 1059 patients without cirrhosis, receiver operating characteristics curve analyses revealed that a peak total bilirubin level of greater than 7 mg/dL was the most sensitive predictor of death from liver failure, with an area under the curve of 0.982 (95% CI, 0.964–0.999) and a cutoff value of 7.0 mg/dL (sensitivity, 93.3%; specificity, 94.3%; accuracy,

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Table 17.1 International Study Group of Liver Surgery grading criteria for posthepatectomy liver failure. (Reprinted with permission from [1] Elsevier 2010)

	Grade A	Grade B	Grade C
Specific treatment	Not required	Fresh frozen plasma	Transfer to intensive care unit
		Albumin	Circulatory support (vasoactive drugs)
		Daily diuretics	Hemodialysis
		Noninvasive ventilation	Intubation and mechanical ventilation
		Transfer to intermediate care unit or intensive care unit	Extracorporeal liver support
			Rescue hepatectomy/liver transplantation
Hepatic function	Adequate coagulation (INR <1.5)	Inadequate coagulation (INR $\geq 1.5, <2.0$)	Inadequate coagulation (INR ≥ 2.0)
	No neurological symptoms	Beginning of neurologic symptoms (i.e., somnolence, confusion)	Severe neurologic symptoms/hepatic encephalopathy
Renal function	Adequate urine output (≥ 0.5 mL/kg/h), BUN <150 mg/dL, no symptoms of uremia	Inadequate urine output (≤ 0.5 mL/kg/h), BUN <150 mg/dL, no symptoms of uremia	Renal dysfunction not manageable with diuretics, BUN ≥ 150 mg/dL, symptoms of uremia
Pulmonary function	Arterial oxygen saturation $>90\%$. May have oxygen supply via nasal cannula or oxygen mask	Arterial oxygen saturation $<90\%$ despite oxygen supply via nasal cannula or oxygen mask	Severe refractory hypoxemia (arterial oxygen saturation $\leq 85\%$ with high fraction of inspired oxygen
Additional evaluation	Not required	Abdominal ultrasonography/CT, chest radiography, sputum, blood, urine culture, brain CT	Abdominal ultrasonography/CT, chest radiography, sputum, blood, urine culture, brain CT, intracranial pressure monitoring device

BUN blood urea nitrogen, *CT* computed tomography, *INR* international normalized ratio

94.3%) (Table 17.2) [3]. In this study, peak total bilirubin level predicted postoperative morbidity (both any morbidity and major morbidity), liver-related mortality, and death from any cause, independent of transfusion status.

Risk Factors for PHI

Reported risk factors for PHI or liver failure are summarized in Table 17.3.

Among the surgery-related factors, small FLR volume is the most important and modifiable factor for patients undergoing extended resection. A strong correlation between small FLR volume and increased risk of PHI is widely recognized, and various FLR volume criteria have been used to select patients who are at high risk of PHI. The poorer the quality of the underlying hepatic parenchyma, the larger the FLR required; therefore, the minimum FLR volume required should be determined according to the status of the underlying liver.

At The University of Texas MD Anderson Cancer Center, we calculate the estimated total liver volume (TLV) using a formula that relies on the linear correlation between the TLV and body surface area (BSA): TLV (cm^3) $= -794.41 + 1267.28 \times$ BSA (m^2) [4]. The standardized FLR (sFLR) is then calculated as the ratio of the FLR volume to the estimated TLV. In a large cohort study seeking optimal cutoff values for minimum sFLR required, it was estimated that for patients with normal underlying liver, sFLR of at least 20% is needed to avoid PHI or death from liver failure [5], while for patients who received

Table 17.2 Diagnostic characteristics of various criteria for predicting liver failure-related death. (Reprinted with permission [3] © Elsevier 2007)

Characteristic	Postoperative peak serum bilirubin level >7.0 mg/dL	Postoperative peak INR >2.0	Postoperative peak serum bilirubin level >7.0 mg/dL and postoperative peak INR >2.0	Prothrombin time <50% and serum bilirubin level >50 μmol/L on postoperative day 5 ("50–50 criteria")
Sensitivity, *n* (%)	28/30 (93.3)	23/30 (76.7)	22/30 (73.3)	14/28 (50.0)
Specificity, *n* (%)	963/1021 (94.3)	828/1010 (82.0)	982/1005 (97.7)	964/997 (96.6)
Positive predictive value (*n*)	0.326 (28/86)	0.112 (23/205)	0.489 (22/45)	0.292 (14/48)
Negative predictive value (*n*)	0.998 (963/965)	0.992 (828/835)	0.992 (982/990)	0.986 (964/978)
Positive likelihood ratio	17.2	4.34	32.6	15.3
Negative likelihood ratio	0.07	0.28	0.27	0.498

INR international normalized ratio

Table 17.3 Risk factors for postoperative hepatic insufficiency. (Reprinted with permission from [31] © John Wiley and Sons)

Surgery related
Small future liver remnant volume
Excessive intraoperative blood loss
Prolonged operating time
Patient related
Preexisting liver disease
Cirrhosis
Steatosis
Cholestasis
Chemotherapy-associated liver damage
Male gender
Advanced age (65 years or older)
Comorbid conditions
Malnutrition
Others
Hepatic parenchymal congestion
Ischemia–reperfusion injury
Infection

extensive chemotherapy (≥3 months) before surgery, sFLR should be at least 30% [6]. For patients with liver cirrhosis, it was reported that sFLR should be 40% or more [7]. Current clinical evidence regarding the sFLR required is summarized in Fig. 17.1.

Another risk factor for PHI is chemotherapy-associated liver damage. Currently, the most common indication for hepatectomy is colorectal liver metastases. Because of advances in effective chemotherapy, the vast majority of patients with colorectal liver metastases are treated with perioperative systemic therapy in combination with surgery. Specific associations between chemotherapy regimens and types of liver injury have been reported. Sinusoidal injury has been associated with oxaliplatin [8, 9], and steatohepatitis has been linked to irinotecan, particularly in patients with high body mass index [10]. In particular, steatohepatitis after major hepatectomy

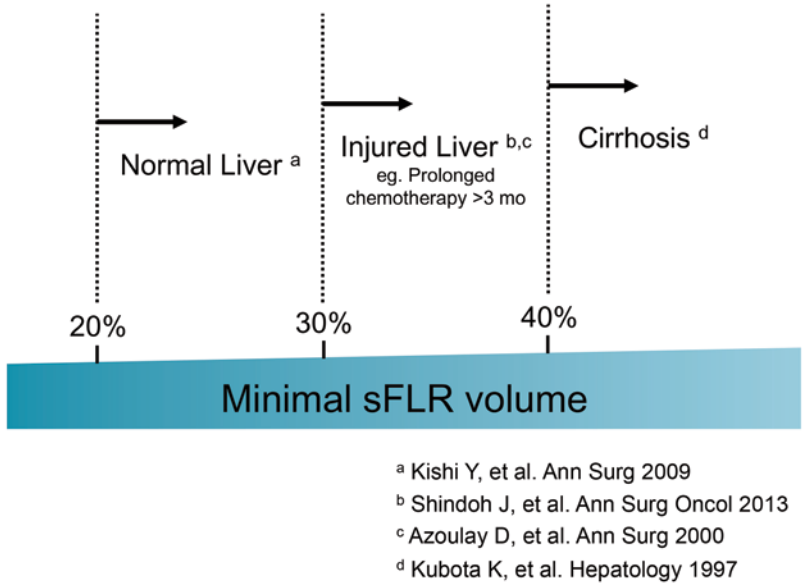

Fig. 17.1 Minimal standardized future liver remnant (sFLR) required to prevent postoperative hepatic insufficiency. (With permission from: *a* [5]©Wolters Kluwer 2009; *b* [29] ©Springer Science and Business Media; *c* [32] ©Wolters Kluwer; *d* [7] ©John Wiley and Sons 1997)

has been correlated with high mortality rates [10]. Chemotherapy-associated liver injuries cannot be accurately predicted, but two factors are known to correlate with increased likelihood of chemotherapy-associated complications: longer duration of preoperative chemotherapy and shorter time interval between the cessation of chemotherapy and surgery. In patients who received chemotherapy for more than 3 months [6], the possibility of hepatic injury should be entertained, and in-depth histopathologic review of the nontumorous liver, volumetry, and laparoscopy should all be considered.

Prevention of PHI

Systematic Volumetry of the "Fully Functioning" Part of the Liver

Volumetry of the liver is essential to assess the risk of PHI. A previous anatomic study revealed that the left lateral bisegments account for only 16% of the total liver volume (Fig. 17.2) [11]. Thus, routine volumetry using an adequate method is recommended, especially in patients undergoing extended right hepatectomy. FLR volume should be defined as the absolute volume of the "fully functioning" part of the liver, in other words, the part of the liver that will have adequate inflow and outflow after hepatectomy. When a hepatic vein draining a specific part of the liver is deprived, the corresponding part of the liver will be congested and will atrophy because of loss of its normal function [12, 13]. A recent study using indocyanine fluorescent technique revealed that portal uptake function in the venoocclusive part of the liver is approximately 40% of that in the nonocclusive part of the liver [14]. However, precise estimation of the volume of the area to be congested is difficult without the use of three-dimensional liver simulation techniques (Fig. 17.3) [15, 16]. Therefore, on volumetry for patients undergoing extended right hepatectomy in which the middle hepatic vein will be deprived, segment IV should not be included in the FLR volume because most of segment IV will be congested and lose its normal function after deprivation of the middle hepatic vein even when part of segment IV is preserved.

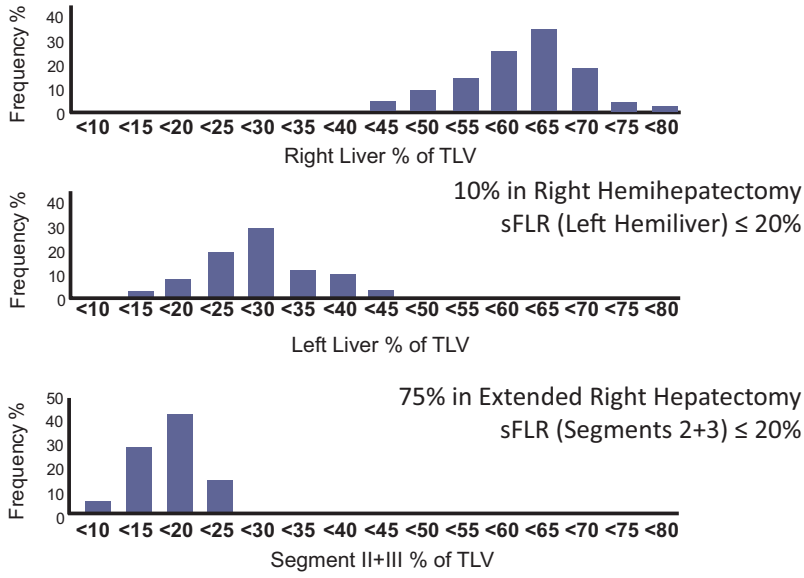

Fig. 17.2 Proportion of total liver volume (*TLV*) contributed by right liver, left liver, and segments II and III. (Adapted with permission from [11] ©Elsevier 2004)

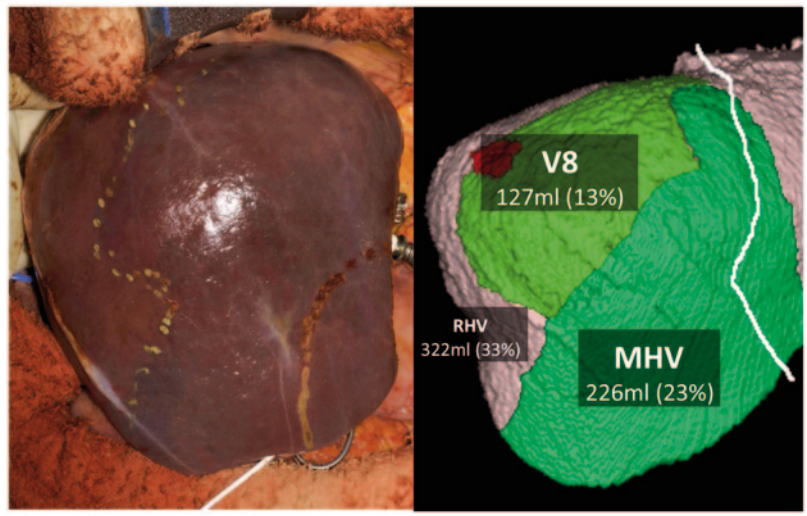

Fig. 17.3 Venous congestion after deprivation of drainage vein during hepatectomy**.** After extended left hepatectomy including the middle hepatic vein, a large part of the right hemiliver is congested (**a**) as predicted on a preoperative three-dimensional simulation (**b**). Normal liver function cannot be expected in the congested part of the liver. Venous reconstruction should be considered when the volume of remaining full-functioning liver is insufficient. *MHV* drainage area of the middle hepatic vein, *RHV* drainage area of the right hepatic vein, *V8* drainage area of the intermediate vein for segment VIII

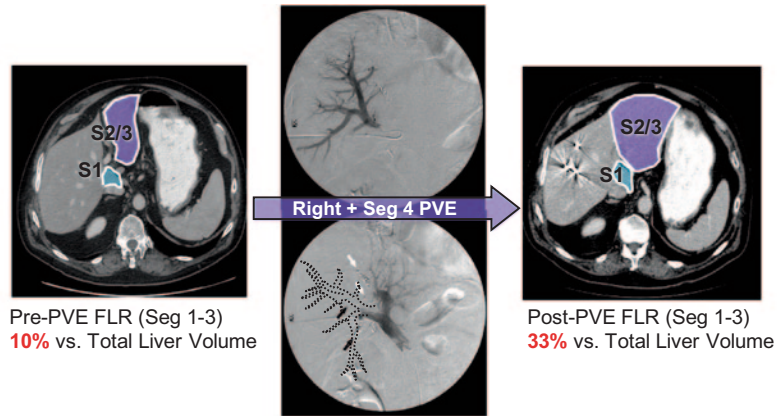

Fig. 17.4 Regeneration of the future liver remnant (*FLR*) after right + segment IV portal vein embolization (*PVE*). *Seg* segment, *S* segment

Portal Vein Embolization

Portal vein embolization (PVE) is a safe, minimally invasive procedure in which the portal branches of the side of the liver to be resected are embolized, leading to atrophy of the side of the liver to be resected and compensatory hypertrophy of the FLR [17–19]. PVE should be considered if pretreatment measurement of the FLR (Fig. 17.1) shows insufficient FLR volume.

Several studies have demonstrated the efficacy of PVE in terms of hepatic functional shift from the embolized liver to the FLR and reduction of surgical risk. First, dynamic functional shift from the embolized liver to the FLR after PVE was confirmed by three studies using indocyanine green excretion rate [20], technetium Tc-99m galactosyl human serum albumin scintigraphy [21], and bile clearance [22]. These three studies indicated that PVE produced a clear functional shift from the embolized liver to the nonembolized FLR with a concomitant increase in FLR volume. In addition, another study showed that when patients achieved sufficient growth of the FLR to meet the minimum criteria for FLR volume, operative risk was significantly reduced compared to the risk in patients who did not meet the minimum criteria for FLR volume after PVE [5]. To maximize regeneration of the FLR after PVE, optimal selection of embolic materials [23] and concurrent embolization of segment IV portal vein [24, 25] have been recommended. Our previous work comparing right PVE with and without segment IV embolization revealed a significantly greater increase in volume in segments II + III with segment IV embolization (median increase, 26 vs. 54 %; $p = 0.021$) (Fig. 17.4).

Post-PVE sFLR is a sensitive predictor of PHI. In addition, Ribero et al. reported that degree of hypertrophy in the sFLR after PVE is significantly associated with surgical outcomes [26]. Degree of hypertrophy greater than 5 % after PVE along with sFLR greater than 20 % predicted good postoperative outcomes with high specificity and sensitivity in patients with normal liver function. Our group has recently found that kinetic growth rate, defined as the degree of hypertrophy at initial volume assessment divided by the number of weeks elapsed between PVE and initial volume assessment, further predicted the risk of PHI. Kinetic growth rate greater than 2.0 % per week is strongly associated with a low risk of postoperative morbidity and mortality irrespective of the sFLR (Fig. 17.5) [27].

Recently, a European group reported safety and efficacy data for a short-interval, two-stage liver surgery technique consisting of an initial open right portal vein ligation with in situ splitting of the liver parenchyma followed by reexploration for right trisectionectomy, termed "associating liver partition and portal vein ligation for staged hepatectomy" or "ALPPS" [28].

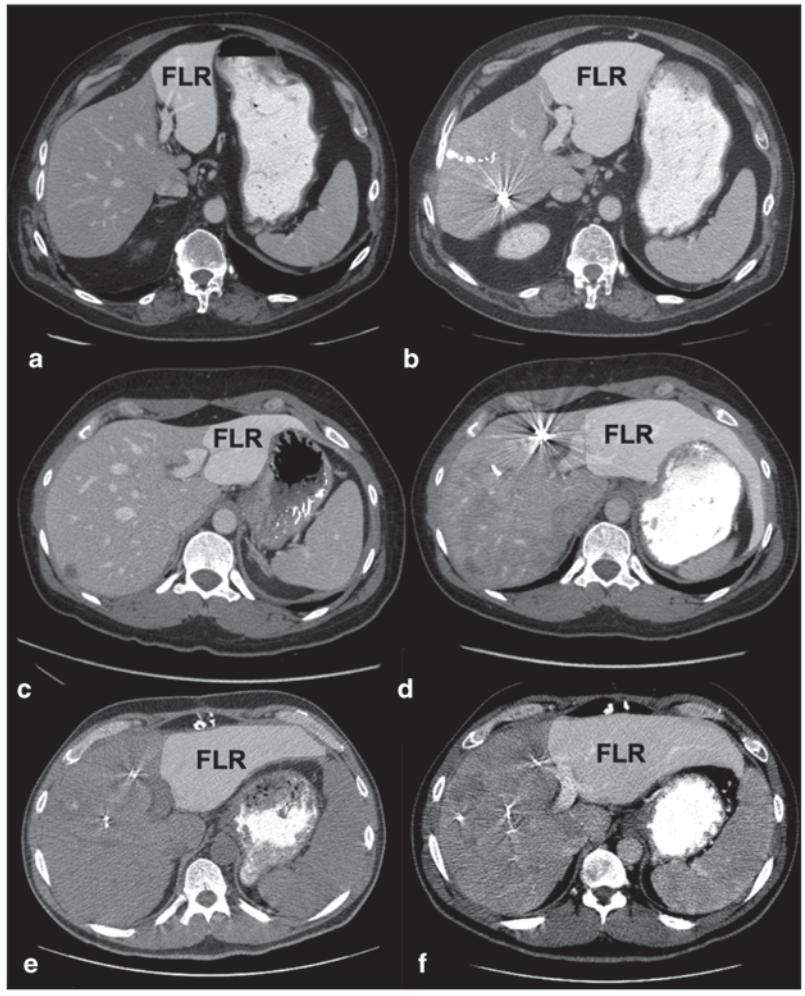

Fig. 17.5 Examples of the clinical utility of kinetic growth rate (KGR). All patients had standardized future liver remnant (*sFLR*) ≥30% and degree of hypertrophy (DH) ≥7.5% (suggested eligibility criteria for resection); however, KGR was a more accurate predictor of outcome. A/B: Findings in a 60-year-old man. **a** On the basis of the initial computed tomography (CT) scan, sFLR was estimated at 9%. **b** Final CT 35 days after right portal vein embolization (PVE) extended to segment IV indicated an sFLR of 33%, DH of 24%, and KGR of 4.8% per week. The patient had an uneventful postoperative course. C/D: Findings in a 37-year-old woman. **c** On the basis of the initial CT scan, sFLR was estimated at 15%. **d** Final CT 35 days after right PVE extended to segment IV indicated an sFLR of 30%, DH of 15%, and KGR of 3.0% per week. The patient had an uneventful postoperative course. E/F: Findings in a 43-year-old man. **e** On the basis of the initial CT scan, sFLR was estimated at 23%. **f** Final CT 70 days after right PVE extended to segment IV (required additional waiting time to attain adequate remnant volume) indicated an sFLR of 31%, DH of 8%, and KGR of 0.3% per week (determined after the first CT 28 days after PVE). The patient died of postoperative liver failure. (Source: Reprinted with permission [27] ©Elsevier 2013)

The combination of portal vein ligation and in situ splitting of the liver to prevent crossportal circulation between the lobes of the liver was believed to lead to profound hypertrophy of the FLR. However, preliminary data suggested that this new procedure was associated with a high incidence of major morbidity (40%) and inpatient mortality (12%). The true efficacy of ALPPS in the prevention of PHI remains controversial, and this procedure should be considered investigational at this time.

Limiting the Duration of Preoperative Chemotherapy

Longer duration of chemotherapy has been correlated with higher risk of liver damage, as mentioned previously [6]. We previously showed that prolonged chemotherapy did not improve the response rate but did increase the risk of PHI among patients with colorectal liver metastases [8]. In a recent study investigating the relationship between duration of chemotherapy and the incidence of PHI according to FLR volume, we have shown that short-duration modern chemotherapy (up to 3 months or six cycles) with or without biologic agents does not increase the risk of PHI even in patients with marginal sFLR (i.e., 20−30%), whereas when the patient has a history of prolonged chemotherapy prior to surgery, sFLR should be at least 30% [29]. Therefore, the duration of preoperative chemotherapy should be minimized among patients with potentially resectable colorectal liver metastases.

Treatment of PHI

Because clinical manifestations and severity of PHI or liver failure vary considerably from patient to patient, treatment for PHI or liver failure should be individualized according to the patient's degree of functional disturbance with respect to circulation, renal function, pulmonary function, coagulation, and mental status influenced by hyperammonemia. Plasma exchange with or without continuous hemodiafiltration is the only effective therapy for patients suffering from severe liver failure, though whether this therapy improves survival has not been established [30]. For selected patients, rescue liver transplantation is another option. However, comorbid conditions and underlying malignant disease (even if it is resected) frequently preclude rescue liver transplantation. In addition, given the chronic shortage of liver donors, it is not ethical to perform extensive hepatectomy in a patient with a high risk of PHI or liver failure and assume that rescue liver transplantation will be an option if serious complications occur. Preoperative risk assessment and prevention of PHI are paramount in the current extensive surgical approach to hepatobiliary malignancies.

Conclusion

The risk of postoperative mortality due to liver failure is inversely associated with the quality of the underlying liver parenchyma and the volume of the FLR. The risk of PHI, which is a strong predictor of liver-related death, should be assessed by routine systematic volumetry in patients for whom major hepatectomy is being considered. If pretreatment measurement of the FLR shows insufficient FLR volume, adequate preoperative management including PVE should be added to avoid preventable morbidity or mortality after extensive hepatobiliary surgery.

Key Points

1. Postoperative serum peak bilirubin level of greater than 7.0 mg/dL is a simple and reliable definition of PHI, predicting morbidity and death from liver failure with high sensitivity and specificity.
2. FLR volume is a strong predictor of PHI and death from liver failure. The minimum FLR volume required should be determined according to the quality of the underlying liver parenchyma.
3. PVE is a safe and minimally invasive procedure that results in hypertrophy of the FLR and decreases the risk of PHI. PVE should be considered for patients with insufficient FLR volume.
4. Prolonged preoperative chemotherapy (>3 months) is associated with increased risk of PHI. The possibility of liver damage should be carefully considered in patients with a history of prolonged chemotherapy prior to surgery. Biopsy of the nontumorous liver parenchyma should be considered in selected patients.
5. Because of the limited availability of effective treatment for severe liver dysfunction,

prevention of PHI using systematic volumetry and adequate preoperative management is paramount in the surgical approach to hepatobiliary malignancies.

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Biliary Leaks and Thoracobiliary Fistula

18

Kengo Asai and David M. Nagorney

Introduction

The potential for a biliary leak and fistula exists whenever procedures are performed on the biliary tract. These procedures include a wide range of operations that may be performed by the general or hepatopancreaticobiliary surgeon. Laparoscopic cholecystectomies to more complex procedures such as liver and bile duct resections and pancreaticoduodenectomy all have an associated risk of biliary leakage. A persistent biliary leak can be a significant source of postoperative morbidity, has been associated with increased mortality, and in the setting of malignancy may affect survival. Thus, an understanding of the risk factors, diagnosis, prevention, and management of biliary leaks is relevant for any surgeon undertaking procedures of the biliary tract.

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Definitions

Biliary Leak and Grading System

Multiple definitions of a postoperative biliary leak exist in the literature. Most definitions of biliary leak require a measured volume of bilious output, typically ranging from 20 to 50 mL/day, or a concentration of bilirubin, ranging from 5 to 20 mg/dL, in the drain effluent [1]. Drainage from a biloma (contained) or bile peritonitis (uncontained) is also consistent with a biliary leak. Because of the lack of a uniform definition for biliary leak in the literature, the International Study Group of Liver Surgery (ISGLS) proposed a formal definition and grading system in 2011 [1]. The ISGLS defines a biliary leak as a bilirubin concentration in the drain fluid at least three-times the serum bilirubin concentration on or after postoperative day 3. This classification scheme is applicable to radiologic or operative procedures for bilomas or bile peritonitis as well. Drain volume was not included because the presence of ascites and lymphatic leaks confounds accurate measurement. However, most authors suggest a volume of output greater than 100–200 cc/day as sufficient to warrant intervention [2].

The ISGLS also proposed a grading system to stratify the severity of the biliary leak. Grade A biliary leaks do not affect clinical management (Table 18.1). Grade B biliary leaks require active therapeutic intervention either radiographically or endoscopically, and Grade C biliary leaks require operative intervention. Biliary leaks may

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Table 18.1 ISGLS biliary leak grading system

Grade	Change in clinical management
A	No or minimal
B	Radiographic or endoscopic intervention or Grade A for >1 week
C	Operative intervention

Biliary leak defined as bilirubin concentration 3 × serum bilirubin on or after postoperative day 3 or if procedure performed to manage leak
ISGLS International Study Group of Livery Surgery

resolve or persist. Uncontained or persistent biliary leaks that require additional intervention to control are labeled Grade B or C. A precise definition for persistent bile leak has not been established. However, the ISGLS classified a biliary leak that persists for >1 week as Grade B. Given its relatively recent publication, the proposed definitions and grading system of a biliary leak have not been validated widely.

Controlled and Uncontrolled Biliary Leaks

A controlled biliary leak occurs when there is no communication with an intraperitoneal collection. In contrast, an uncontrolled biliary leak communicates with an intraperitoneal collection or flows freely throughout the peritoneal cavity. An uncontrolled biliary leak generally requires further drainage or manipulation of extant drains to establish control and prevent secondary infection.

Source

The source of the biliary leak can either arise from an incomplete division or disrupted side branch of the involved duct that is contiguous or communicates with that duct distally or a complete division of the involved duct that becomes discontiguous and does not communicate with that duct distally. The former sources are likely to resolve without operative intervention while the latter typically require such intervention. Discontiguous ductal injuries from an entire liver segment or more that lack communication with the central biliary tree are also termed excluded or orphan leaks [3]. These biliary leaks generally persist because the parenchyma harboring that duct maintains its vascularity. A classic example of this biliary leak would be a divided right segmental or sectional biliary duct after laparoscopic cholecystectomy. Regardless, the source of the biliary leak has implications on its diagnosis and management.

Risk Factors and Prevention

Risk factors and prevention of biliary leaks from the extrahepatic biliary system during laparoscopic cholecystectomy and bilioenteric anastomoses will be followed by discussion of bile leaks following hepatic resection.

Biliary leaks after laparoscopic cholecystectomy is estimated at 0.3–0.5 % [4]. Given the large number of cholecystectomies performed annually, this operation is associated most commonly with biliary leaks. The cystic duct stump, ducts of Luschka, other ducts in the gallbladder fossa, and major extrahepatic bile ducts comprise the potential sites of biliary leakage. The cystic duct stump represents the most common site of leak and reported risk factors include emergency surgery, incomplete or disrupted closure of the cystic duct, width and degree of inflammation of the cystic duct, and presence of common bile duct stones [5, 6]. The risk factors for biliary leaks related to major bile duct injury and classification of biliary injury following cholecystectomy have been reported previously and a complete discussion is beyond the scope of this chapter [7]. Commonly cited factors include operator inexperience and technical errors, inflammation, and most importantly anatomic misidentification of the extrahepatic bile duct.

Prevention

To prevent cystic duct stump leaks, one must ensure the cystic duct stump is appropriately identified and secured. A variety of methods of securing the cystic duct stump have been described. These include use of titanium clips, locking clips, harmonic scalpel, suture ligature, and endovascular stapling devices. There is no evidence-based data to suggest that any one method is vastly superior. The technique used should ensure that the clip or device is securely fastened, will not be dislodged, and should span the entire cystic duct. The cystic duct wall must be vascularized and free of significant inflammation. For a wide cystic duct, additional clips, ligature, or an endovascular stapler may be used after confirming the anatomy. Cautery injury proximal to the site of ligation should be avoided by careful dissection and use of cautery. Gentle traction should be used to avoid avulsion of the cystic duct from the common hepatic duct. Leakage from ducts of Luschka or from the fossa is likely related to dissection into the liver parenchyma. Efforts to stay in the correct plane and ligation of accessory ducts entering the gallbladder from the fossa should decrease peripheral biliary leaks. Preventing biliary leaks from major bile duct injuries requires correct identification of the anatomy. The critical view of safety in which the cystic duct and cystic artery are isolated and the cystic plate is exposed has been shown to decrease the rate of major biliary injuries [8]. The role of routine cholangiography to prevent injury is controversial [9]. Clearly cholangiography can define anatomy and unsuspected injury intraoperatively. Selective intraoperative cholangiography based on operative conditions and lack of anatomic clarity is utilized most frequently but such use does not address misidentification errors.

Risk Factors for Bile Leaks After Extrahepatic Bilioenteric Anastomosis

Excluding the transplant population, few studies have investigated risk factors for biliary leaks after bilioenteric anastomoses. Biliary reconstruction to the small bowel is undertaken through Roux-en-Y hepaticojejunostomy or hepatico- or choledochoduodenostomy. Typically, Roux-en-Y hepaticojejunostomy is favored because anastomotic leaks actually represent a pure biliary fistula as reflux of enteric content through the fistula is rare with appropriate length of construction of the Roux limb. In contrast, biliary anastomoses to the duodenum are not pure biliary fistulae because gastroduodenal contents are constantly exposed to the fistula site and comprise part of the effluent. The volume and contents of the effluent from these biliary leaks likely contribute to their severity. Roux-en-Y hepaticojejunostomy is the most versatile biliary reconstruction method. It can be used in any operation after transection of the extrahepatic bile duct. In a review of 519 hepaticojejunostomies performed for a wide range of indications including pancreatic cancer, chronic pancreatitis, cholangiocarcinoma, and transplantation, bile leaks occurred in 5.6% of patients [10]. Independent risk factors for leakage were preoperative radiochemotherapy, preoperative low cholinesterase levels, simultaneous liver resection, and reoperation after liver transplant. Another high-volume center reported hepaticojejunostomy leak rates of 2.2% after pancreaticoduodenectomy [11]. The only risk factor identified was a low preoperative albumin.

Hepatico- or choledochoduodenostomy either in an end-to-side or side-to-side fashion can be used in the setting of biliary calculus, strictures, bile duct cysts, and malignancy. Concerns about choledochoduodenostomy include sump syndrome and potential for duodenal fistula in the event of anastomotic leak. Sump syndrome can occur with side-to-side choledochoduodenostomy with the accumulation of debris in the distal blind end of the bile duct. One recent retrospective study demonstrated fewer anastomotic complications when the duodenum was used for biliary reconstruction [12] and no difference in frequency of biliary fistulae following end-to-side choledochoduodenostomy (8%) when compared with Roux-en-Y jejunal reconstruction (16%). It should be noted, however, that Roux-en-Y was used more frequently when the reconstruction

was above the confluence. In another retrospective review from India, 270 patients underwent side-to-side choledochoduodenostomy with a biliary leak documented in 2% of patients [13]. Sump syndrome was not observed in any of these patients, the majority of whom underwent preoperative endoscopic retrograde cholangiography (ERC) and papillotomy. While retrospective, these studies suggest the frequency of biliary leaks may be comparable to Roux-en-Y reconstruction with low incidence of sump syndrome.

Choledochocholedochostomy is primarily used in the setting of orthotopic liver transplantation (OLT), but has also been described in the repair of bile duct injuries. In general, end-to-end choledochocholedochostomy has not been favored for repair of iatrogenic bile duct injuries given concern for subsequent stricture formation [14]). Limited data exist to support this technique outside of transplant. One retrospective study comparing Roux-Y hepaticojejunostomy with end-to-end reconstruction in 94 patients demonstrated similar rates of biliary leaks and bilomas (10 and 7% respectively) [15]. End–end reconstruction was used with ducts greater than 4 mm in diameter in the absence of inflammation. With a mean long-term follow-up of 62 months, no significant difference in strictures was identified.

In contrast to bile duct injuries, choledochocholedochostomy is commonly used in orthotopic liver transplantation. A recent systematic review of over 11,000 orthotopic liver transplants documented biliary leaks in 8% of cases [16]. The use of T-tubes to reduce biliary complications remains an area of debate. Numerous prospective randomized trials have been performed to address this issue with conflicting results [17]. Many centers have abandoned routine use of T-tubes given the evidence from several prospective randomized trials indicating the anastomoses can be performed with similar or lower rates of strictures and biliary leaks. Indeed, in the systematic review by Akamatsu et al., 82% of over 6000 deceased donor liver transplantations with duct-to-duct anastomoses were performed without a T-tube. In contrast, many centers continue to use splinting stents for biliary reconstruction during live donor liver transplantation, and use of a transcystic stent for biliary reconstruction during OLT has also been described [18].

Prevention

Specific criteria for optimal construction of bilioenteric anastomoses are sparse and techniques vary widely. Primary recommendations for prevention of biliary leaks after bilioenteric anastomoses are (1) well-vascularized bile duct, (2) absence of cholangitis and inflammation of the bile duct, (3) tension-free anastomosis, (4) well-vascularized duodenum or jejunum, and (5) atraumatic suture placement. For dilated bile ducts, a single running layer of absorbable monofilament suture is effective and efficient. For nondilated ducts or for complex biliary anastomoses involving multiple ducts, interrupted absorbable sutures are used. If multiple duct orifices are present, adjacent ducts can be joined with interrupted absorbable sutures to reduce the number of bilioenteric anastomoses. Biliary stenting to bridge the bilioenteric anastomosis has not been shown to reduce biliary leaks after biliary reconstruction. Stents, however, may be indicated to bridge anastomoses after R1–2 resection to ensure biliary access for subsequent intraluminal therapy or dilatation.

Risk Factors for Bile Leak After Liver Resection

Risk factors for biliary leak after hepatic resection have been confounded by the lack of uniform definition of biliary leak in the literature. Several recent studies have retrospectively investigated the incidence and risk factors for biliary leaks. In a review of 2628 consecutive resections, preoperative jaundice, portal vein embolization, liver resection for biliary tumors, repeat hepatectomy, extended hepatectomy, caudate resection, two-staged resection, en bloc diaphragm resection, bile duct resection and reconstruction, longer operative duration, greater estimated blood loss (EBL), larger tumors, portal lymph node dissection, and intraoperative transfusion were risk

factors for biliary leak on univariable analysis [19]. Of these factors, repeat hepatectomy, bile duct resection, intraoperative transfusion, en bloc diaphragm resection and extended hepatectomy were found to be independent predictors for biliary leak on multivariable analysis. It is unclear whether factors such as increased blood loss or intraoperative transfusion are simply surrogates for increased operative complexity or directly affect biliary leaks.

In another study of 505 consecutive liver resections without bile duct resection, biliary leaks were identified in 6.7% of patients. Multivariable analysis identified repeat hepatectomy, a large cut surface area, and intraoperative blood loss as independent predictors for biliary leaks [20]. In 610 patients undergoing liver resection without bile duct resection, peripheral cholangiocarcinoma, left hepatectomy including segment 1, transection plane outside of the main portal scissure, and hepatectomies including the caudate or segment four were independent predictors of biliary leakage. On multivariable analysis, peripheral cholangiocarcinoma and resection of segment 4 were risk factors for bile leaks. Use of fibrin glue and cirrhosis were found to decrease the incidence of leaks [21].

Collectively, these studies suggest that complex liver resections involving the caudate, extended hepatectomy, and increased blood loss increase the risk for biliary leak and may warrant additional methods to assess for biliostasis intraoperatively.

Prevention of Biliary Leaks After Hepatectomy

Apart from intraoperative blood loss and transfusion, most identified risk factors are not modifiable. Techniques used to reduce intraoperative blood loss and transfusion requirements include use of intermittent inflow occlusion, low central venous pressure, and meticulous hemostatic technique. A variety of parenchymal transection techniques have been described. These include the clamp crush, Cavitron ultrasonic surgical aspirator (CUSA-Tyco Healthcare, Mansfield, MA), water-jet dissection, stapling devices, and energy devices, e.g., Ligasure (Valleylab, Tyco Healthcare, Boulder, CO, USA), Harmonic scalpel (Ethicon Endosurgery, Cincinnati, OH, USA), TissueLink (Salient Surgical Technologies, Portsmouth, NH). No parenchymal transection method has been shown superior in reducing the rate of biliary leaks. One randomized control trial assessing the impact of parenchymal transection technique in 120 patients who were allocated to either clamp crushing or Ligasure showed no difference in biliary leak between groups [22]. A retrospective analysis of 141 patients undergoing hepatic resection without bilioenteric anastomosis compared clamp crushing, stapling, and Tissuelink with no difference in the rate of biliary leakage [23]. Among 300 patients undergoing stapler hepatectomy, the incidence of biliary leak was 8% and was claimed to be comparable to other parenchymal transection techniques [24]. For open or laparoscopic hepatectomy, identification and stapling transection of lobar, sectional, or segmental biliary duct provide secure closure. Minor or intrasegmental biliary ducts are secured with clips or suture ligature. Transection methods should avoid trauma to the hilar ducts that can predispose to late leaks. Laparoscopic hepatic resections utilize the Harmonic scalpel and endovascular staplers. The former technology likely fuses small ductules; however, conflicting data exist on the incidence of biliary leaks ranging from 24 to 1% [25, 26].

Intraoperative Tests for Bile Leaks

A variety of methods have been used to detect biliary leaks intraoperatively. A simple method to assess for biliary leaks is to place a white surgical sponge on the cut surface to detect bile staining. Identified sites of bile leakage are oversewn with suture. However, this method is dependent upon bile flow. Evacuation of bile from the biliary ducts intraoperatively may lead to falsely negative findings. Other intraoperative biliary leak tests utilize perfusion of the ducts. These methods include the injection of saline, methylene blue, or indocyanine green retrograde through the

cystic duct [27]. The efficacy of these intraoperative tests remains unclear. One randomized trial of 103 consecutive patients undergoing hepatic resection without biliary enteric anastomosis showed no difference in bile leaks when isotonic saline was injected through the cystic duct [28]. Another report indicated decreased incidence of bile leaks with indocyanine green and fluorescent cholangiography in 102 randomized patients [29]. Finally, a recent report of 223 patients, half of which underwent an intraoperative air leak test by introduction of air through a transcystic cholangiogram catheter, demonstrated a reduction in biliary leaks from 10 to 1.9% [19]. Further validation of various techniques and comparative trials will be required to confirm optimal.

Postoperative Drains

The role of postoperative drains after hepatic resection remains controversial. Proponents claim that drains are infrequently the source of morbidity and, if appropriately positioned and of appropriate type, control biliary leaks. Conversely, opponents claim drains are unnecessary given the low frequency of biliary leaks and can cause morbidity, specifically surgical site infection, biliary erosion, and leak or inadequate biliary leak control if present. Many centers place drains prophylactically at the parenchymal transection site. Some evidence suggests that routine placement of drains is unnecessary and may be associated with increased infection [30, 31]. In the largest series, an audit of over 1000 liver resections failed to demonstrate increased morbidity in the 80% of patients who were not drained. Intraoperative drains were placed if patients underwent a simultaneous thoracotomy, an uncontrolled bile leak was encountered, bilioenteric anastomosis was performed, or if the field was infected. A metaanalysis did not demonstrate a statistically significant difference in rate of biliary fistula, reoperation, intraabdominal collections requiring aspiration or drainage, with or without an operatively placed drain [32]. Minor liver resections are drained rarely. Biliary reconstruction combined with major hepatectomy, and major resections leaving a large cut surface are drained.

Diagnosis

The diagnosis of a biliary leak is generally straightforward if an operative drain was placed and it communicates with the site of bile leakage. In general, inspection of the effluent is confirmatory of a biliary leak. If diagnostic uncertainty exists, analysis of bilirubin concentration is performed. If a drain was not placed or does not communicate with the site of leakage, patients may present with signs of systemic inflammatory response (fever, tachycardia, tachypnea, leukocytosis), localized abdominal pain, expression of bilious fluid from the incision, or more subtle findings such as delayed gastric emptying or ileus. Suspicion for a biliary leak should be raised in the setting of an unexplained leukocytosis or increase in bilirubin in the postoperative period. In this setting, an ultrasound or contrast-enhanced computed tomography (CT) scan may demonstrate the presence of perihepatic fluid collections. Image-guided drain placement with bilious output is generally diagnostic of a biliary leak.

Investigations

A number of imaging modalities are used to evaluate biliary leaks. These include abdominal ultrasonography (US), CT scan, fistulogram/sinogram, magnetic resonance cholangiography (MRC), ERC, and percutaneous hepatic cholangiography (PTC). Hepatobiliary iminodiacetic acid (HIDA) scans, though used, rarely provide useful anatomic information.

Ultrasonography or CT Scan

When a biliary leak is suspected, abdominal ultrasonography or crosssectional imaging is recommended. Initially, a noninvasive imaging modality is used to detect an undrained collection and may provide clues to the origin of the leak

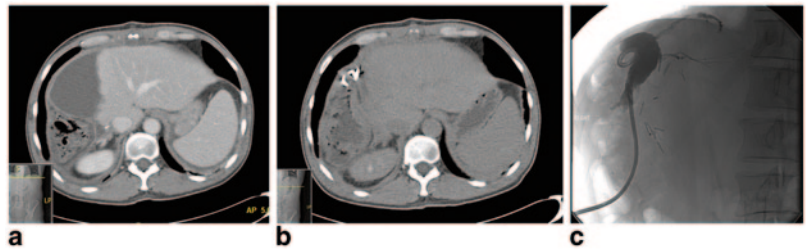

Fig. 18.1 **a** CT abdomen demonstrates perihepatic fluid collection after right hepatectomy. **b** CT-guided percutaneous drain placement of biloma. **c** Sinogram demonstrates opacification of a cavity communicating with the biliary tree

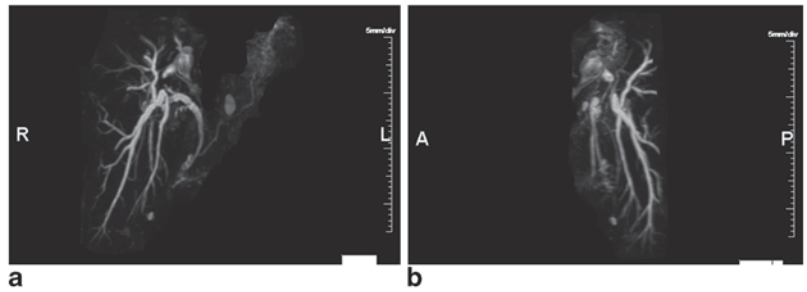

Fig. 18.2 Magnetic resonance cholangiography. **a** Moderate dilation of the right posterior sectoral ducts after left hepatectomy. **b** Rotation demonstrates separation of the right posterior duct from common hepatic duct

(Fig. 18.1). Identification of biliary dilatation and assessment for concomitant vascular injury are also important.

Fistulogram

If bile is present in the drain, a fistulogram can reveal the source of the bile leak. Injection of contrast through the drain and subsequent opacification of the communicating area of the biliary tract allows definition of anatomy and guides subsequent management (Fig. 18.1c). Fistulography also allows assessment of the adjacent area or collection and whether or not biliary obstruction distal to the site of leakage exists.

MRC, ERC, and PTC

MRC is a noninvasive method of assessing the biliary tract. It can clearly display the anatomy and is useful for identifying strictures, biliary dilation, and isolated segments (Fig. 18.2). Potential limitations include obscured images secondary to surgical clips, cost, motion artifact, claustrophobia, and lack of interventional capability. ERC is a direct cholangiographic method that has the advantage of clearly displaying the anatomy, identifies leaks from the central ducts, and is potentially therapeutic. Disadvantages include post-ERC pancreatitis, inability to access the biliary system with altered postoperative anatomy (e.g., Roux-en-Y), inability to identify leaks disconnected from the main biliary tree or after complete bile duct transection and infection. A biliary leak demonstrating an otherwise normal biliary tree by ERC is diagnostic of an excluded segment. PTC has similar advantages to ERC in that it can be used both as a diagnostic and therapeutic tool. It is particularly valuable when the site of biliary leak does not communicate with the central bile duct and therefore inaccessible by ERC (Fig. 18.3). It is not our preferred initial investigation because of its invasive nature.

HIDA

The injection of Tc99-labeled HIDA, which is secreted into the biliary tract has been used to diagnose biliary leaks. The appearance of the labeled dye outside of the biliary or gastrointestinal tract is diagnostic. However, the limitation of the

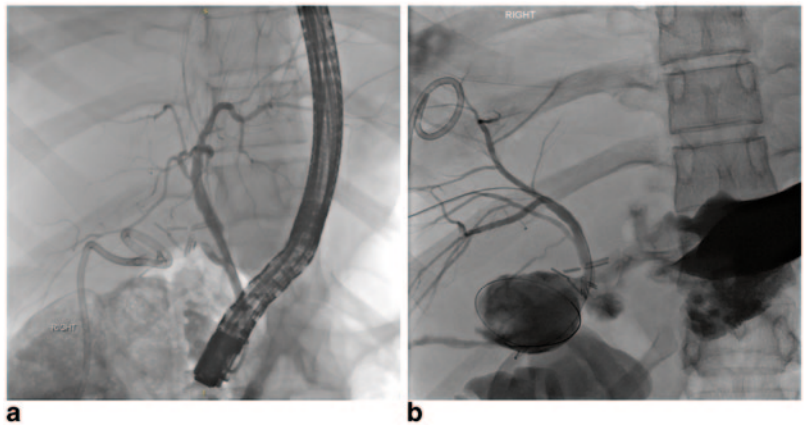

Fig. 18.3 **a** Endoscopic retrograde cholangiography—demonstrates right anterior and left ductal systems. **b** Percutaneous transhepatic cholangiography—demonstrates right posterior ductal system

study is that it is often difficult to determine the site of leakage. Also, unlike ERC or PTC it lacks therapeutic capability.

Management

The underlying principles for the management of a biliary leak are to achieve source control with adequate drainage, determine the anatomy of the leak to guide further treatment, and assess for distal obstruction. Many biliary leaks resolve with conservative measures. However, few studies identify risk factors for failure of conservative management. In one retrospective review of over 500 patients undergoing hepatic resections without bilioenteric anastomosis, 76 % of biliary leaks resolved with conservative management in a median time of 15 days [33]. On multivariable analysis, drainage of greater than 100 mL/day on day 10 was the only independent predictor of failure of conservative management. Depending on the location of the leak endoscopic, interventional radiology or operative techniques may be required for resolution.

Medical Management

Patients with biliary leaks and associated signs of infection require antibiotics covering Gram-negative and anaerobic organisms. Sepsis must be controlled prior to cholangiography and ductal intervention. The use of octreotide for the treatment of biliary fistula has been described in a limited number of patients [34]. It may decrease the volume of bile secreted, but whether fistula closure is promoted remains unclear. Most surgeons consider octreotide as an adjunct for the treatment of biliary fistula given the effectiveness of endoscopic, interventional, and operative approaches. In addition to treatment of infection, ensuring adequate nutrition, replacement of fat-soluble vitamins, and correction of electrolyte abnormalities are important components of the medical management of biliary fistula [2].

Endoscopic Management

ERC can identify the site of the biliary leak and concurrently direct therapeutic stenting of the biliary tree. Examples of therapy include sphincterotomy, indwelling biliary stent placement with or without sphincterotomy, and insertion of a nasobiliary tube. The principle behind endoscopic drainage is to decrease intraductal pressure to allow preferential flow into the small bowel rather than from the leak. The ability to bridge the actual site of biliary injury is another advantage. ERC is highly effective for postcholecystectomy bile leaks with reported efficacy of up to 100 % [35] as well as for bile leaks following hepatic resection for polycystic disease [36]. Nasobiliary drains avoid the need for a repeat ERC for stent removal but can be uncomfortable

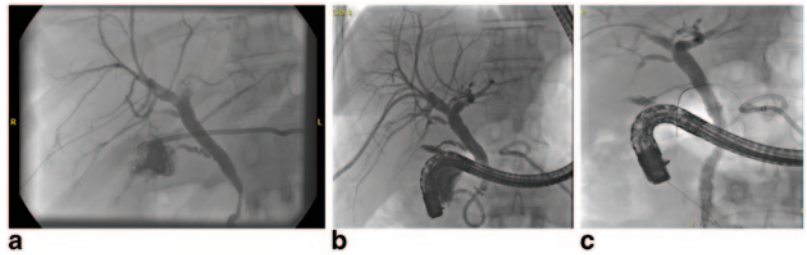

Fig. 18.4 Rendezvous procedure. **a** PTC performed due to difficult ERC. Large cystic duct stump leak with pigtail percutaneous drain in gallbladder fossa. **b** Persistent leak despite PTC. **c** Successful ERC using PTC to guide endobiliary prosthesisOperative Management

for the patient and can become displaced. We have limited experience with nasobiliary drains although similar outcomes to internal stents have been reported [37].

Interventional Radiology

Interventional radiology techniques have an important role in the management of biliary leaks. They include the ability to obtain source control with drainage of a biloma or abscess, dilate-associated biliary strictures using a percutaneous transhepatic approach, and to divert bile flow from the site of leakage to promote healing. In one study of 381 patients undergoing hepatic resection with or without hepaticojejunostomy, all biliary leaks associated with bilioenteric anastomoses were successfully managed by a percutaneous approach [38]. In another study of biliary leaks at the hepaticojejunostomy following pancreaticoduodenectomy, all leaks were managed nonoperatively with the most severe leaks managed with percutaneous biliary drains [11]. PTC can be challenging particularly when the biliary system is not dilated. However, PTC may be the only nonoperative way to achieve biliary drainage and evaluate the anatomy if the bile duct does not communicate with the central biliary system.

Combined Endoscopic and Interventional Radiology Approaches—Rendezvous Procedures

In some cases, endoscopic and percutaneous approaches alone are unable to provide adequate drainage or restore bilioenteric continuity. Rendezvous procedures utilize a combined endoscopic and interventional radiology approach (Fig. 18.4). PTC is used to cannulate the biliary tract in an antegrade fashion to allow the endoscopist to successfully complete the ERC. Rendezvous procedures have been described for the management of complex biliary leaks post hepatic resection as well as complete transection of the common bile duct [39, 40]. Whether these combined approaches will gain wider use and reduce the need for reoperation remains to be determined.

Operative Management

Indications for operative exploration in the setting of biliary leaks or fistula include (1) inability to achieve adequate source control by endoscopic or percutaneous approaches, (2) generalized peritonitis, (3) biliary leaks associated with complete division of the common hepatic duct or common bile duct, and (4) biliary leaks from an excluded segment.

Typically definitive repair is delayed until the effects of contamination and inflammation secondary to the biliary leak have subsided. Unless sepsis is uncontrolled by nonoperative means, early operation is contraindicated. In the setting of postcholecystectomy biliary injury, some authors have recommended a delay in definitive repair beyond 6 weeks if repair cannot be performed within 72 h of the injury [41]. For complete transection of the bile duct, our preferred method is the construction of a 40 cm Roux-en-Y hepaticojejunostomy using the Hepp–Couinaud approach. This makes use of the long extrahepatic course of the left hepatic duct and has been highly successful in the management of iatrogenic biliary tract injury [42]. In the case

of segmental bile duct injuries, a hepaticojejunostomy is constructed in an end to side, duct to mucosa fashion. In rare cases where it is not possible to perform a duct to mucosa anastomosis, a mucosal patch with transhepatic drain may be considered, although some reports indicate complications including separation of the jejunal limb and obstruction of adjacent secondary biliary radicles by the mucosal patch [43].

Thoracobiliary Fistula

Thoracobiliary fistulae include biliopleural and bronchobiliary fistula, which are abnormal communications between the biliary tract and pleura or bronchus, respectively. They are uncommon complications of hepatobiliary procedures but have been described after formation of subphrenic abscesses in the setting of biliary obstruction, radiofrequency ablation, and transarterial chemoembolization. These fistulae almost always require a mechanical breach of the adjacent diaphragm by either intervention or operation. Congenital, traumatic, and thoracobiliary fistulae related to hydatid disease will not be discussed.

Diagnosis

The presence of bilirubin in pleural fluid is pathognomic of a biliopleural fistula. Bronchobiliary fistula may present as bilioptysis, and the presence of bile stained fluid in a sputum sample supports the diagnosis. Patients may also present with bronchiolitis or bronchopneumonia secondary to the presence of bile in the airway. Once the diagnosis is suspected, CT scan, MRC, ERC, HIDA scan, and bronchoscopy have been used to confirm the diagnosis and determine the anatomy of the fistula [44].

Treatment

Given the low incidence of thoracobiliary fistula, there is no clear consensus on the treatment. However, the underlying principles of management are similar to management of biliary leaks in the abdominal cavity. It is important to prevent respiratory complications with adequate drainage of the pleural space with a chest tube or percutaneous drain, along with decompression of the biliary tract with ERC. Most reports favor a surgical approach to thoracobiliary fistula [45]. Thoracic procedures include decortication for biliopleural fistula and resection of the involved area of lung in the case of bronchobiliary fistula. Concomitant decompression of the biliary system by ERC is generally recommended. Placement of a pedicled tissue flap at the site of the fistula has been described with satisfactory outcomes [44]. Minimally invasive therapies including percutaneous thoracostomy tubes combined with endoscopic decompression have been proposed as definitive management [46]. Other case reports exist with use of octreotide alone or in conjunction with endoscopic biliary drainage with either resolution or reduction in symptoms [45]. The durability of nonoperative approaches remains unclear.

Five Key Points to Avoid Complications

1. Ensure biliary anatomy is correctly identified and perform intraoperative cholangiography if uncertain.
2. Assess for bile leaks intraoperatively—bile leak tests may be used as an adjunct.
3. No one method of parenchymal transection technique has been shown to eliminate bile leaks.
4. Postoperative drain placement in selected patients.
5. Referral to hepatobiliary specialist when biliary injury is identified.

Five Key Points to Diagnosis or Manage Complications

1. Define the anatomy of the leak using MRC, ERC, or PTC.

2. Establish a controlled biliary fistula with intraoperative drain, ultrasound, or CT-guided drain placement.
3. Ensure absence of distal obstruction and dilate strictures.
4. Employ a multidisciplinary approach including interventional radiology, therapeutic endoscopy, and surgery to diagnose and manage bile leaks.
5. Rarely operate when leak is contiguous with biliary tree. Reoperation is common if leak is discontiguous with biliary tree after infection and inflammation are controlled.

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Contralateral Bile Duct Injury During Hepatic Resection

19

Vikas Dudeja and Yuman Fong

Introduction

Although biliary complications occur in only 10% of liver resections, they are a major source of morbidity and account for one-third of postoperative mortality [1]. Though multiple studies have studied postoperative biliary leak after liver resection, only a few small studies have attempted to define bile duct injury during liver resection as a separate entity [2]. Contralateral bile duct injury, defined as injury leading to a leak from or the occlusion of the biliary drainage of the remnant liver, is a life-threatening complication and leads to multiple interventional and endoscopic procedures and even surgical reintervention. Sometimes, devascularization injury to the biliary drainage of the remnant does not present as leak or occlusion in immediate postoperative period but rather remotely as a stricture. In the current chapter, the etiology, presentation, prevention strategy, and treatment modalities for the biliary injury of the remnant will be described.

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Etiology and Risk Factors

Anatomical Variations

Typically, the right anterior and posterior sectoral ducts join to form the right hepatic duct (RHD), which in turn joins with the left hepatic duct (LHD) to form the common bile duct (Fig. 19.1a). However, this typical anatomy is present only little more than half the time and over 40% of the patients have variant biliary anatomy [3–6]. These anatomical variations can predispose to biliary injury during liver resection. In about 10–12% of cases, the right anterior and posterior sectoral duct do not join together to form RHD but instead join LHD at same point forming a triple confluence or trifurcation (Fig. 19.1b) [3, 4, 6]. The anatomic variation which puts the biliary drainage of the remnant at risk the most is when the right sectoral ducts, either posterior or anterior, drain into LHD instead of joining with its counterpart to form RHD. In up to 19% of the cases, the right posterior sectoral duct joins the LHD and is at risk during left-sided resection [3, 4, 6] (Fig. 19.1c). Thus, an unwary operator may come across the right posterior duct as it crosses the transection plane in left hepatectomy. This leads to an even graver situation in extended left hepatectomy when right posterior duct, the only outflow of the remnant, is in plane of transection and at risk. Less commonly, the right anterior duct can drain into LHD (Fig. 19.1d). Furthermore, both right anterior and posterior sectoral ducts can drain directly into the common hepatic

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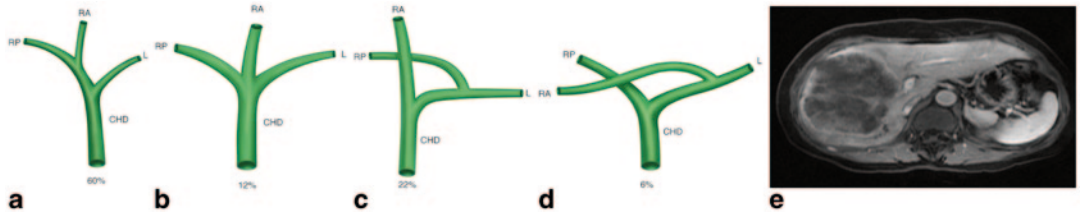


Fig. 19.1 Variation in biliary anatomy and aggressive hilar dissection in patients with large tumors close to hilum are risk factors for biliary injuries. **a** Variation in biliary anatomy of the right biliary system is more common than that in left side. Normal anatomy where the right anterior (*RA*) and posterior (*RP*) sectoral combine to form right hepatic duct which then joins the left hepatic duct to form common hepatic duct (*CHD*) is seen only in 60% of the patients. **b** In about 12% of patients, right anterior and posterior sectoral ducts do not join to form right hepatic duct but in fact join left hepatic duct at the same point to form a trifurcation. **c** In a fifth of all patients, the right posterior sectoral duct crosses the midline to join the left-sided duct. The right anterior sectoral duct joins the left hepatic duct to form the *CHD*. **d** In a minority of patients, the right anterior instead of posterior sectoral duct crosses midline to drain into left hepatic duct. **e** MRI shows a large tumor encroaching on the hilum. Such large tumors place the contralateral outflow at risk

duct (CHD). Preoperative knowledge of the patient's biliary anatomy, with respect to presence of these anatomical variations, is critical to preserve an intact remnant outflow.

Difficult Surgical Resection and Reoperation

Reoperative surgery is a perfect setup for biliary injury as scarred hilum as well as extensive adhesions make identification of segmental anatomy difficult. In addition, excessive blood loss, which is considered a risk factor for biliary injury [2, 7], can make the procedure even more challenging by impairing visualization and by making proper identification of hilar structures difficult.

Type of Liver Resection

Left-sided resection is typically associated with higher risk of biliary complications including large duct injuries [1, 2, 8]. There are two potential explanations for this phenomenon. Firstly, as mentioned, there is increased incidence of variant anatomy in the right ductal system. Secondly, the outflow of the right liver has a short extrahepatic course and in an attempt to get margin on the left duct, the operator may encroach on the remnant right ductal system.

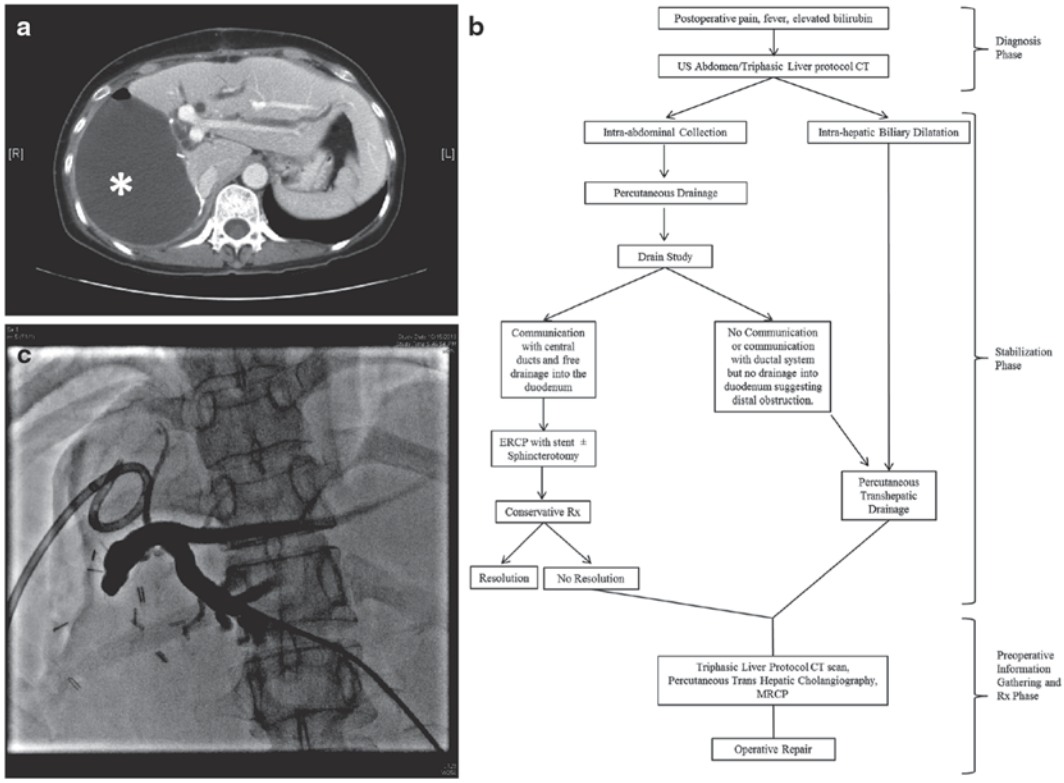
Aggressive Dissection and Devascularization of Bile Ducts

Another situation where the contralateral outflow is in peril is when the tumor is encroaching upon the hilum (Fig. 19.1e). In such patients in an effort to get enough clearance from the tumor, the operator can encroach and injure the contralateral duct. The contralateral duct is at even increased risk when a stapler is used to divide the bile duct in the presence of large hilar tumor as a bulky stapler can impair vision and needs more clearance from tumor as compared to division and suture closure. Also, preoperative endoscopic and interventional procedures including stent placement leads to intense inflammation and can make the hilar dissection difficult. In such cases, aggressive circumferential dissection of the hilar ducts in an attempt to get control can lead to devascularization and predispose to postoperative bile leak or late stricture formation.

Initial Investigations and Management

Initial Investigations

Patients with injury to the biliary outflow of the remnant will typically present with biliary leak, biliary obstruction, or a combination of the two.



Postoperative fever and rising white count may point to the presence of a collection necessitating a computed tomography (CT) scan (Fig. 19.2a). CT scan with contrast, besides demonstrating a collection, may demonstrate biliary dilatation suggesting a component of distal obstruction (Fig. 19.2a). Rising bilirubin, which does not plateau or which settles at much higher level than expected for the size of remnant, suggests a possibility of biliary injury and obstruction and may prompt an ultrasound or CT scan with contrast. Derangement of alanine transferase/aspartate transferase (ALT/AST) is very common after hepatectomy and is generally not helpful. Alkaline phosphatase will also be elevated in case of biliary obstruction.

Fig. 19.2 Presentation and management of contralateral bile duct injury during hepatectomy. **a** Abdominal CT scan of a patient who suffered injury to left hepatic duct following right hepatectomy. CT scan demonstrates a large fluid collection (*asterisk*) which turned out to be a bilioma when drained percutaneously. CT scan also demonstrates left intrahepatic biliary system dilatation (*arrowhead*). **b** Contrast study through percutaneously placed drain opacifies the left biliary system and shows an abrupt cutoff at the hilum. **c** Schematic depicting the management of contralateral outflow injury

Stabilization and Operative Planning

In patients with biliary injury leading to leak or obstruction, the stabilization of the patient by control of sepsis and relief of any obstruction is the priority (Fig. 19.2b). When an intraabdominal collection is observed on CT scan in setting of fever and rising white count, percutaneous drainage should be performed under ultrasound or CT guidance (Fig. 19.2b). Most bilomas are

due to leak of bile from the cut surface of the remnant rather than from major bile duct injury. The ongoing output from percutaneously placed drain suggests the presence of biliary fistula. Any evidence of biliary obstruction (intrahepatic biliary radical dilatation on imaging or elevated bilirubin which does not show a trend toward normalization), should prompt decompression of biliary system. The decompression is best achieved by percutaneous transhepatic route, though it may rarely be possible through endoscopic retrograde cholangiopancreatography (ERCP; see below).

Once the patient is stabilized and the collection is adequately drained, more information is needed to guide further management. The site of injury to the biliary system, severity of injury, adequacy of drainage, and the presence or absence of distal obstruction need to be ascertained. A good quality follow-up liver protocol CT scan can suggest the presence of any undrained collections and information about associated vascular injury. Contrast study through the drain can suggest the site of large bile duct injury (if it shows communication with biliary system) and also evaluate for presence of distal obstruction (if contrast does not drain into the intestines) (Fig. 19.2b). Further management depends on the presence or absence of distal obstruction.

No Evidence of Distal Obstruction with Fistula

If no distal obstruction is suspected (contrast study through the percutaneous drain drains freely into the biliary system and then into the duodenum and there is no intrahepatic biliary radical (IHBR) dilatation), then an ERCP and sphincterotomy can decompress the biliary system and provide radiologic evaluation of distal biliary system and site of leak (Fig. 19.2b). In such cases, prolonged conservative management with nutrition, correction of electrolyte and fluid deficits due to fistula losses, replacement of fat soluble vitamins, and treatments of infection is in order. Many fistulas with no distal obstruction will heal with conservative management and endoscopic stenting.

Evidence of Distal Obstruction with Fistula

If distal obstruction is suspected on the drain study or on CT scan then ERCP is rarely of utility. In such circumstances, the goal is to adequately drain the biliary system to prevent adverse consequences of biliary obstruction (inadequate remnant hypertrophy, cirrhosis, and portal hypertension). The biliary system may already be adequately decompressed through the fistula. However, if any suggestion of inadequate decompression is present, e.g., dilated IHBR on CT scan or ultrasound (US) or elevated bilirubin, then adequate drainage of the biliary system with percutaneous transhepatic approach is in order (Fig. 19.2b). Once all the collections are drained and the biliary system is adequately decompressed, conservative management should be instituted and the surgeon should wait for 4–6 weeks to let the inflammation settle down before attempting operative correction.

Evidence of Distal Obstruction but no Fistula

In patients who present with stricture without any fistula, the foremost priority is to decompress the biliary system. A liver protocol CT scan or US done to evaluate for the etiology of elevated bilirubin will demonstrate dilated intrahepatic biliary radicals. Drainage in these patients is best achieved through percutaneous transhepatic method (Fig. 19.2b). Drainage catheter also helps in identification of ductal structures intraoperatively at the time of operative repair, by palpation.

Detailed information about the ductal anatomy is critical in planning operative repair of the biliary stricture. This detail can be provided by cholangiography performed through the percutaneously placed drainage tube (Fig. 19.2c) or through magnetic resonance cholangiopancreatography (MRCP). MRCP not only provides striking images and detailed anatomic information but can also help in evaluation of liver parenchyma as well as relationship of ducts with vascular structures (Fig. 19.2b).

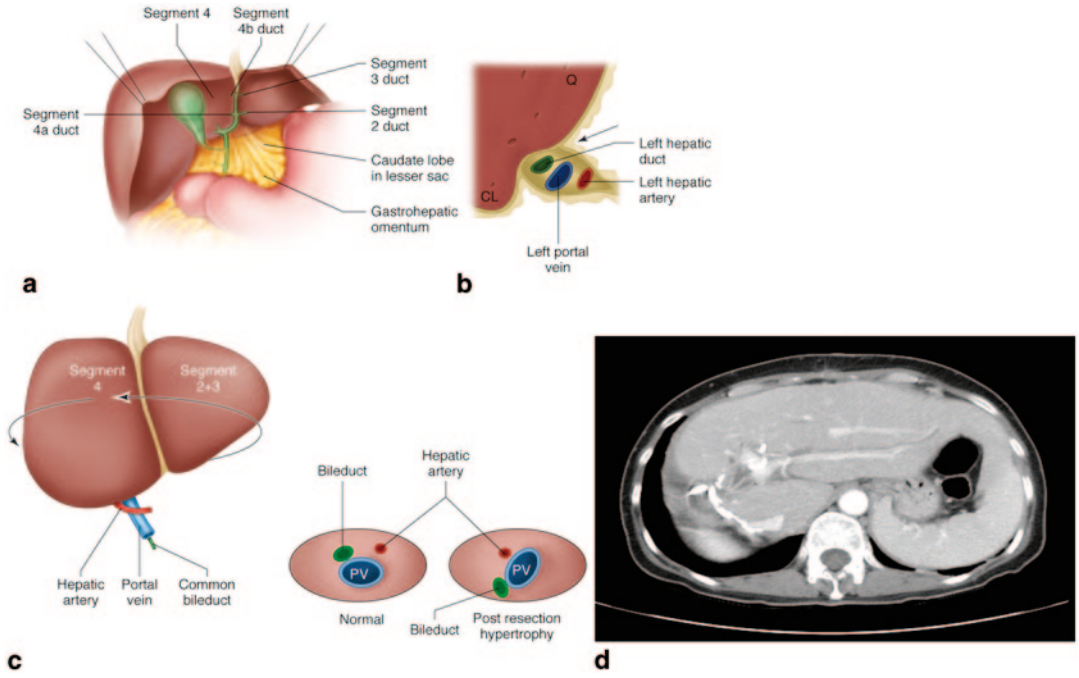


Fig. 19.3 Essentials of anatomy and anatomical alterations for biliary reconstruction. **a** Normal anatomy of biliary system. The right hepatic duct has a short extrahepatic course. On the other hand, the left hepatic duct has a long extrahepatic course and runs transversely at the base of *segment IV* before entering the umbilical fissure. In the umbilical fissure, the left hepatic duct gives rise to *segment IVa* and *IVb* ducts on the right and *segment II* and *III* ducts on the left. **b** Schematic demonstrating the lowering of hilar plate. Left portal pedicle runs transversely between quadrate lobe (*Q*) and caudate lobe (*CL*). Division of the reflection of Glisson's capsule onto the gastrohepatic ligament in the plane shown by the *arrow* lowers the hilar plate and exposes the *left hepatic duct* which is situated deeper to the portal vein. **c** Schematic demonstrating how hypertrophy of the left liver after right hepatectomy displaces the hilum posteriorly and laterally and also changes the normal orientation of structures in the hilum. **d** CT scan in a patient postright hepatectomy depicting how posterolateral displacement of the hepatic hilum due to left liver hypertrophy may lead to difficulty in access to the portal structure and may require the use of thoracoabdominal incision

Definitive Management

Anatomy Relevant to Operative Repair of Biliary Outflow of Remnant

In contrast to the biliary anatomy of the right hemiliver, the left biliary system anatomy is relatively consistent. Also, fortuitously, the left hepatic duct has a long extrahepatic course as it runs along the undersurface of segment IVb. In this transverse course, the left hepatic duct is accompanied by left portal vein and this portal diad (notice the absence of left hepatic artery, normal or variant) is ensheathed in the peritoneal reflection of the gastrohepatic ligament (Fig. 19.3a). Thus, the left duct can be exposed at the base of segment IVb by dividing the reflection of Glisson's capsule onto the gastrohepatic ligament, a maneuver called "lowering the hilar plate" (Fig. 19.3b). Left hepatic artery joins the "portal diad" at the base of the umbilical fissure. As the left hepatic duct runs in the umbilical fissure, it receives biliary ducts from segments II, III, and IV. Often, the left duct in the umbilical fissure is covered by a bridge of hepatic tissue that crosses from the left lateral section to the base of segment IV, and these need to be divided to gain access to the biliary and vascular structures in the umbilical fissure.

Operative Repair

Operative repair of outflow injuries (stricture or fistula) to the remnant liver after major hepatectomy is not an easy undertaking. It is a difficult task being performed in a nonideal setting. Postoperative adhesions and inflammation due to biliary leak makes the access to a healthy piece of duct for hepaticoenterostomy challenging. Furthermore, regeneration alters the normal anatomic configuration of the portal structures [9] and the access to the hepatic hilum is often limited and critically dependent on the nature of prior resection. As the liver regenerates and the remnant expands to fill the space created by liver resection, an unavoidable distortion of the hepato-duodenal ligament and hilar structure follows [9, 10]. After a right hepatectomy, regeneration and hypertrophy of left lobe leads to posterolateral and upward displacement of the hepatic hilum. This may lead to difficulty in access to the portal structure and may require the use of thoracoabdominal incision (Fig. 19.3c and d). On the other hand, compensatory hypertrophy of right lobe after left hepatectomy leads to rotation of the portal triad towards midline. Furthermore, caudate hypertrophy would lead to anterior displacement of the hepato-duodenal ligament. This puts hepatic hilum at a very superficial location in harm's way to an unwary operator. Thus, bile duct repair after previous hepatic resection involves safe definition and isolation of a healthy bile duct for anastomosis and construction of a well-vascularized hepaticoenterostomy.

Given these changes in configuration of portal structure, as soon as we enter the abdomen, we identify important landmarks that help in safe conduct of the operation. After previous right hepatectomy, we identify following structures. (1) Remnant of the ligamentum teres is then followed to the base of umbilical fissure to define the location of left hepatic artery. This is the constant location of left hepatic artery, whether it arises from common hepatic artery or from left gastric artery in its variant configuration. (2) Lesser omentum is opened early in the operation to identify the caudate lobe. Once identified, a finger can be passed in front of the caudate towards the foramen of Winslow to define the location of portal vein. (3) Inferior vena cava (IVC) is identified next by performing a Kocher maneuver and mobilizing duodenum off IVC. Early identification of IVC helps in dissection of liver off vena cava and isolation of the hepatoduodenal ligament for the application of Pringle maneuver. In patients with prior left hepatectomy, as mentioned before, the operator should be wary of the unpredictably anterior location of the portal vasculature. We typically mobilize the liver and perform the Kocher maneuver, thus identifying the IVC which can then followed caudally to identify the portal vein from the right. Once the liver is mobilized, cephalad retraction of the undersurface of liver along the base of segment IVb enhances optimal visualization of the hilar structures. After the identification of the critical structures, the attention can be focused on managing the bile duct pathology.

The tenets of operative repair of biliary injuries are as follows: (1) identification of healthy bile duct mucosa proximal to the site of obstruction, (2) preparation of a segment of alimentary tract (generally in the form of roux limb), and (3) creating a direct anastomosis between biliary and jejunal mucosa. Detailed evaluation of preoperative imaging studies to comprehend the lay of the land in terms of location of vascular anatomy and determining the site of anastomosis as well as judicious use of preoperative biliary stents is critical to the success of this endeavor. If an injury is discovered during the initial liver resection itself, small injuries can be closed with interrupted 4-0 vicryl or other fine absorbable suture. In case of large defects or loss of tissue, a hepatoenterostomy is imperative.

Repair of Injury to Right Liver Outflow

In patients with injury to right hepatic duct during conduct of a left hepatectomy, anastomosis to the right hepatic ducts is necessary. Lowering what is left of the hilar plate may demonstrate the junction of right hepatic duct with the stump of left hepatic duct forming the common hepatic duct. If a stapler was used to divide the left hepat-

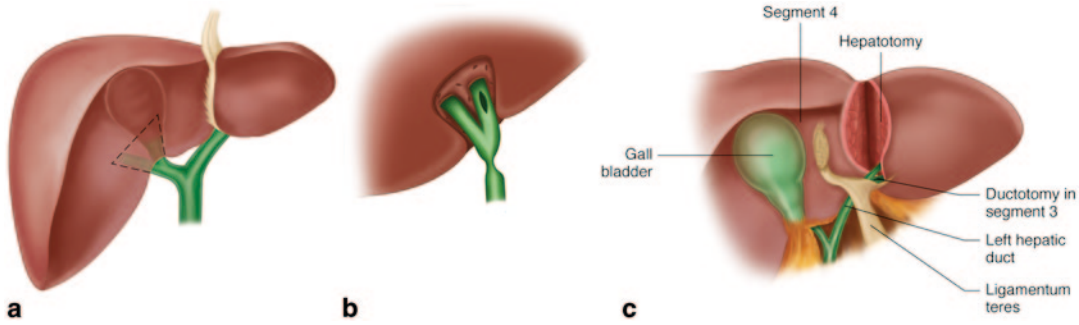


Fig. 19.4 Approach to the right sectoral ducts for bypass. **a** If the extrahepatic course of the right hepatic duct is strictured then anastomosis with one of the sectoral ducts, usually the anterior, is required. For this, a triangular piece of liver tissue between the base of the gallbladder fossa and the caudate process, which overlies the confluence of the right anterior and posterior sectoral ducts to form the right hepatic duct, is removed. **b** Once exposed, a ductotomy is made in the anterior sectoral duct and can be carried onto the stump of right hepatic duct and a wide anastomosis between the right duct and the Roux limb of jejunum can be fashioned. **c** Exposure of the *segment III* duct for bypass can be achieved by dividing the liver tissue between *segment IV* and left lateral segment. Liver is split just to the left of the falciform ligament, and the tissue is divided superiorly until the *segment III* duct is reached. Duct is opened longitudinally, and anastomosis with Roux limb constructed

ic duct in previous operation, then location of staples may help identify the left duct stump which can be traced to the hepatic duct confluence. If the extrahepatic course of the right hepatic duct is not sufficient then exposure of the confluence of the right anterior and posterior sectoral ducts to form the right duct and anastomosis with one of the sectoral ducts, usually the anterior, is a fallback plan. For this, a triangular piece of liver tissue between the base of the gallbladder fossa and the caudate process, which overlies the confluence of the right anterior and posterior sectoral ducts to form the right hepatic duct, is removed (Fig. 19.4a and b). This tends to be a little bloody and patience is paramount. Once exposed, a ductotomy is made in the anterior sectoral duct and carried onto the stump of right hepatic duct and a wide anastomosis fashioned between the right duct and the Roux limb of jejunum. If the confluence of the right anterior and posterior ducts is destroyed, then this anastomosis would not drain the right posterior sector and a separate anastomosis to the right posterior duct needs to be carried out.

Repair of Injury to Left Liver Outflow

In patients with left duct injury after a right hepatectomy, anastomosis to the left hepatic duct in its transverse location at the base of segment IVb is the preferred method of biliary bypass. Hypertrophy of left liver generally places the hilum posteriorly and laterally and a good access, which is critical to the success of this procedure, generally requires a right lateral thoracic extension of the incision. Anterocephalad traction on the falciform ligament and elevation and retraction of segment IVb with the help of a curved retractor expose the transverse course of left hepatic duct. Opening the bridge of liver tissue between segment IVb and II allows access to the base of the left portal pedicle. By dissecting between Glisson's capsule and the peritoneum encasing the portal triad at the base of segment IV, the hilar plate is lowered. At this location, the portal vein is more superficial to bile duct. Deepening the plane of dissection moves the portal structures away from the front of bile duct. If a good length of left duct can be exposed, it is incised longitudinally and a side-to-side single-layer interrupted mucosa to mucosa anastomosis is carried out between the duct and the Roux limb.

If the transverse portion of the left duct is not suitable for drainage, a segment III bypass can be performed. For this, ligament teres is retracted caudally and to patient's right. The peritoneum of its upper surface on the left side is divided, and the tissue between the ligamentum teres and segment III is divided between ligatures. This exposes the segment III duct. Sometimes, a wedge of tissue over the duct needs to be resected to expose the duct properly; this also broadens the area where the Roux limb can sit (Fig. 19.4c and d).

Prevention of Contralateral Bile Duct Injury

Attention to Variation in Biliary

Detailed evaluation of preoperative imaging can alert the surgeon to variation in biliary anatomy. As more than a third of patients are expected to have variant biliary anatomy, the abnormal anatomy should be actively sought for. In cases with variant anatomy, the plane of transection can be modified to protect the contralateral bile duct.

Intrahepatic Control of Biliary Radicals

Biliary radicals can be controlled extrahepatically or intrahepatically. In the extrahepatic method, the bile duct is dissected and divided extrahepatically. This method is associated with higher risk of biliary injury, especially on right side where the anatomic variations of the sectoral duct drainage are common. We prefer intrahepatic transection of biliary radicals when possible. Portal vein and the hepatic artery may be divided extrahepatically, thus demarcating the liver. The bile duct is not divided extrahepatically and biliary radicals encountered in the plane of transection are divided. We find this technique safer as the division of biliary radicals is being performed away from the contralateral outflow. However, intrahepatic ligation of biliary radicals may not be feasible for hilar cholangiocarcinoma as well as tumors that are close to the hilum. In left-sided resections, we find extrahepatic ligation of bile duct at the base of umbilical fissure equally safe due to long extrahepatic course of left pedicle.

Tumor Close to the Hilum

If the tumor is close to the hilum and the contralateral outflow is at risk, we avoid using stapler for biliary division. In such cases, the bile duct is sharply divided with a knife and specimen removed. This protects the contralateral bile duct and provides a little extra length for anastomosis if a hepaticoenterostomy is needed.

Outcomes

Given the low incidence of posthepatectomy contralateral bile duct injury, data on long-term outcomes after repair of such injuries are lacking. However, some inferences can be gleaned from outcome data of benign postcholecystectomy biliary stricture repair. Data on outcomes of hepatico-jejunostomy to right-sided bile duct system are limited. However, it appears that in experienced hands, good long-term outcomes and low rate of restricture can be achieved. In a small series of 23 patients with a limited follow up of median 3 years (8 months–7 years), no restructuring was reported [11]. Similarly, in experienced hands, biliary bypass to the transverse segment of left hepatic duct seems to be durable as well. The group from Mayo has reported excellent short-term outcomes with biliary–enteric anastomosis to extrahepatic transverse segment of left hepatic duct [12]. Likewise, in a study from Poland [13], at a median follow-up of 59 months (range 6–102 months), a low restricture rate of 6% was observed after reconstruction of complex high biliary stricture using this approach. Data suggest that timing of repair may also affect outcomes with repairs conducted in the intermediate period (>72 h but<6 weeks) were significantly associated with more strictures [14]. However, it is important to execute the repair in a timely fashion and to take steps to protect liver func-

tion and prevent obstruction-induced cirrhosis and portal hypertension, as mortality with these procedures is markedly influenced by preoperative liver function and the presence or absence of portal hypertension [15].

Five Key Points to Avoid Contralateral Bile Duct Injury

1. Preoperative image should be evaluated critically to alert the surgeon to patient-specific variation in biliary anatomy.
2. In patients with variant anatomy of the biliary ductal system, the plane of transection should be modified to protect the contralateral bile duct.
3. When feasible, the bile duct should be controlled intrahepatically, as this allows bile duct division away from the contralateral outflow.
4. In left-sided resections, the bile duct should be ligated at the base of umbilical fissure away from outflow of right side.
5. If the tumor is close to the hilum and the contralateral outflow is at risk, avoiding the use of a stapler for biliary division can help protect the contralateral bile duct from injury.

Five Key Points to Diagnose and Treat Contralateral Bile Duct Injury

1. In case of contralateral bile duct injury, control of sepsis with adequate drainage of any intraabdominal collection, antibiotics, and relief of obstruction are the priorities.
2. Biliary system of the remnant should be adequately drained to prevent adverse consequences of biliary obstruction. Drainage is typically obtained through percutaneous transhepatic route.
3. MRCP and drain study through percutaneously placed transhepatic catheter help define the anatomy and facilitate preoperative planning.
4. Due to remnant hypertrophy, the normal anatomic configuration of the portal structures is altered, and the access to the hepatic hilum is often limited and critically dependent on the nature of prior resection.
5. The tenets of operative repair of biliary injuries are as follows: (1) identification of healthy bile duct mucosa proximal to the site of obstruction, (2) preparation of a segment of alimentary tract (generally in the form of Roux limb), and (3) creating a direct anastomosis between biliary and jejunal mucosa.

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Massive Intraoperative Hemorrhage During Hepato-Biliary and Pancreatic Surgery

20

Vikas Dudeja and William R. Jarnagin

Introduction

Historically, progress in liver surgery was hindered by absence of surface landmarks, incomplete understanding of the well-defined internal anatomy, and the lack of ability to control bleeding from the liver tissue and associated vessels. For many years, major hepatic resection was complicated by large volume blood losses and its attendant mortality and morbidity. Only with a better understanding of liver's segmental anatomy, coupled with refinement in operative technique and advancements in intra- and peri-operative management, has liver surgery emerged as a safe and effective therapeutic option. Even with current progress and increased exposure to hepatic surgery in surgical training, expertise in major liver surgery requires focused training and is largely limited to specialized centers.

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Hemorrhage During Liver Surgery

Magnitude of Problem

Risk of hemorrhage remains a major concern during liver resection. In a review of major liver resections, excluding wedge resections, performed between 1991 and 1997 at Memorial Sloan-Kettering Cancer Center [1], mean blood loss was 848 ± 972 ml and ranged from 40 to 9000 ml. Over 13 % of patients experienced intra-operative blood loss of more than a quarter of their estimated blood volume [1]. Even in a more contemporary series of major hepatectomies, median blood loss of 700 with an inter-quartile range of 400–1050 is reported [2]. Excessive bleeding has been shown to correlate with post-operative morbidity. 30–47 % of patients are reported to receive allogenic blood components during or within 24 h of major hepatectomy [1, 2]. Allogenic blood transfusion in itself is not a benign intervention. Despite markedly increased safety of national blood supply, transmission of various viral and bacterial pathogens is a persistent concern [3]. Furthermore, immunomodulatory effects of blood transfusion may lead to increased predisposition to infection and reduction in cancer disease-free survival [4, 5]. Though hemorrhage can occur during liver transection, as well as from and during control of hilar vessels, injury to hepatic vein and retro-hepatic vena cava is the most common cause of major intraoperative hemorrhage. Precise knowledge of liver

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anatomy is the key to successful and safe hepatic resection.

Hepatic Vascular Anatomy

Despite lack of any corresponding surface landmark, liver has an intricate, intrinsic, functional, and segmental anatomy. Liver is divided into four sectors and eight segments. Each segment is supplied by an independent portal pedicle containing triad of branch of hepatic artery, portal vein (PV), and bile duct. The sectors are separated by portal scissura which are defined by location of hepatic veins. Thus, the intrahepatic vascular anatomy forms the basis of segmental anatomy of the liver.

a. **Hepatic Venous Anatomy:** The liver has three major veins, which drain from the posterior surface directly into the IVC. These veins divide the liver into four scissura, sectors, or sections. The right vein runs in the right scissura and divides the right liver into anterior and posterior sector. It has a short extrahepatic course of about 1 cm. The left hepatic vein runs in the left scissura and form the division between segment 2 and 3. The middle hepatic vein runs in the portal scissura and forms the division between left and right liver. Generally, the left and the middle hepatic veins join intrahepatically and enter the retro-hepatic IVC as a single vessel. Multiple small hepatic veins drain directly from the posterior sector of right liver and the caudate lobe into the IVC. These veins appear small but should be divided carefully between ligatures or clips as they can cause troublesome bleeding impeding vision. The umbilical fissure, the only surface marking of significance, contains the left portal pedicle but no hepatic vein.

b. **Hepatic arterial Anatomy:** Hepatic artery flow provides oxygenated flow to the liver and constitutes 25% of total blood supply, the remaining 75% being supplied by portal venous flow. Anatomical variations are very common in hepatic arterial anatomy, and the common description of hepatic arterial anatomy is present only 60% of the time. In this description, the common hepatic artery, which arises from celiac trunk and forms proper hepatic artery after giving rise to the gastroduodenal artery, divides at the hilum to give rise to right and left hepatic artery. The right hepatic artery courses between common hepatic duct and PV to supply right liver. The left hepatic artery joins the left PV and bile duct at the base of umbilical fissure to supply segments 2, 3, and 4. About 40% of patients have variant hepatic anatomy. A replaced or accessory right hepatic artery arises from the superior mesenteric artery (SMA) near its origin and course posteriorly or through the head of the pancreas and is present ~20% of the time. A replaced or accessory left hepatic artery arises from the left gastric artery and courses transversely towards the base of the umbilical fissure in the lesser omentum 12–15% of the time.

c. **Hepatic Portal Venous Anatomy:** The superior mesenteric vein (SMV) and splenic vein join behind the neck of the pancreas to form PV which runs in the free edge of hepato-duodenal ligament en route to liver. This location of PV makes the Pringle maneuver feasible. At the hilum, the PV divides into right PV, which has a short extrahepatic course, and left PV, which has along extrahepatic course of 3–4 cm (Fig. 20.1a). The right PV, after entering the liver substance, divides into anterior and posterior sectoral branches (Fig. 20.1a). These sectoral branches can sometimes arise directly from the main PV extrahepatically. The left PV runs transversely along the base of segment 4b before turning anteriorly and caudally in the umbilical fissure where it gives branches to the segment 2 and 3 and recurrent branches to segment 4 (Fig. 20.1a). The hepatic portal venous anatomy has much less anatomical variation when compared with hepatic arterial or biliary anatomy. The most common variations include portal trifurcation (~12–20%), where the right anterior, right posterior, and left portal branches share a common origin (Fig. 20.1b), and the right posterior PV branch arising as a direct branch of main PV (~9%) (Fig. 20.1c–e) [6–8]. In the latter situation, the left PV and right anterior PV share a common trunk (Fig. 20.1c–e).

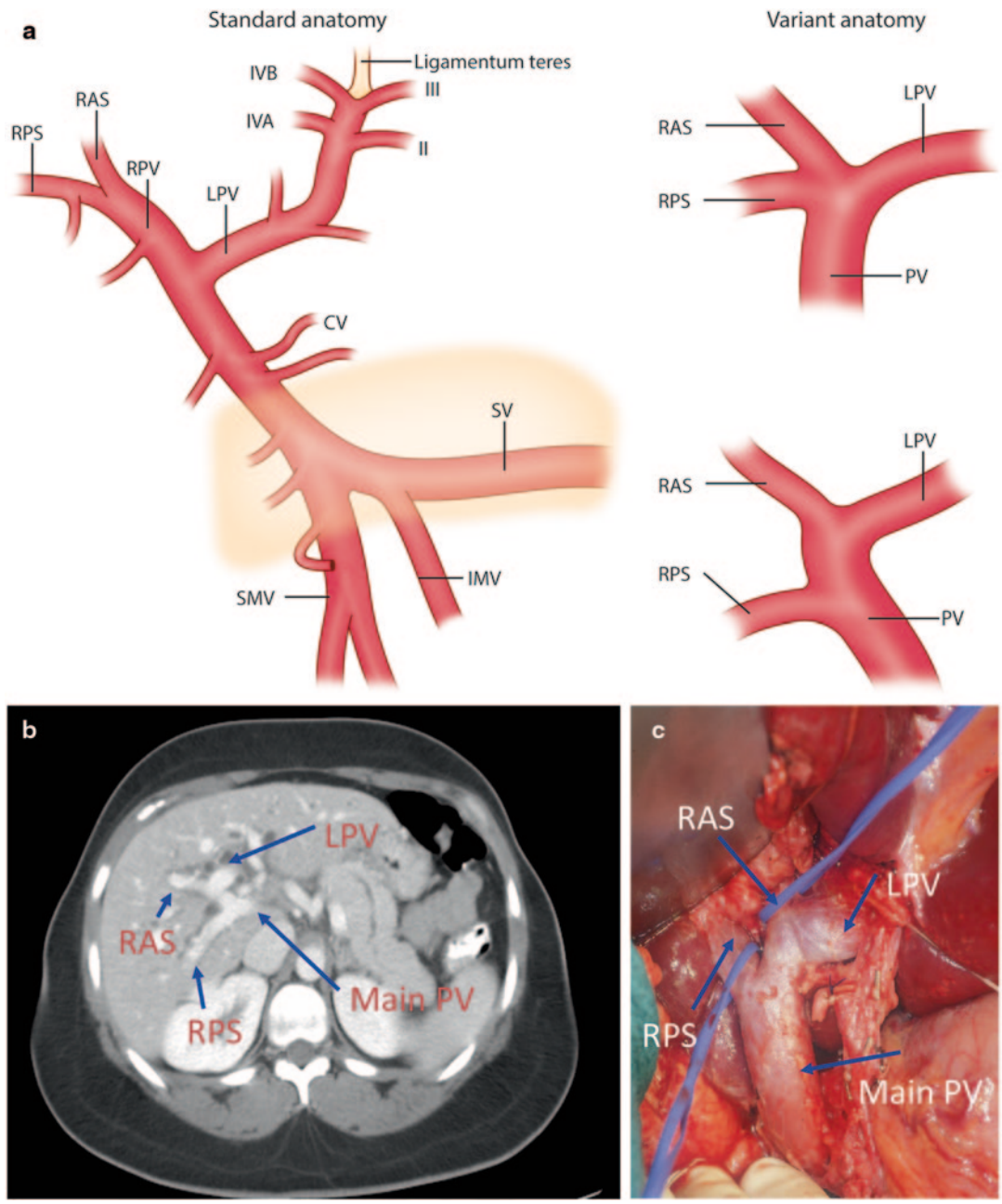

Fig. 20.1 Standard and variant portal venous anatomy. **a** In standard portal venous anatomy, superior mesenteric vein (*SMV*) and splenic vein (*SV*) join behind the neck of the pancreas to form portal vein (*PV*). At the hilum, the *PV* divides into right portal vein (*RPV*) and left portal vein (*LPV*). RPV after entering the liver substance divides into right posterior sectoral (*RPS*) and right anterior sectoral (*RAS*) branches. The *LPV* runs transversely along the base of segment 4b before turning anteriorly and caudally in the umbilical fissure where it gives branches to the segments *II*, *III*, *Iva*, and *IVb*, much less anatomical variation when compared with hepatic arterial or biliary anatomy. **b** The most common variations include portal trifurcation (~12–20%), where *RPS*, *RAS*, and *LPV* share a common origin (*arrow*). **c** Second most common variant is where *RPS* branch arises as a direct branch of *PV* (~9%). In the latter situation, the *LPV* and right anterior *PV* share a common trunk (*bracket*). **d** CT scan of a patient with the separate origin of *RPS* from *PV*. **e** Intraoperative image of the same patient. Notice that *RAS* shares a common origin with *LPV*

Prevention of Major Hemorrhage During Hepatic Resection

As mentioned before, a thorough understanding of the liver anatomy and detailed review of cross-sectional imaging to ascertain patient-specific anatomical variation are fundamental for safe liver resection. Over the past few decades, improvements in operative technique and advances in intraoperative and postoperative management have contributed to significant reduction in the risk of major intraoperative hemorrhage [9]. Techniques aimed at reducing blood loss during hepatic resection are discussed below.

Techniques Aimed at Reducing Blood Loss During Hepatic Surgery

One of the most important techniques shown to reduce blood loss during hepatic surgery is the use of low central venous pressure. Before the description of this technique, expansion of intravascular volume was a commonplace to provide a buffer for potential hemorrhage and hemodynamic instability. The resulting increase in central pressure is transmitted to the entire hepatic venous system; the major and accessory hepatic veins become distended and difficult to control, and there is increased back bleeding from hepatic veins during parenchymal transection. This is especially important as injury to the hepatic vein during parenchymal transection or at their junction with the vena cava is the most common cause of life-threatening intraoperative hemorrhage. With the low central venous pressure (CVP) approach, the CVP is maintained below 5 mmHg. Maintenance fluid at a low rate and hypotensive effects of the anesthetics helps in achieving the low CVP. Intermittent fluid bolus may be employed to maintain a goal urine output of 25 ml/h and systolic blood pressure greater than 90 mmHg. Maintenance of low CVP precludes vena caval distension, thus facilitating retro-hepatic dissection as well as dissection of major hepatic veins. It also reduces the bleeding during transaction of hepatic parenchyma. In case of inadvertent venous injury, the low CVP approach facilitates control of the injury. The risk of air embolism is minimized by performing the dissection in slight trendelenburg position, although this may not be necessary. The low CVP approach has been shown to reduce both the blood loss and transfusion requirements when compared to standard management [1]. Furthermore, the low CVP approach is associated with low rate of renal dysfunction when compared to total hepatic vascular exclusion.

Deliberate Dissection and Exposure of Retro-Hepatic Vena Cava and Major Hepatic Veins

We perform extensive hepatic mobilization with exposure of major hepatic veins before embarking on major hepatic resection. This provides the necessary exposure to accomplish major hepatic resection safely as well as facilitates control of veins in case of difficult intraoperative bleeding. The extrahepatic exposure and control of vein is prudent even when intrahepatic exposure and control of veins during parenchymal transaction are planned. The isolation and control of hepatic veins is especially critical when performing resection for central tumors which are close to hepatic vein-inferior vena cava (IVC) confluence as it enables adequate tumor clearance with reliable control of hemorrhage.

For right and extended right hepatectomy, control of the right hepatic vein should be achieved extrahepatically, in most cases, after the vena caval dissection has been completed. Complete division of the falciform ligament exposes the suprahepatic IVC and the right hepatic vein. Right triangular ligament is divided next to completely expose the bare area of the liver on the right. Next, the short retro-hepatic veins draining directly from the caudate lobe into the IVC are divided, progressing from the inferior aspect toward the hepatic veins (Fig. 20.2a). Complete exposure of the retrohepatic vena cava as well as the right hepatic vein requires division of vena caval ligament, which often contains of fibrous tissue but may consist of liver tissue. Care must be taken to avoid injury to the right hepatic vein or lateral wall of the IVC (see below). Division of vena caval ligament can generally be achieved using a vascular load of Endo GIA stapler. Next the tunnel between the right hepatic vein and

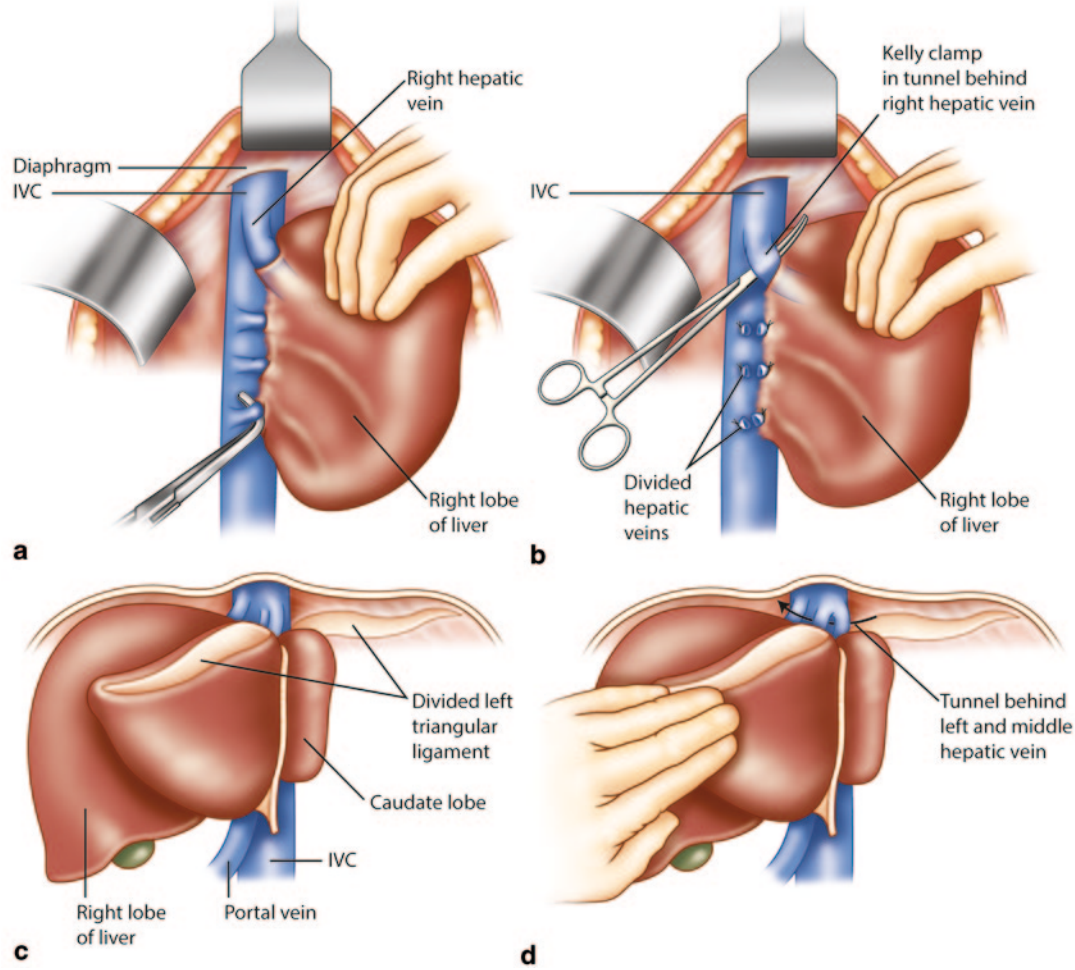

Fig. 20.2 Extensive mobilization of the liver provides access to hepatic veins and retro-hepatic *IVC*, which facilitates the liver resection and facilitates control of hepatic veins in case of intra-operative hemorrhage. **a** Division of the retro-hepatic veins draining directly into the *IVC* exposes the *IVC*. **b** A tunnel is developed between the *IVC* and right hepatic veins. If needed, right hepatic vein can be controlled with clamps. **c** For left-sided resections, left triangular ligament is divided and the left lobe is retracted medially. **d** Division of ligamentum venosum exposes the tunnel between left/middle hepatic vein and *IVC*

IVC is gently developed and the right hepatic vein is encircled and controlled with vessel loop (Fig. 20.2b). No undue force should be used for any of these steps.

For the left and extended left hepatectomy, exposure of left and middle hepatic veins should be achieved. The left lateral sector is mobilized by division of the left triangular ligament (Fig. 20.2c). As the left triangular ligament is opened and this dissection is carried out medially, the left side of the upper part of the IVC and the left hepatic vein become visible. This dissection is carried to the right to expose the middle hepatic vein. It should be noted that, in most patients, the left and middle hepatic veins drain into the vena cava as a common trunk. Next, the ligamentum venosum is divided to achieve adequate exposure (Fig. 20.2d). The left lateral sector of the liver is turned upward and to the right, and the gastrohepatic ligament is fully divided; the ligamentum venosum, which runs in the groove between the left lateral sector and caudate lobe, is divided near its entry into the left hepatic vein. With careful dissection along the right side of the

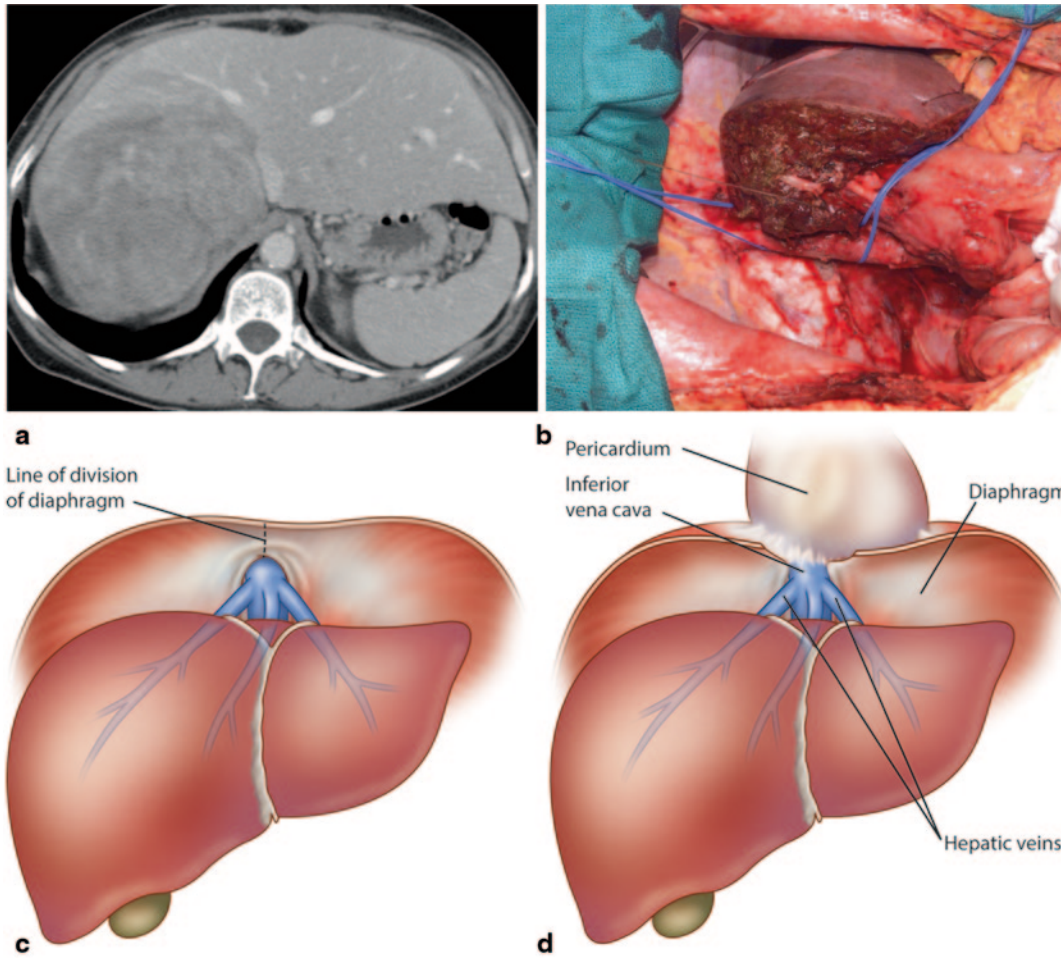

Fig. 20.3 : Preemptive control of supra- and infra-hepatic IVC should be obtained for posteriorly located large tumors. **a** Representative CT scan demonstrating a large hepatic tumor abutting the IVC. **b** Control of supra- and infra-hepatic IVC was obtained prior to proceeding with liver resection. **c** and **d** In case of massive intra-operative hemorrhage, if access to supra-diaphragmatic IVC is needed, xiphoid is resected, plane between diaphragm and pericardium is developed, and the diaphragm is divided from the xiphoid down to the IVC

middle hepatic vein and from the left, where the ligamentum venosum attaches to the left hepatic vein, the tunnel between the left and middle hepatic veins and the IVC can be developed, allowing circumferential dissection and control of the left/medial hepatic veins. Care must be taken during this dissection in order to avoid injury to the hepatic veins (see below).

Rarely, for superiorly located tumors involving the outflow vessels near their insertion into the vena cava, control of supra- and infrahepatic IVC should be obtained preemptively (Fig. 20.3a). For infrahepatic control, an umbilical tape can be passed around the IVC below the liver but above the right renal vein (Fig. 20.3b). To control the suprahepatic IVC, division of falciform ligament and bilateral triangular ligament provides adequate exposure and the suprahepatic IVC can be dissected out and encircled (Fig. 20.3b). If difficulty is encountered in controlling the suprahepatic IVC from the abdomen, as may happen in cases of large superiorly located tumors, the incision should be extended into the right chest or vertically as median sternotomy. In such cases,

persisting from the abdomen can be dangerous. Once in the mediastinum, the pericardium can be opened to get supradiaphragmatic control of IVC.

Though we generally recommend extensive mobilization of liver with control of hepatic veins early in the operation, in certain situations this may not be feasible and modification of approach is necessary. This is specifically the case for large right-sided tumors that extend into the retroperitoneum and/or extensively involve the right hemi-diaphragm. In the presence of such large tumors, the mobilization of the right liver for exposure of the right hepatic vein and lateral vena cava is difficult, and attempts to do so carry a high risk of tumor disruption and significant bleeding. In such cases, anterior approach or hanging maneuver may be employed. In the anterior approach [10], hilar vessels are controlled and the liver parenchyma is transected from the anterior surface of the liver working posteriorly until the anterior surface of the right hepatic vein and IVC are encountered. The hanging maneuver [11] is a modification of anterior approach where lifting the liver with a tape passed between the anterior surface of IVC and the liver parenchyma helps to guide the resection and to control the bleeding in the depths of transection plane.

Hepatic Inflow Control

Hepatic inflow control by Pringle maneuver, which interrupts the arterial and portal venous inflow to the liver, is typically employed during hepatic resection. The lesser sac is entered by opening the lesser omentum at the level of pars flacida, finger, or blunt dissector is passed through the foramen of Winslow and the hepato-duodenal ligament containing the PV and proper hepatic artery is encircled with a vessel loop or umbilical tape. When preoperative imaging or intraoperative examination demonstrates an accessory or replaced left hepatic artery, its occlusion is needed to provide complete hepatic inflow control. The Pringle maneuver reduces inflow blood loss during hepatic resection and is generally well tolerated and does not require special anesthetic management. The major concern with hepatic inflow clamping is the ischemic injury to the hepatic remnant. This is of heightened relevance when the resection is being performed in liver with underlying cirrhosis, chemotherapy-associated steato-hepatitis, or when remnant volume is borderline. With prolonged, continuous portal venous occlusion, there is concern for splanchnic congestion with attendant consequences like bowel edema, threatened bowel anastomosis, difficult abdominal closure, increased risk of abdominal compartment syndrome, and even pancreatitis. However, these are uncommon events and can be addressed with intermittent inflow occlusion with intervals of reperfusion, which reduces hepatic ischemia as well as splanchnic congestion. We employ 10–15 min of clamping interspersed with 5 min of reperfusion. During the periods of unclamping, bleeding from the transected surface can be controlled with argon beam coagulator, clips, and/or suture ligatures. Up to 60 min of cumulative pedicle clamping time is well tolerated even with diseased liver [12].

Control of the hepatic arterial and portal venous blood supply to the portion of liver to be removed can be obtained by extrahepatic dissection or by intra-hepatic control of pedicles. This selectively interrupts the arterial and portal venous inflow to the liver to be resected and provides clear demarcation of the limits of resection. For the extrahepatic approach, we usually control the hepatic artery and PV but do not control the biliary outflow extrahepatically unless needed for tumor clearance. For right-sided resections, the right hepatic artery and PV need to be divided. To prevent inadvertent damage to the contralateral vascular inflow and troublesome bleeding, it is critical to be aware of patient's anatomy, as up to 20% of patients have variant right hepatic artery and nearly 20% will have variant right portal venous anatomy. While controlling the right PV, special care should be taken to identify the posterior branch to caudate process and divide it in a controlled fashion to prevent troublesome bleeding. Extrahepatic control of inflow vessels for left-sided resection is relatively straightforward and carried out at the base of umbilical fissure.

Alternatively, the vascular pedicles can be controlled intra-hepatically and has the advantage of being rapid and unlikely to cause injury to the vascular inflow and biliary drainage of the contralateral liver. This approach is most useful for right-sided tumors located away from the hilum, which allow the use of this technique without compromising tumor clearance. The method relies on intrahepatic definition and control of the vascular pedicles. The intrahepatic pedicles are exposed after appropriate hepatotomies, dissected, encircled, and clamped. It is important to ligate the most caudal retro-hepatic veins draining from the caudate process and inferior part of the liver to the vena cava before attempting pedicular ligation. Failure to do so can result in hemorrhage during dissection of pedicles. Also, before dividing the pedicle, the integrity of vascular flow to the contralateral liver should be confirmed by ensuring good color of the remnant as well as by demonstrating the flow in the contralateral PV by intra-operative ultrasound.

Vascular Isolation

This technique is described for completeness, as it is rarely required, even during the removal of large tumor close to or involving the hepatic veins or IVC. As compared to inflow control with a Pringle maneuver, hepatic vascular exclusion combines inflow control with outflow occlusion, with or without interruption of caval flow and has more profound hemodynamic consequences. The advantage potential advantage of vascular exclusion is that the resection is performed in a relatively bloodless field; however, after flow is restored, there is often significant bleeding that requires control. Additionally, hepatic vascular exclusion is associated with 40–50% decrease in cardiac index, 50% increase in heart rate, 10% decrease in mean arterial pressure, and significant increase in systemic vascular resistance. Hepatic vascular exclusion also requires prolonged continuous inflow clamping and is not well tolerated by diseased liver. Combination of inflow control with low anesthetic central venous pressure-aided resection has largely obviated the need for total hepatic exclusion.

Acute Normovolemic Hemodilution (ANH)

Acute normovolemic hemodilution (ANH) is not intended to reduce the blood loss during hepatic resection but is actually aimed at blood conservation, thus reducing the consequence of resulting blood transfusion including risk of transmitting infections as well as immunosuppression. ANH involves the removal of whole blood from a patient immediately before a liver resection that is likely to be associated with significant blood loss. After blood removal, euvolemia is restored with crystalloid infusion. Crystalloid infusion reduces the hematocrit, and thus, the blood lost during the procedure has lower hematocrit. After the completion of the procedure, or if needed during the procedure, the harvested blood with higher hematocrit than the blood lost during the procedure is transfused back into the patient. For hemodilution to be effective and feasible, the patient must have adequate starting hemoglobin, sufficient blood volume must be removed, and surgical blood volume should fall within a certain range. ANH has been shown to reduce the requirement for allogenic blood transfusion by about 50% [13]. Despite concerns that ANH combined with significant blood loss during surgery can be potentially hazardous, multiple studies have demonstrated safety of this approach [14]. One of the major issues is the identification of patients who may benefit from the use of ANH. With improvement in surgical technique and better understanding of liver anatomy, the blood loss and the need for transfusion during and after liver surgery have decreased [9] and up to 75% of patients undergoing major hepatectomy (>3 segments resected) may not need allogenic blood transfusion [9]. Thus, selective application of ANH by identifying patients who have >50% likelihood to receive transfusion based on validated transfusion prediction model [15, 16] is both effective and resource conserving.

Management of Intra-Operating Bleeding During Liver Resection

When faced with more than usual bleeding during hepatectomy, inflow occlusion should be performed with a Pringle maneuver and then maintenance of low CVP should be confirmed. This can be ascertained by anesthesiologist measuring it through central monitoring; however, with experience, this can be estimated by looking at collapsibility, pulsations, and turgidity of the IVC. If necessary, the CVP can be lowered pharmacologically using venodilators (e.g., nitroglycerine). If the bleeding is from transected liver surface or from bottom of the hepatotomy, it should be located and controlled with a figure of eight stitches with 3-0 or 4-0 vicryl or suture ligature. Major pedicle or hepatic vein encountered in the line of transection can be controlled with vascular load of GIA stapler.

Bleeding from major hepatic veins or from the retro-hepatic IVC is a much more challenging and a potentially lethal problem. With low CVP, initial control can be obtained with pressure while exposure is optimized and the surgical and anesthesia teams prepare for the possibility of major blood loss. It must be emphasized that small injuries in these often difficult-to-access structures can turn quickly into much bigger problems if not managed appropriately. Small tears in hepatic vein or IVC can be controlled with one or two interrupted sutures, while larger lacerations may require a running suture. If there is a laceration in the IVC, before any attempt at controlling it, a stitch should be placed at its superior most aspect. This prevents the cephalad extension of the tear into the chest and thus prevents the aggravation of the problem. If the injury is in the accessible infra- or retrohepatic IVC, then pressure on either side of the tear, using sponge sticks or similar instruments, stops the bleeding and allows sutures to be placed more precisely. When injury to the hepatic veins or vena cava proves difficult to control with sutures, an alternative is to achieve control with direct pressure, using sponges or laparotomy pads and then to proceed with transection of the liver parenchyma, as planned. This strategy allows better exposure of the injured vessel, which can then be controlled definitively with a vascular stapler or sutures.

In case of ongoing catastrophic bleeding from major hepatic veins, the low CVP strategy will need to give way to large volume resuscitation with blood products. If usual efforts to control the bleeding are not successful, then infra-hepatic and supra-hepatic IVC control may be required sometimes through a median sternotomy or by splitting the diaphragm. For access to the supra-diaphragmatic IVC, diaphragm can be circumferentially dissected around the IVC which then provides access to supra-diaphragmatic IVC [17]. Alternatively, the xiphoid is resected and diaphragm below the xiphoid is incised. Then plane between diaphragm and pericardium is developed bluntly and the diaphragm is incised all the way from the xiphoid to the IVC, providing access to supra-diaphragmatic IVC (Fig. 20.3c and d) [18]. IVC clamping may lead to marked decrease in preload with drop in cardiac output and arterial pressure and may require volume expansion. A final alternative is to pack the abdomen with laparotomy pads, similar to hemorrhage control after major trauma, in order to stop the bleeding and transferring the patient to the ICU for resuscitation, correction of coagulopathy and hypothermia, and return to the operating room in 2–3 days. For peri-hepatic packing, the right costal margin is elevated, and the pads are strategically placed over and around the bleeding site. Additional pads should be placed between the liver, diaphragm, and the anterior chest wall. Pads are also placed under the liver in the Morrison's pouch. These packs essentially compress the liver from top and bottom and thus control bleeding from most venous sources.

Massive Hemorrhage During Pancreatic Surgery

The mortality and morbidity observed with pancreatic operations have decreased markedly over the past few decades. Early series in 1960s reported a mortality of up to 25 %, which in more contemporary times have decreased markedly to as low as 1–2 % mortality at large-volume centers. Massive intraoperative hemorrhage during pancreatic surgery is an uncommon event,

especially when performed at high-volume centers [19]. Pancreas sits in the retro-peritoneum cradled in a nest of major blood vessels. Hence, a detailed understanding of the vascular anatomy and potential areas of pitfalls is critical to perform safe pancreatic resection.

Pancreatic Anatomy

The pancreas is divided into four regions: head, neck, body, and tail. The head of the pancreas is surrounded by the C-loop of the duodenum. Just behind the neck is the IVC, the right renal artery, and both renal veins. The neck of the pancreas lies over the confluence of SMV, PV, and splenic vein. The SMV projects from the lower border of the pancreas and PV from the upper. Behind the pancreatic neck, there are no anterior branches of PV, which makes creation of retropancreatic tunnel anterior to the PV feasible. Another important branch with respect to pancreaticoduodenectomy is the first jejunal branch of SMV. This tributary can course either anterior or posteriorly to the SMA and may be carefully ligated to adequately expose the SMA for clear resection margin. The location and course of this branch can be determined preoperatively on cross-sectional imaging. The uncinate process of the pancreas wraps around the SMV and is in close broad contact with the SMA. This forms the most important surgical margin in resection of pancreatic cancer; the inferior pancreaticoduodenal artery is encountered in the course the uncinate resection.

Bleeding During Pancreaticoduodenectomy

Given the proximity of pancreas to major blood vessels, a potential for major hemorrhage exists during almost every step in pancreatic resections. Overall, SMV, PV, and SMV-PV confluence behind pancreatic neck is the major source of any troublesome hemorrhage during pancreatic surgery. Potential pitfalls during various steps during pancreaticoduodenectomy and methods to avoid them are described below.

1. **Kocherization of Duodenum:** The pancreatic head lies over the anterior surface of IVC, renal veins, and renal artery. Although uncommon, these major vessels can be inadvertently injured during this step. Also, the gonadal vein on the right side drains into the anterior surface of the IVC and is at risk for avulsion/injury during this dissection, causing troublesome bleeding. Knowledge of the relationship of these large caliber vessels with head of the pancreas and dissection in the correct avascular plain should help avoid this complication. In case of injury to the IVC or renal vessels, the bleeding initially should be controlled by pressure and ensuring adequate exposure with completion of Kocher maneuver and any additional necessary steps. Two sponge sticks placed on either side of the site of injury can help control bleeding, which can then be carefully localized and controlled by figure of eight 3-0 or 4-0 Prolene depending on the size of the vessel.
2. **Exposure of SMV in the infra-pancreatic location.** In the early steps of pancreaticoduodenectomy, the SMV is identified in the infra-pancreatic location. Extensive Kocher maneuver identifies the root of small bowel mesentery crossing anterior to the third portion of duodenum and provides access to the lateral aspect of SMV. Division of the greater omentum provides access to the lesser sac. As this division is carried to the right, it exposes the junction of right gastro-epiploic vein with the middle colic vein to form the gastrocolic trunk which then drains into the SMV. This conglomeration of delicate veins impedes access to the front wall of SMV. Injury or avulsion of these veins during dissection of SMV can cause significant bleeding and hinders visualization. Further, unplanned and ill-advised efforts to control the bleeding can make the injury worse or compromise mesenteric venous drainage. The hemorrhage should be controlled by gentle pressure while exposure is optimized. Precise identification of the source of bleeding, which generally is from

an avulsed vein branch, is the key and should be controlled with interrupted fine suture. Prevention revolves around gentle dissection and control of individual vein tributaries. If difficulty is encountered or the exposure is limited in this area due to tumor infiltration or aberrant anatomy, then SMV should be better defined by broadly opening the lesser sac and dividing the peritoneum on the lower border of pancreas before ligating the venous tributaries. Dividing the gastro-epiploic vein at its origin will improve exposure of the SMV. If there is tumor involvement of the SMV at this level, then distal control will be required; care must be taken to avoid injury to venous tributaries in this area.

3. **Circumferential dissection and division of CBD.** The two pitfalls possible during circumferential dissection and division of CBD are injury to PV, which is situated behind CBD, and if present injury to replaced or accessory right hepatic artery. Preoperative stenting of CBD may lead to intense inflammation in the space between CBD and PV and can make this dissection difficult. Identification of PV in the supra-pancreatic location by division of GDA and displacement of common hepatic artery toward the left will help expose and protect the PV. The CBD should be dissected from both medial and lateral aspects, staying close to the CBD wall. Undue force should be avoided. The presence of a replaced or accessory right hepatic artery should be evident by review of preoperative cross-sectional imaging as well as by intra-operative palpation of a pulse posterior-lateral to the CBD. To prevent injury, the replaced/accessory right hepatic artery should be carefully dissected off the CBD in its complete length. In case of inadvertent injury, the bleeding should initially be controlled by pressure, localized and then PV repaired with monofilament suture. Proper exposure may require division of CBD. An injured accessory hepatic artery can be tied off but replaced right hepatic artery should be repaired with a monofilament suture.
4. **Retro-pancreatic dissection of PV.** Dissection of the retro-pancreatic portion of the PV is another area where vascular injury can be a source of troublesome bleeding. The dissection of retro-pancreatic PV should be attempted only once both infra-pancreatic SMV and supra-pancreatic PV are clearly identified and dissected (Fig. 20.4a). Removal of the hepatic artery lymph node and division of gastroduodenal artery will help in clear identification of the supra-pancreatic PV. After the SMV is identified at the lower border of the pancreas and the PV is identified above the superior border of the pancreas, the next step is creation of retro-pancreatic tunnel. The lower border of pancreas is gently lifted with the help of a vein retractor or another blunt instrument, and retro-pancreatic PV is separated from the pancreatic neck by gentle blunt dissection. The key is to always stay on the anterior surface of PV. As mentioned before, there are no branches on the anterior surface, while there are multiple branches that enter on either lateral aspect. Also, it is important to realize that the PV, from its origin behind the pancreatic head, runs obliquely, toward the patient's right shoulder. Hence, it is critical to keep the supra-pancreatic PV in sight while developing this tunnel to guide the direction of dissection. No undue force should be applied and patient gentle strokes should be used. If any resistance is felt, then the dissection should be attempted from supra-pancreatic PV downwards.

If an injury occurs to the retro-pancreatic portion of SMV/PV, then the area should be packed and gentle pressure applied. The anesthesia team should be made aware of expected blood loss and should be given time to gain adequate access and blood products should be called for. Once adequately prepared, an attempt should be made to identify the injury by gently lifting the lower border of the pancreas. If the injury is substantial and inaccessible, behind the mid-portion of pancreatic neck, then the area should be packed, and consideration should be given to carefully dividing the pancreas to achieve better exposure; however, this maneuver may exacerbate the injury, and caution is advised. The bleeding can be controlled by compressing the vein

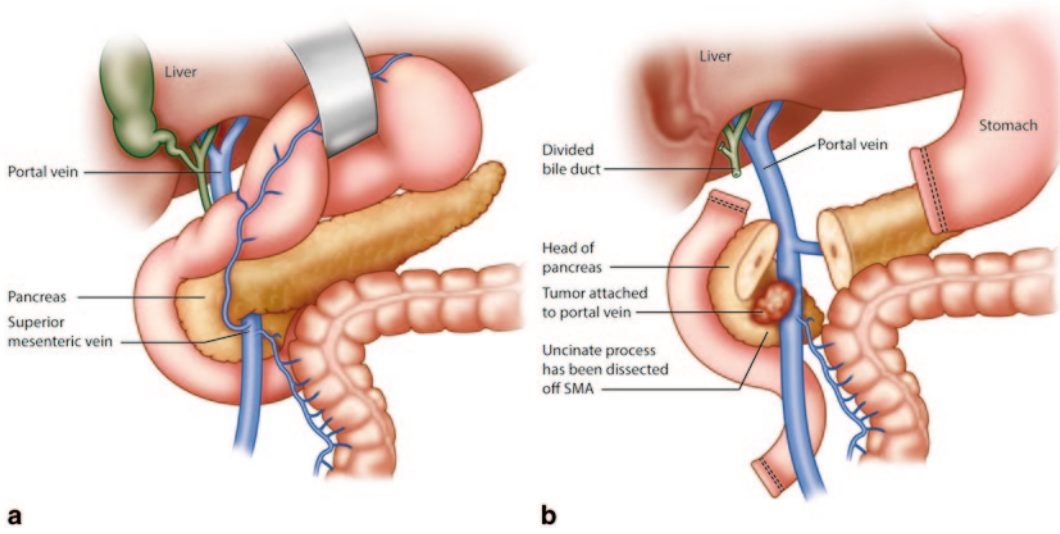

Fig. 20.4 Preventing injury to the retro-pancreatic *portal vein* during pancreaticoduodenectomy. **a** Prior to development of retro-pancreatic tunnel, supra-pancreatic *portal vein* and infra-pancreatic SMV should be well exposed. This facilitates proximal and distal control if there is an injury in retro-pancreatic location with major intra-operative hemorrhage. **b** When portal vein is involved with the tumor then *portal vein* resection/reconstruction should be left as the last step in the procedure. Even the posterior dissection of the uncinate process off the SMA should be carried out before resection and reconstruction of portal vein. Once this is accomplished, the extent of involvement of *portal vein* can be assessed and either side wall or segment of *portal vein* resected/reconstructed

with manual pressure from behind the pancreatic head. If needed, infra-pancreatic SMV and the supra-pancreatic PV can be encircled and controlled as they are well exposed at this point. If, despite control of infra-pancreatic SMV and supra-pancreatic PV, there is ongoing bleeding, then the splenic vein may have to be controlled. This can be achieved by encircling the body of the pancreas along with the splenic vein with a Rummel tourniquet.

5. **Dissection of the pancreatic head and uncinate process off the PV.** Division of the pancreatic neck exposes the lateral branches of SMV and PV to the head and uncinate process of pancreas. These branches are carefully dissected and controlled with suture ligature. In case of inadvertent injury and bleeding from these vessels, lifting the head of the pancreas and vein by placing a hand behind the head of the pancreas and duodenum controls the bleeding and allows localization of the site of bleeding. Bleeding can then be controlled with a monofilament suture. If the tumor is adherent to the vein, then an early decision should be made to resect and repair the vein. Continued attempt at dissecting the vein away from the tumor will lead to injury to the vein and will result in positive margin. When PV reconstruction is required, it is critical to complete all dissection, including dissection of uncinate process off the SMA, so that the resection of the vein is the last step (Fig. 20.4b). To dissect the uncinate process off the SMA, the specimen is retracted medially by the operator on the left side of the patient and with slow deliberate dissection uncinate process is dissected off the SMA. Extensive dissection of PV and division of the splenic vein can usually provide enough length to carry out PV reconstruction without vein graft.
6. **Dissection of the uncinate process off the SMA.** In the final steps of pancreaticoduodenectomy, the uncinate process is dissected off the right lateral aspect of the SMA. Branches from the SMA, particularly the inferior pancreaticoduodenal artery, course through soft tissue to the uncinate process and must be controlled. Undue traction should be avoided

at this step to prevent avulsion of these branches and more ominously the injury to the wall of SMA. If bleeding is encountered blind placement of clamps, cautery or energy devices should be avoided as accidental injury of SMA may occur with disastrous consequences. For minor arterial bleeding, lifting the specimen and the artery by placing a hand behind the head of the pancreas and duodenum may provide sufficient control to allow repair with monofilament suture. Proximal and distal control will be necessary to control and repair major injuries to the SMA.

7. **Mesenteric dissection.** Another potential problem area is the division of mesentery of distal duodenum and proximal jejunum. This generally is not a source of major intraoperative bleeding but can lead to bleeding in immediate postoperative period. The vessels should be controlled either with energy devices or with sutures and divided edge of mesentery should be carefully examined for any bleeding before closing.
8. **Distal Pancreatectomy in Presence of Splenic Vein Occlusion/Thrombosis.** Distal pancreatectomy is not commonly associated with major hemorrhage, but there are exceptions. First, in patients with tumors of the body or tail with splenic vein occlusion, extensive venous collateralization may occur, with risk of excessive bleeding. In this situation, control of the splenic artery on the superior border of the pancreas should be achieved early in the course of the dissection. This maneuver reduces splenic blood flow and decompresses the collaterals thus minimizing the bleeding. Second, tumors in the proximal pancreatic body may involve porto-splenic confluence, requiring a more extensive dissection of the portal and superior mesenteric veins, which is usually pursued after division of the splenic artery and the pancreatic neck. Proximal and distal control of the portal and superior mesenteric veins is required if the splenic vein is to be divided at its insertion; it must be remembered, however, that bleeding from lateral and posterior venous branches is not controlled with this maneuver and must be individually dividing. Finally, large tumors in the pancreatic body may extend posteriorly, putting the SMA and left renal vessels at potential risk for injury, and caution should be taken in these situations.

Summary

Hepato-pancreaticobiliary procedures are among the most complex abdominal operations, requiring extensive experience and specialized training. Successful hepatic and pancreatic resection requires detailed knowledge of anatomy, potential pitfalls, and awareness of strategies to circumvent difficult intra-operative situations. With comprehensive knowledge, adequate experience, meticulous technique, and sound judgment, these procedures can be performed with low morbidity and mortality.

5 Key Points to Avoid Complications

1. Comprehensive knowledge of vascular anatomy of the liver and pancreas is paramount for safe resection.
2. Deliberate dissection and exposure of hepatic veins and retro-hepatic vena cava facilitate control of bleeding in case of hepatic vein injury.
3. Maintenance of low central venous pressure during hepatic resection reduces blood loss and facilitates dissection of the hepatic veins and retro-hepatic vena cava and control of hepatic veins in case of bleeding.
4. Supra-pancreatic PV and infra-pancreatic SMV should be well exposed before attempting dissection of the retro-pancreatic PV. This helps in proximal and distal control in case of bleeding from the retro-pancreatic PV.
5. An early, deliberate decision to resect and repair the SMV/PV, when involved by tumor, prevents positive margin as well as injury and uncontrolled bleeding from PV.

5 Key Points to Manage Complications

1. In case of intra-operative hemorrhage during liver resection, inflow control, if not already underway, should be obtained with Pringle maneuver. If present, separate control of an accessory/replaced left hepatic artery should also be obtained.
2. In the presence of low CVP, bleeding from hepatic veins or retro-hepatic veins can generally be controlled by pressure followed by suture control. Rarely, in the face of massive hepatic venous blood loss and hemodynamic instability, placement of abdominal packs is the only means of achieving temporary control.
3. Control of catastrophic bleeding from hepatic veins or retro-hepatic vena cava may require increased exposure, by carrying the incision into the right chest, by incising diaphragm or with a median sternotomy and control of the infra- and supra-hepatic vena cava.
4. In case of bleeding from the retro-pancreatic PV, division of pancreas provides good exposure to the injury and allows for suture control. Proximal and distal control and control of splenic vein may need to be obtained.
5. Bleeding from the lateral branches of SMV and PV can be controlled by placing a hand behind the head of the pancreas and duodenum and applying pressure, thereby allowing localization and suture control.

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Intraoperative Injury to Hepatic Arterial Structures

21

Vinod P. Balachandran and Michael I. D'Angelica

Introduction

Hepatic arterial branches serve as important anatomic landmarks in surgery of the liver, pancreas, and biliary tree. Their close proximity to the common bile duct (CBD) and portal vein (PV), as well as anatomic variations in 20–50 % of patients [1, 2], make them susceptible to inadvertent injury during hepatopancreatobiliary (HPB) surgery. Hence, a thorough understanding of normal and variant anatomy, clinical scenarios permitting sacrifice or dictating preservation of hepatic arterial branches, and techniques to anticipate, prevent, and safely navigate intraoperative injury are essential components of the armamentarium of every HPB surgeon.

Normal Anatomy of the Hepatic Arterial Vasculature

The celiac trunk, arising off the aorta below the aortic hiatus of the diaphragm, provides blood supply to the liver and upper abdominal viscera. After a short course, it trifurcates into the splenic artery, left gastric artery (LGA), and common hepatic artery (CHA) (Fig. 21.1). The CHA curves to the right along the superior border of the pancreas and gives off the gastroduodenal artery (GDA) as it crosses anterior to the PV. The GDA runs inferiorly, giving rise to superior pancreaticoduodenal arteries (SPDA) that anastomose to branches of the inferior pancreaticoduodenal artery (IPDA) from the superior mesenteric artery (SMA). This collateral circulation between the SPDA and IPDA contributes to a rich arterial plexus supplying the head of the pancreas and duodenum and allows for preservation of flow to upper abdominal viscera in the setting of pathologic decreased flow through the celiac trunk. Distal to the GDA origin, the CHA becomes the proper hepatic artery (PHA), courses superiorly, and bifurcates into the right hepatic artery (RHA) and left hepatic artery (LHA). The PHA gives off a smaller right gastric artery (RGA) from its anterior surface that supplies the lesser curvature of the distal stomach. The origin of the RGA is variable, occasionally arising from the CHA, RHA, or LHA. The LHA gives rise to a middle hepatic artery (MHA) supplying segment IV of the liver, smaller branches to the caudate lobe, and a separate branch feeding segments II and III of the liver. The MHA occasionally arises from the proximal RHA. The arterial branches to the left liver then join the left PV and left hepatic duct in the umbilical fissure invaginating Glisson's capsule and forming the left inflow pedicle. Shortly after its origin, the RHA gives off a cystic

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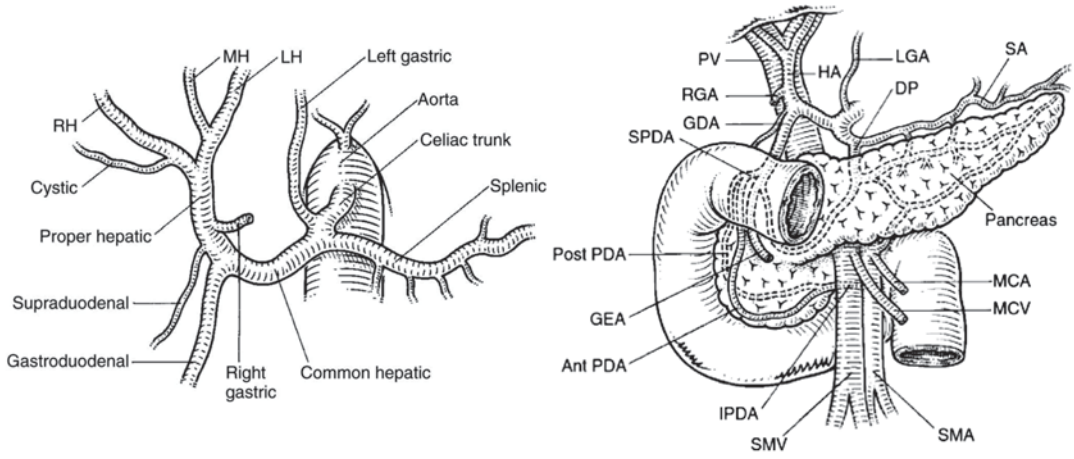

Fig. 21.1 Normal arterial anatomy of upper abdominal viscera. *RH* right hepatic artery, *MH* middle hepatic artery, *LH* left hepatic artery, *PV* portal vein, *RGA* right gastric artery, *GDA* gastroduodenal artery, *SPDA* superior pancreaticoduodenal artery, *Post PDA* poster branch of the superior pancreaticoduodenal artery, *Ant PDA* anterior branch of the superior pancreaticoduodenal artery, *GEA* gastoepiploic artery, *IPDA* inferior pancreaticoduodenal artery, *SMV* superior mesenteric vein, *SMA* superior mesenteric artery, *MCV* middle colic vein, *MCA* middle colic artery, *SA* splenic artery, *DP* dorsal pancreatic artery, *LGA* left gastric artery, *HA* hepatic artery (proper hepatic artery). (With permission from [82] © Springer 2012)

artery supplying the gallbladder and continues to supply segments V, VI, VII, VIII, and the caudate process [3]. In 80% of patients, the RHA runs posterior to the common hepatic duct before entering the substance of the right liver along with the right portal and biliary branches as the right portal pedicle. The RHA commonly branches into posterior and anterior sectoral vessels, which can often be dissected extrahepatically. Overall, the hepatic arteries supply 25% of blood flow to the liver and 50% of the liver's oxygen content, while the remainder is derived from the PV [4]. The blood supply to the CBD arises from the RHA and the retroduodenal branches of the GDA (Fig. 21.1). The most important vessels lie at the 3 o'clock and 9 o'clock locations. Approximately 40% of the blood supply runs downward from branches of the RHA [3, 5].

Variant Anatomy of the Hepatic Arterial Vasculature

Anatomic variations of the hepatic arterial vasculature are common, and a thorough knowledge of these anomalies is essential to preventing injury. Although Haller first published his treatise on variant hepatic arterial anatomy in 1756, a systematic analysis of hepatic arterial variations was not undertaken until 1966 when Michels described 10 anatomic variants based on 200 cadaveric dissections [6]. Following Michels, Hiatt and colleagues classified hepatic arterial variations into six types (Fig. 21.2) based on 1000 patients who underwent liver harvest for transplantation [7]. Numerous other groups have since reported on variant hepatic arterial vasculature, based on cadaveric dissections, liver harvest for transplantation, and angiographic evidence (Table 21.1) [8–11]. A hepatic arterial branch is termed *replaced* when it does not arise off the PHA but supplies a hemi-liver. A hepatic arterial branch is termed *accessory* when it supplies part of a hemi-liver in addition to an arterial branch off the PHA. The most common variations are a replaced RHA (RRHA) arising from the SMA (3–15%), replaced LHA (RLHA) arising off the LGA (2–10%), normal anatomy with an accessory LHA (ALHA) off the LGA (≤10%), and normal anatomy with an accessory RHA (ARHA) off the SMA (≤7%) (Table 21.1) [6, 9–16].

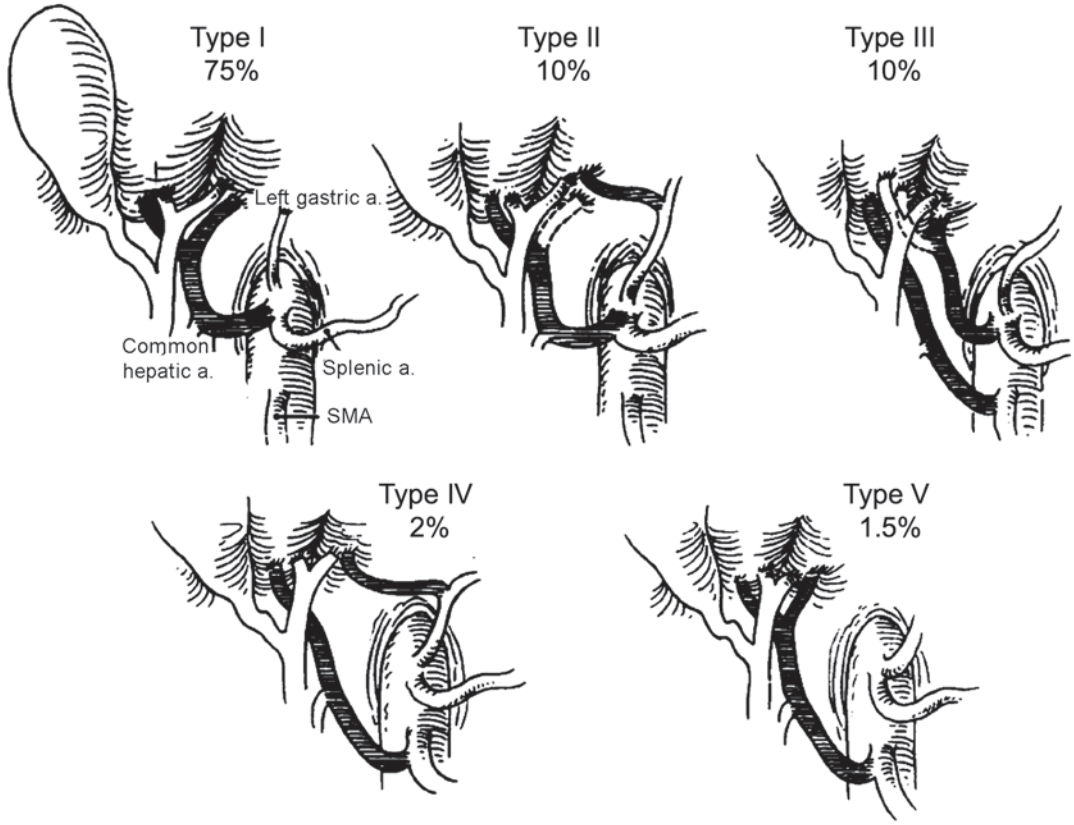

Fig. 21.2 Hiatt's classification of hepatic arterial variations. *Dotted lines* indicate that the variant artery may be accessory (*if branch shown by dotted line is present*) or replaced (*if absent*). *Type I*: normal anatomy; *Type II*: replaced or accessory left hepatic artery; *Type III*: replaced or accessory right hepatic artery; *Type IV*: replaced or accessory right hepatic artery+replaced or accessory left hepatic artery; *Type V*: Common hepatic artery from the superior mesenteric artery; *Type VI*: Common hepatic artery from the aorta (not shown). (With permission from [7] © Lippincott Williams and Wilkins 1994)

Replaced and Accessory Right Hepatic Arteries

Aberrant RHA anatomy is the most common and surgically relevant variant. Both a RRHA and ARHA arise from the SMA, travel posterior to the pancreatic head, and enter the hepatoduodenal ligament posterolateral to the CBD. Although many anatomic courses including through the pancreatic parenchyma have been reported, including through the pancreatic parenchyma [1], a dissectable groove usually exists between these vessels and the pancreas (Table 21.1, Fig. 21.2).

Replaced and Accessory Left Hepatic Arteries

Replaced and accessory LHAs arise from the LGA, run in the substance of the lesser omentum anterior to the caudate lobe, and join the left PV and left hepatic duct on the left side of the base of the umbilical fissure (Table 21.1, Fig. 21.2).

Replaced Common Hepatic Artery

A replaced CHA (RCHA), referred to as the hepatomesenteric trunk, most commonly arises from the SMA posterior to the pancreatic head [17], but also can run through the pancreatic parenchyma

Table 21.1 Variant hepatic arterial anatomy [6, 9–16]

Arterial anatomy	Frequency (%)
Proper hepatic artery branching into right and left hepatic arteries	52–80
Replaced arteries	
Left hepatic artery from left gastric artery	2–10
Right hepatic artery from superior mesenteric artery	3–15
Left hepatic artery from left gastric, right hepatic from superior mesenteric artery	<3
Common hepatic artery from superior mesenteric artery	1–5
Common hepatic artery from left gastric artery	<1
Common hepatic artery from the aorta	<1
Accessory arteries	
Left hepatic artery from left gastric artery	≤10
Right hepatic artery from superior mesenteric artery	≤7
Left hepatic artery from left gastric, right hepatic from superior mesenteric artery	<1
Replaced and accessory arteries	
Replaced right hepatic artery (from superior mesenteric artery), accessory left hepatic artery (from left gastric artery)	<2%
Replaced left hepatic artery (from left gastric artery), accessory right hepatic artery (from superior mesenteric artery)	<2%

(Table 21.1, Fig. 21.2) [18–20]. Rare variants include RCHA off the LGA, or off the aorta [17].

Celiac Artery Stenosis

Although not an anatomic variant, celiac artery stenosis (CAS) is an important vascular abnormality in HPB surgery. Blood supply through the celiac trunk is impaired, leading to retrograde flow from the SMA through the pancreaticoduodenal arcades, dorsal pancreatic artery, and arc of Buhler (an embryonic communication between the celiac and SMA observed in 2% of population) [21]. In patients with CAS, retrograde flow through the GDA is the primary source of arterial blood to the liver and commonly manifests as an unusually large GDA or pancreatic collateral vessel. The incidence of CAS ranges from 10 to 25% of the population [21]. The pathophysiology may be divided into the following three categories:

- *Extrinsic compression:* It is commonly due to the median arcuate ligament, an enlarged celiac ganglion, or fibroinflammatory tissue. The median arcuate ligament joins the left and right diaphragmatic crura, contacting the aorta cephalad to the celiac trunk. However, it can pass anterior to the celiac artery in up to 25% of individuals. Extrinsic compression is the most common cause of CAS in Asian populations (55%) [21, 22].
- *Intrinsic stenosis:* Intrinsic stenosis is secondary to atherosclerotic disease and is the most frequent cause of CAS in Western countries [21, 23].
- *Other etiologies*: These include neoplastic invasion, pancreatitis, acute or chronic dissection, or intimal disruption [21].

Preoperative Radiographic Assessment

Careful radiographic assessment allows for the identification and anticipation of anatomic and pathologic factors such as variant anatomy or malignant vascular invasion that may increase susceptibility to injury, necessitate ligation, or require reconstruction. For preoperative evaluation prior to pancreas resections, the best imaging modality is a pancreas protocol CT scan, which includes contrast-enhanced thin-cut arterial and venous phase imaging through the pancreas [24]. Although direct angiography remains the gold standard for assessing vascular anatomy and is the only modality that identifies directional flow, it is rarely used as arterial phase CT angiography, with or without angiographic reconstruction has a reported accuracy of 98% for detecting arterial anatomic variations [25, 26], and has the advantage of delineating the relationship of arteries to adjacent organs or tumor [27]. The advent of multidetector-row CT scanners has further enhanced pancreatic imaging, enabling prediction of visceral vessel involvement and resectabil-

ity in 80–90% of pancreas resections [28]. MRI typically includes arterial and portal phase imaging and is comparable with CT in predicting vascular invasion and local tumor extension. It is particularly useful when patients are intolerant to intravenous contrast agents and when greater soft-tissue contrast or visualization of the pancreatic duct and biliary tree is desired, such as while evaluating cystic pancreatic neoplasms [29]. Arterial reconstruction is also possible with MR imaging (MR angiography). Endoscopic ultrasound (EUS), an operator-dependent modality, has not been shown to be superior to CT in determining arterial involvement [30]. We do not routinely use EUS to assess resectability or vascular anatomy.

For radiographic evaluation prior to liver resection, CT scans using a triphasic protocol (noncontrast, arterial, and portal venous phase) are helpful in assessing hepatic parenchymal disorders such as steatosis, cirrhosis, lobar/segmental atrophy, as well as normal and variant hepatic anatomy. CT angiography can also be used and is a valuable tool in facilitating surgical planning and avoiding iatrogenic injury [31]. MRI/MRCP is considered by many to be superior to CT in assessing the liver and biliary tree and can be combined with MR arteriography to simultaneously assess vascular structures [29].

Preoperative Considerations

Preoperative management focuses on recognizing clinical scenarios where hepatic artery injury and subsequent arterial compromise can lead to liver and biliary ischemia/necrosis. The hepatic arteries contribute to 25% of hepatic blood flow and 50% of oxygen delivery [4]. Ligation of hepatic arterial branches was historically a feared complication due to the consequent risk of liver necrosis and death. These beliefs were based on very early experiences with hepatic arterial ligation—in 1933, Graham and Cannell reported a mortality rate of approximately 60% in a review of 28 cases where the CHA, PHA, RHA, or LHA was ligated [32]. Mortality in that era, however, was heavily influenced by deficiencies in perioperative care, including anesthetic techniques, antibiotics, and transfusion medicine. In 1964, Starzl and colleagues observed in four patients that ligation of the CHA, PHA, RHA, and LHA in patients with normal liver function only resulted in mild transaminitis and not death [33]. They went on to examine all reports of hepatic artery branch ligation in patients without cirrhosis or hepatic artery aneurysms between 1933 and 1964. They concluded that ligation of any hepatic arterial branch (CHA, PHA, RHA, or LHA) in patients with normal liver function results in mild transient transaminitis and rarely leads to liver necrosis and death. Flow through the PV and arterial collaterals was sufficient to maintain hepatic oxygenation, provided factors increasing hepatic oxygen demand or decreasing PV blood flow (shock, jaundice) were absent. These seminal early observations established the safety of hepatic arterial branch ligation and served as the basis for later investigations into its mechanisms and therapeutic potential.

Following these data demonstrating its safety, Plengvanit demonstrated that ligation of the CHA, RHA, or LHA resulted in collateral formation commonly through the right inferior phrenic and subcostal arteries in addition to multiple other collateral sources, which was evident angiographically as early as 1 week after ligation [34]. Mays and Wheeler made similar observations, demonstrating collateral circulation could develop as early as 10 h after ligation of the RHA or LHA [35]. With these data and advances in perioperative care of the surgical patient, hepatic artery ligation was used to control hemorrhage in the setting of liver trauma [36, 37] and also as therapy for metastatic disease to the liver [38]. Ligation of the PHA was accompanied by a transient increase in transaminases, alkaline phosphatase, and bilirubin, confirming the earlier observations by Brittain and Starzl [33, 39]. We employ these principles of hepatic arterial branch ligation routinely in HPB surgery, particularly during placement of hepatic arterial pumps for regional chemotherapy [40, 41]. We have noted through dye injection perfusion tests performed while placing hepatic artery pumps that cross-perfusion after ligation of arterial branches occurs within minutes. These principles have also been utilized for tu-

Table 21.2 General principles of hepatic artery preservation

No jaundice or liver dysfunction
Ligation of the CHA and PHA has been shown to be safe; however, attempts at reconstruction are reasonable
Ligation of a hepatic arterial branch(es) is generally safe with one patent hepatic arterial branch
Ligation of all hepatic arterial branches is generally not advised although historical data have shown it to be safe
Jaundice or liver dysfunction
Ligation of any hepatic arterial branch is not advised due to the risk of hepatic ischemia/necrosis
Biliary anastomosis
Ligation of either RHA/RRHA or GDA alone is safe
Ligation of both RHA/RRHA and GDA is not advised due to the risk of anastomotic dehiscence or stricture

CHA common hepatic artery, *PHA* proper hepatic artery, *RHA* right hepatic artery, *RRHA* replaced right hepatic artery, *GDA* gastroduodenal artery

mors of the body/tail of the pancreas involving the celiac axis, where en-bloc resection of the celiac and CHA is performed (Appleby procedure) after confirming adequate collateral flow through the GDA [42, 43]. In summary, with respect to the risk of clinically significant liver ischemia/necrosis, ligation of hepatic arterial branch(es) is safe in patients with normal liver function, no jaundice, and hemodynamic stability, provided a single remaining hepatic arterial branch is patent (Table 21.2). Ligation of the CHA or PHA in patients with normal liver function, no jaundice, and hemodynamic stability has also been shown to be safe; however, avoiding injury is preferable and reconstruction of an injured CHA/PHA is reasonable. In the setting of liver dysfunction or jaundice, hepatic reliance on arterial supply for oxygenation is increased, possibly due to increased metabolic demand of hepatocytes and greater susceptibility to hypoxia and decreased intrahepatic portal flow due to local compression from dilated bile ducts [44–46]. Ligation of any hepatic arterial branch in these settings should be avoided as it may worsen liver dysfunction and precipitate liver failure.

A second concern with ligation of a hepatic arterial branch, primarily the RHA/RRHA, is the effect on the biliary tree. Isolated ligation of the RHA/RRHA has not been shown to increase the risk of biliary stricture formation or biliary anastomotic dehiscence, likely due to arterial cross-perfusion at the hilar plate from the LHA, and intact blood supply from the GDA [47]. However, interruption of both components of biliary blood supply (RHA and GDA) in the setting of a biliary reconstruction is associated with a risk of anastomotic dehiscence and stricture formation [48, 49].

Preoperative interventions are therefore directed toward clinical situations that may violate principles of hepatic artery preservation, thereby increasing the risk of liver and biliary complications (Table 21.2). Three preoperative techniques have been described to minimize the risk of liver ischemia when a hepatic artery branch is at risk for injury. The first and most commonly used technique is preoperative biliary drainage in jaundiced patients. Although demonstrated to increase overall perioperative complications for pancreas resections [50, 51], preoperative biliary drainage improves liver function and likely relieves pressure on the portal system from the bile ducts, thereby minimizing the risk of postoperative liver ischemia [52]. We recommend preoperative biliary drainage in patients with obstructive jaundice when a hepatic arterial branch is at risk for injury or clearly requires ligation or reconstruction (and hence risks thrombosis) during surgery (Fig. 21.3). A second technique that has been described but is less commonly used is embolization of the arterial branch to be sacrificed, to preoperatively promote development of collateral flow to the corresponding hepatic segment(s), thereby minimizing postoperative ischemia [53]. We have only occasionally used this technique in our practice. A third preoperative technique to minimize liver ischemia, used in patients with CAS and expected GDA ligation at surgery, is celiac artery stent placement (Fig. 21.3). Stenting of the celiac artery has been reported to decrease the risk of biliary/pancreatic anastomotic disruption and liver ischemia [54–57], with 80–95%

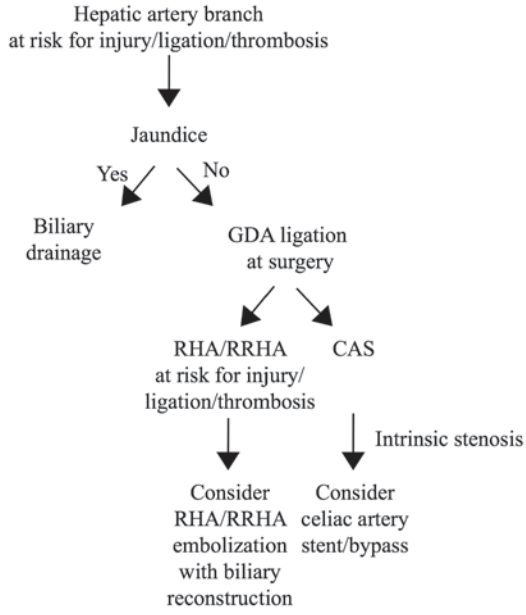

Fig. 21.3 Preoperative vascular considerations in hepatobiliary and pancreatic resections. *RHA* right hepatic artery, *RRHA* replaced right hepatic artery, *CAS* celiac artery stenosis, *GDA* gastroduodenal artery

success rates [21, 58, 59]. Anticoagulation to prevent stent thrombosis and an adequate waiting period to allow for collateral development are important considerations prior to staged resection. If stenting is not possible, surgical bypass, either at the time of or prior to planned resection, is the only option.

Preoperative considerations to minimize the risk of biliary ischemia are relevant in patients with a RRHA and GDA that will be ligated or are at risk for injury or thrombosis. In this setting, embolization of the RRHA to allow for collateral flow to develop to the bile duct prior to resection and anastomosis has been reported (Fig. 21.3) [60]. However, we rarely use this technique as the RRHA can often be preserved without margin compromise, or can be reconstructed [61, 62].

Intraoperative Considerations

Meticulous dissection with complete exposure and identification of structures prior to division is essential to prevent inadvertent hepatic artery injury. The CHA can be identified by its relationship to the hepatic artery lymph node (HALN), located at the superior border of the pancreas, medial to structures in the HD ligament. The HALN abuts the superior wall of the CHA, just proximal to the GDA origin and careful removal exposes the CHA near the GDA origin. The CHA can be mistaken for the RHA, the LHA, or even the splenic artery and inadvertently ligated, underscoring the need for complete exposure and identification as well as test clamping prior to division of any structure. Injury to the CHA and PHA can be difficult to successfully suture repair primarily, although this has been described [63]. Reconstruction options include primary anastomosis, transposition of native arteries (splenic artery, right gastroepiploic artery, GDA) [64–68], or interposition grafts with autologous tissue such as the gonadal vein [69]. Vascular reconstruction of the hepatic artery is technically challenging and not commonly performed by HPB surgeons; hence, assistance from a vascular or transplant surgeon can be helpful and sought out if necessary.

Specific Intraoperative Considerations

Pancreaticoduodenectomy (PD)

Replaced/Accessory Right Hepatic Artery

A RRHA/ARHA is in close proximity to the bile duct and head of the pancreas (and therefore close to tumors in the head of the pancreas) in the posterolateral space of the hepatoduodenal ligament and is therefore at risk for injury during a PD. If the patient is jaundiced, preoperative biliary drainage is indicated (Fig. 21.3). Meticulous dissection during mobilization of the CBD, duodenum, and pancreatic head commonly allows preservation of a RRHA/ARHA, without compromise of margin status or outcomes [61, 62]. Altering the operative approach has also been described as a technique to minimize the risk of injury. The most common approach to a PD is through an anterior approach, dissecting the head and uncinate process off the PV, followed by dissection along the SMA. Although this may still be safely feasible, a posterior or "artery first"

approach should be considered when a RRHA/ARHA is noted. A posterior approach allows for early assessment of resectability, SMA identification, and proximal control [70–74]. If intraoperative injury or involvement by tumor necessitates ligation of a RRHA, reconstruction is recommended to prevent bilio-enteric anastomotic and hepatic ischemia as the GDA is commonly ligated in a PD. Reconstruction of an ARHA is advised in jaundiced patients to prevent liver necrosis, as discussed earlier (Table 21.2). Injury to the RRHA/ARHA can be repaired by primary anastomosis, venous or prosthetic interposition, or reconstruction using a ligated GDA stump [65, 75–77].

Replaced Common Hepatic Artery

A RCHA is a rare anatomic variant and of greatest significance during a PD. If identified on preoperative workup, a posterior approach is helpful, whereby the SMA and the RCHA takeoff is identified first and GDA ligation is delayed until the RCHA is clearly identified and noted to be free of tumor. The anatomic course of a RCHA is important in choosing the best operative strategy. If it courses through the pancreas, it can be preserved by dividing the pancreas lateral to it—this approach however may compromise margin status. If it has an anastomotic connection to the LGA or another accessory artery, ligation without compromise of arterial supply to the liver and extrahepatic biliary tree has been reported. Finally, if it is involved and must be sacrificed, reconstruction is indicated and has been described using autologous vascular grafts such as the GDA or saphenous vein [78].

Celiac Artery Stenosis

CAS is of significance in a PD if the liver is dependent on retrograde GDA flow for arterial supply. If test clamp of the GDA leads to loss of a pulse in the porta hepatis, four options exist.

- *Examination of the celiac axis for extrinsic compression*
  Division of external compression due to median arcuate ligament, fibrous tissue, or an enlarged celiac ganglion can be effective at immediately restoring arterial flow.
- *Preservation of GDA*
  GDA-preserving PD has been described and is technically demanding, however feasible [79]. It may be a less attractive option for patients with malignant tumors due to an incomplete nodal clearance and may be more appropriate for benign or small tumors.
- *Revascularization*
  Revascularization can be achieved through either bypass or arterial reimplantation. Bypass can be performed using autologous vein or PTFE between the aorta and the hepatic artery, middle colic artery to the GDA stump, and venous bypass between the splenic artery and iliac artery [21]. Arterial reimplantation can be achieved through reimplantation of the celiac trunk into the aorta, or the splenic artery into the SMA [21].
- *Postpone procedure*
  Postponing the resection allows for celiac stent placement or elective revascularization followed by a delayed attempt at resection.

Hemi-hepatectomy

Preservation of arterial supply to the remnant liver during a hemi-hepatectomy is crucial to prevent liver ischemia to the regenerating future liver remnant. As a general principle, we advocate complete arterial dissection and visualization of both right and left hepatic arteries, test clamping of the ipsilateral artery to be ligated, and confirmation of a contralateral pulse prior to dividing any structures in the porta.

Right Hepatectomy For a right hepatectomy, the RHA is most easily ligated to the right of the common hepatic duct to protect the LHA from inadvertent injury. Preservation can be confirmed by palpating a pulse at the base of the umbilical fissure after temporary occlusion of the RHA. Division of the RHA distal to the common hepatic duct also allows for medial traction of the proximal stump, which is useful in exposure of the right PV. Injury to the LHA is rarely a concern during division of a RRHA/ARHA.

Left Hepatectomy During a left hepatectomy, the LHA can occasionally be mistaken for the

GDA if it has an initial inferior course. The PHA can also be mistaken for the LHA if the division into a RHA and LHA occurs distally in the porta hepatis. The safest technique to ensure selective ligation of the LHA is to perform a test clamp of the artery and ensure a contralateral pulse prior to division. A RLHA/ALHA is easily visualized in the gastrohepatic ligament, and contralateral arterial injury is not a concern as it is divided.

Hilar Tumors Tumors in the hepatic hilum can present unique surgical problems as they may invade vascular structures entering the liver. Hilar cholangiocarcinomas that extend along the left hepatic duct can present particular difficulty as they require a left hepatectomy to obtain a complete resection, while they can simultaneously invade the RHA given the usual proximity of the RHA to the posterior aspect of the common hepatic duct. Both preoperative and intraoperative techniques have been described to address this, including preoperative embolization of the PHA [53, 80], and reconstruction of the RHA using the gastroepiploic artery, GDA, LHA, and vein grafts [75, 81].

Conclusions

The close relationship of hepatic arterial branches to structures in the porta hepatis and their frequent anatomic variations, compounded with the presence of tumors that often exhibit a tropism toward vasculature, render branches of the hepatic artery particularly susceptible to injury during HPB surgery. Fortunately, much experience has been gained to aid our understanding of the anatomic and clinical factors that predispose the liver and biliary tree to complications following ligation of hepatic arterial branches. A thorough understanding of these clinical principles, comprehensive knowledge of normal and variant anatomy, careful preoperative radiologic evaluation, and meticulous intraoperative technique will allow surgeons to safely navigate potentially fatal clinical scenarios and minimize complications following complex hepatobiliary and pancreatic resections.

Key Points: Preoperative Interventions

1. Evaluate normal and variant hepatic arterial anatomy using CT with arterial phase imaging and/or CT angiography.
2. Perform preoperative biliary drainage in jaundiced patients with significant risk of injury, ligation, or thrombosis of any hepatic arterial branch.
3. In a hemi-hepatectomy, consider preoperative embolization of the arterial supply to the remnant liver if it is at substantial risk of ligation, injury, or thrombosis.
4. Consider stent or arterial bypass in patients with hemodynamically significant atherosclerotic stenosis of the celiac artery and expected operative ligation of the gastroduodenal artery.
5. Consider preoperative embolization of the right hepatic artery in patients requiring biliary reconstruction with significant risk of loss of both the right hepatic artery and the gastroduodenal artery.
6. In situations where preservation of a hepatic artery branch(es) is critical, make necessary preparations for possible operative reconstruction such as availability of appropriate grafts or surgical consultations.

Key Points: Intraoperative Principles

1. Without jaundice, injury to a hepatic arterial branch(es) can generally be treated with ligation, provided a single patent hepatic arterial branch remains. Injuries to the common and proper hepatic arteries have been safely treated with ligation, although reconstruction is reasonable.
2. With jaundice, injury to any hepatic arterial branch requires repair given the risk of hepatic necrosis and life-threatening complications with occlusion.
3. With a biliary-enteric anastomosis, ligation of either the right hepatic artery or the gastroduodenal artery is safe. Ligation of both is not advised given the risk of anastomotic complications.

4. Loss of a pulse in the porta hepatis with gastroduodenal artery clamping indicates celiac artery stenosis. Division of the gastroduodenal artery will hence risk significant hepatic/biliary ischemia and biliary-enteric anastomotic complications. Dividing sources of extrinsic compression and immediate or delayed operative revascularization should be considered.
5. During extrahepatic arterial ligation in a hemi-hepatectomy, test clamp and confirm a pulse to the contralateral liver remnant, and/or expose both hepatic arterial branches before ligation to avoid inadvertent injury to the contralateral arterial supply.

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Hepatic Abscess

22

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Etiology

Recent advances in surgical technique and perioperative management, as well as more careful patient selection and better understanding of liver anatomy and physiology, have significantly improved mortality rates to less than 3–5% after liver and pancreas surgery. However, the overall morbidity rate after hepatic resection remains high, ranging from 15 to 45%, and up to 80% in prospectively collected series evaluating pancreaticoduodenectomy (PD) [1–12]. The incidence of postoperative hepatic infection has been reported to vary between 2.6 and 8.6% in more recent large studies [1–12]. In pancreas surgery, the risk occurs following PD but not distal pancreatectomy, which is likely due to the most well-recognized contributing factor—the presence of a biliary-enteric anastomosis [8].

The negative impact of postoperative complications on long-term oncological outcome has been reported after partial hepatectomy for colorectal metastases and hepatocellular carcinoma with postoperative sepsis being an independent predictor influencing disease free and overall survival [3, 4, 13–15]. The mechanism behind which postoperative sepsis negatively affects long-term outcomes in oncologic surgery is not completely understood, but has been linked to negative effects of the systemic inflammatory response on the immune system. In addition to the adverse effect of postoperative infectious complications on long-term outcomes after liver and pancreas surgery, the morbidity of infectious complications also results in increased hospital stay, resource utilization with subsequent higher costs of inpatient stay, and mortality. Therefore, early recognition and aggressive treatment of infectious complications are of pivotal importance to reduce postoperative complications and improve oncologic outcomes.

Perioperative blood loss and blood transfusion have been associated with systemic side effects and negative impacts on postoperative outcome, with blood loss remaining one of the main predictors of morbidity and mortality after liver and pancreas resection [14–19]. Blood product transfusion has been assumed to have a deleterious effect on the immune system by suppressive effects on host immunity via a reduction in natural killer cell function, decreased cytotoxic T-cell function, increased numbers of suppressor T cells, and decreased function of macrophages and monocytes. Some of these effects may be mitigated by the use of leukocyte depleted allogenic blood

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transfusions; however, larger studies are required to confirm this assumption [20]. The correlation between blood loss and blood transfusion and postoperative infection has been demonstrated in multiple studies involving hepatic resections for colorectal metastases, hepatocellular carcinoma, and cholangiocarcinoma [3–6, 8, 11, 21]. Meticulous surgical technique and advances in hemostatic approaches for liver and pancreas resection have led to a significant decrease in perioperative blood loss and the need for blood transfusion in patients. Despite this, a number of factors contribute to poor postoperative outcomes following liver and pancreas surgery.

The presence of bile leakage is associated with postoperative infectious complications [5, 8–10, 12]. The incidence of bile leakage ranges in the literature from approximately 4.0 to 17%, with common etiologies consisting of inadequate control from the parenchymal transection margin, leakage at a bile duct-intestinal anastomosis, or injury of the remnant bile duct [10, 22–24]. Biliary stricture plays a significant role in development of postoperative hepatic abscess, particularly in patients who have had a biliary stent and thus have contaminated bile. In a recent series evaluating hepatic abscess after PD, both the need for reoperation, the majority of whom required revision of their choledochojejunostomy, and the presence of a biliary fistula contributed to the risk of hepatic abscess [8]. There was no effect on long-term survival, although the numbers were small. If suspicion for bile leak remains elevated, imaging techniques such as hepatic scintigraphy and magnetic resonance imaging (MRI) with hepatocyte-specific contrast agents or more invasive techniques such as endoscopic retrograde cholangiopancreatography can be employed.

Significant steatosis (>30%) has also been associated with a threefold increase in overall postoperative complications following hepatectomy, with a twofold increase in patients with <30% steatosis undergoing more extensive resections involving greater than three segments compared to patients without steatosis [25]. Nonalcoholic fatty liver disease may affect up to 30% of the Western adult population with its prevalence mirroring that of obesity and the metabolic syndrome which is also expected to increase in non-Western countries due to globalization of the Western diet [26]. Imaging techniques, specifically MRI, are being developed to quantify fat composition of the liver, which would allow hepatobiliary surgeons to have an informed discussion with patients with significant steatosis about the risks of major hepatic surgery.

Vascular injury plays a strong role in the development of postoperative hepatic abscess. A poorly perfused liver remnant and/or ischemia to the biliary anastomosis will increase the risk of hepatic abscess, particularly in the setting of contaminated bile and/or biliary stricture. Thus, meticulous technique is essential. Other factors have been associated with postoperative infectious complications, such as serum albumin level, presence of multiple medical comorbidities, longer operative times, and increasing complexity of hepatic resection. Preoperative biliary drainage in patients with hyperbilirubinemia secondary to obstruction has also been associated with increased postoperative infectious complications due to bacterial contamination.

Diagnosis

Technological advances have significantly enhanced the role of radiology in the detection, characterization, and management of postoperative changes in the liver. All cross-sectional imaging techniques allow for a high rate of detection of postoperative fluid collections, and in addition, image-guided percutaneous drainage procedures have greatly improved the clinical treatment of patients with postoperative infections throughout the abdomen and pelvis.

Computed Tomography

Due to its ready availability with high spatial and contrast resolution, computed tomography (CT) is the best approach for imaging patients who are stable enough to be transported to the radiology department. Intravenous contrast is preferred to

evaluate for any complications in the perioperative period as well as to assess the enhancement characteristics of postoperative fluid collections in order to improve detection of infected collections rather than postoperative fluid. The use of intravenous contrast and multiphasic imaging also allows for the assessment of patency of the hepatic vasculature. However, iodinated contrast agents must be used cautiously or not at all in the setting of acute or chronic renal failure and in patients with an iodinated contrast allergy, unless they are appropriately pretreated. Oral contrast is not mandatory but if tolerated will likely be of benefit in aiding the detection of bowel pathology or to distinguish postoperative fluid collections from adjacent loops of bowel. On CT examination, abscesses generally are hypoattenuating on both contrast-enhanced and noncontrast examinations with attenuation values between 0 and 45 Hounsfield units, and are most commonly directly adjacent to the resection bed. Infected collections typically demonstrate a rim of contrast enhancement and will usually result in adjacent inflammatory changes in the peritoneal cavity or retroperitoneal fat. The presence of gas within a collection either as an air-fluid level or bubbles of gas can be a specific sign for postoperative infection, however is not commonly present. Higher attenuation collections in the postoperative bed may represent hematoma or the residual of hemostatic material used intraoperatively. Postoperative intrahepatic abscesses are also hypoattenuating and are generally well-defined masses, which may be unilocular with smooth margins or complex with internal septations and irregular contours [27]. The presence of gas within a collection either as an air-fluid level or bubbles of gas can be a specific sign for postoperative infection, although it is not commonly present. Higher attenuation collections in the postoperative bed may represent hematoma or residual hemostatic material used intraoperatively. The use of oxidized regenerated cellulose (Surgicel) can be identified in the surgical bed up to 1 month after placement. During placement, air likely gets trapped with blood within the interstices of the oxidized cellulose sponge and produces focal linear or curvilinear gas collections which can be confused for postoperative infections [28].

Ultrasound

Ultrasonography (US) is an imaging modality, which can be performed at the bedside in patients not stable enough to travel to the radiology department for other modes of cross-sectional imaging. US is, however, limited by the fact that certain anatomic areas are difficult to visualize and can be affected by patient body habitus, wounds, surgical drains, and overlying bowel gas in the setting of postoperative ileus. Ultrasound is also subject to operator variability and has been shown to be inferior to CT in evaluating postoperative patients with sepsis [29]. At the time of US, large perihepatic fluid collections can demonstrate an appearance ranging from hypoechoic to hyperechoic, with varying degrees of internal echoes and debris. Gas in postoperative fluid collections causes acoustic shadowing or reverberation artifacts. Small intrahepatic abscesses often appear as discrete hypoechoic nodules or ill-defined areas of distorted hepatic echogenecity [27]. Surgical hemostatic packing or omental flaps may appear as echogenic masses in the operative bed and may demonstrate reverberation artifact, which can be suggestive of infection [30]. The patency of the hepatic vasculature can also be assessed at the time of US with the addition of color and pulsed Doppler evaluation when waveform and velocity analysis is included.

Magnetic Resonance Imaging

The role of MRI in evaluation of the early postoperative patient who is displaying signs of potential sepsis may be limited due to patient factors; however, with its multiplanar multisequence capability and the use of hepatobiliary-specific contrast agents, MRI is being used more often for imaging of the postoperative patient. Postoperative fluid collections can have variable T1 and T2 signal intensity based on the protein content in

the collection. Abscesses commonly demonstrate inhomogeneous areas of low T1 signal intensity with intermediate to high T2 signal intensity. After the administration of gadolinium contrast, an infected fluid collection will often display peripheral rim enhancement. Intrahepatic abscesses may also demonstrate some mild perilesional edema, which manifests as intermediate to high signal intensity on T2-weighted images. Air within a collection will demonstrate a signal void on all acquired sequences and may be difficult to differentiate from calcifications; however, the shape and location of the signal void should allow the correct diagnosis. Diffusion-weighted imaging also has been shown to be helpful in distinguishing infected fluid collections from cystic or necrotic tumors and noninfected fluid collections with abscesses typically showing restricted diffusion [31]. Also, in the postoperative setting, if there is concern for bile leak or bile duct injury, the use of hepatocyte-specific contrast agents can add functional information to that obtained using conventional T2-weighted imaging and may be particularly useful in identifying the site of a bile leak, or identifying an area of biliary stricture which may be contributing to the hepatic abscess [32]. Multiphasic MRI protocols also are ideally suited to evaluate the patency of the hepatic vasculature, which may be a complicating factor in the development of abscess formation. Surgicel demonstrates marked low signal intensity on T2-weighted images and is easy to distinguish on MRI from a postoperative fluid collection [33].

Treatment

Once the diagnosis of postoperative hepatic infection is suspected on the basis of clinical findings and supportive imaging results, prompt treatment is of paramount importance, as delay in initiation of treatment may adversely affect patient outcomes [2]. Administration of broad-spectrum antibiotics should not be delayed and aggressive source control should be pursued. The choice of antibiotic regimen should cover the more common pathogens associated with postoperative hepatic infection such as Gram-negative enteric and Gram-positive cocci organisms [2, 34–37]. The choice of antibiotic regimen and duration of therapy is guided by culture results and sensitivities as well as clinical factors such as improvement in symptoms, decreased leukocytosis, and duration of drainage if a catheter is placed.

Minimally invasive image-guided percutaneous treatments such as needle aspiration and catheter drainage have supplanted surgical therapy for the treatment of pyogenic liver abscesses, with resultant significant decreases in hospital stay, overall cost, and morbidity. Thus, percutaneous therapy is now considered first-line treatment in the setting of postoperative hepatic infections [38, 39]. Repeat laparotomy still plays a critical role for the treatment of recalcitrant infections which are failing more conservative percutaneous treatment strategies, but this is exceedingly rare in the context of modern era interventional radiologic techniques and contemporary broad-spectrum antibiotics. Abscesses less than 3 cm in size can usually be treated successfully with parenteral antibiotics alone; however, aspiration plays a critical role in establishing the diagnosis of infection in postoperative fluid collections and specific microbial identification in order to direct antibiotic therapy [40] (See Fig. 22.1). Image-guided needle aspiration by either US or CT has been shown to be highly effective for simple abscesses less than 5 cm in size [38, 41, 42]. Multiple aspiration sessions may be required for complete success. Image-guided percutaneous catheter drainage is preferred for abscesses larger than 5 cm in size, complex abscesses, or those in direct continuity with bile ducts or bowel [38, 39, 42, 43].

Prior to minimally invasive image-guided therapies, assessment should include evaluation of coagulation parameters with a target INR <1.5, aPTT of less than 1.5x control, and platelet count $>50{,}000/\mu L$ with correction of these parameters on a case by case basis [44]. Ultrasound or CT guidance can be used for aspiration or catheter drainage based on operator preference. When choosing a puncture path, the least amount of hepatic parenchyma should be traversed, and care should be taken to avoid damaging adjacent organs or traversing the pleura due to the risk of empyema (See Fig. 22.2). Ultrasound is

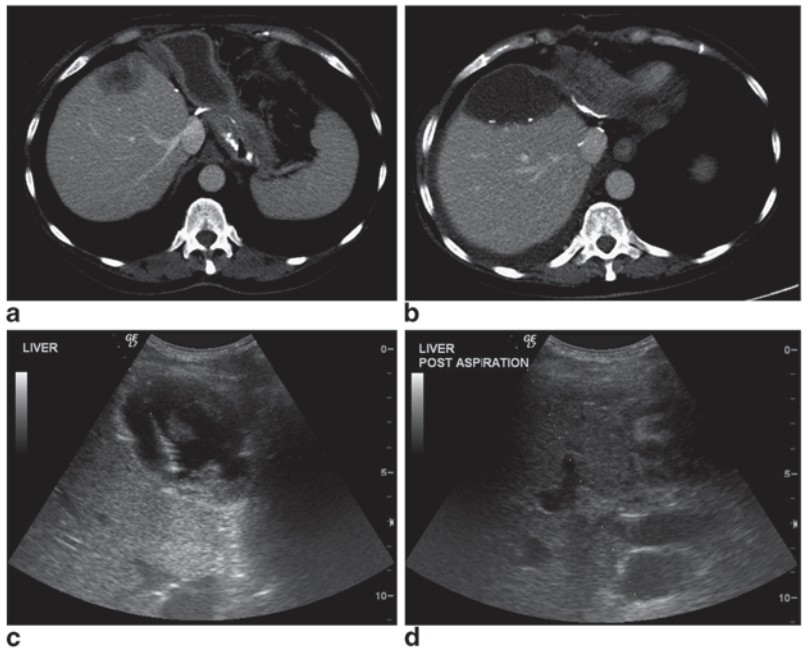

Fig. 22.1 A 50-year-old female presenting with biopsy-proven recurrent epitheliod hemangioendothelioma 6 years post living-related liver transplantation measuring 3.8 × 2.9 cm (**a**) underwent an uneventful nonanatomic wedge resection of the lesion with adequate margins. The patient presented to the hospital on postoperative day 12 with worsening right upper quadrant pain, subjective fevers, and chills. A CT examination demonstrated a 7.8 × 4.6 cm hypoattenuating fluid collection in the resection bed with a few small foci of scattered gas without significant rim enhancement (**b**). The patient's white blood cell count was not elevated at 8.8 K/uL; however, due to her immunosuppression and presenting symptoms there was concern for postoperative infection. The patient was initiated on broad-spectrum antibiotics and the fluid collection was subsequently aspirated under US guidance where it demonstrated a complex appearance with predominantly hypoechoic appearing fluid with echogenic debris (**c**). The collection was completely aspirated with removal of approximately 60 mL of dark bilious appearing fluid (**d**). The Gram stain and culture were negative and the patient did not require any further management

the preferred imaging modality in most cases due to real-time guidance, multiplanar imaging, portability, visualization, and avoidance of major blood vessels and pleura/lung, and lack of ionizing radiation. Ultrasound-guided procedures can be performed via a subcostal or intercostal approach. A subcostal approach is generally favored over an intercostal puncture due to a lower risk of pneumothorax, empyema, or intercostal artery injury. Sonographically guided interventions can be performed using either a free-hand technique (which provides for greater freedom in needle placement), or with an attached biopsy guide which provides greater accuracy. Local anesthetic should be liberally applied from the skin entry site down through the subcutaneous fat and peritoneum directly adjacent to the fluid collection. If possible, the needle should be placed during a breath hold to reduce the risk of capsule laceration and to facilitate needle entry at the site of local anesthetic administration. Visualization of any adjacent large vascular structures can also be assessed with Doppler US prior to needle placement. CT guidance may be beneficial in scenarios where sonographic visualization is limited by either appearance of the collection on US, adjacent wound complications necessitating a different trajectory, and also to confirm appropriate needle placement utilizing US guidance (See Fig. 22.3). Most interventional CT units are capable of CT fluoroscopy and gantry angle adjustment which aid in procedural planning. Needle aspiration is usually performed with an 18-gauge needle and samples should be appropriately sent for microbiologic analysis. During attempted needle aspiration, if the fluid is too viscous for adequate

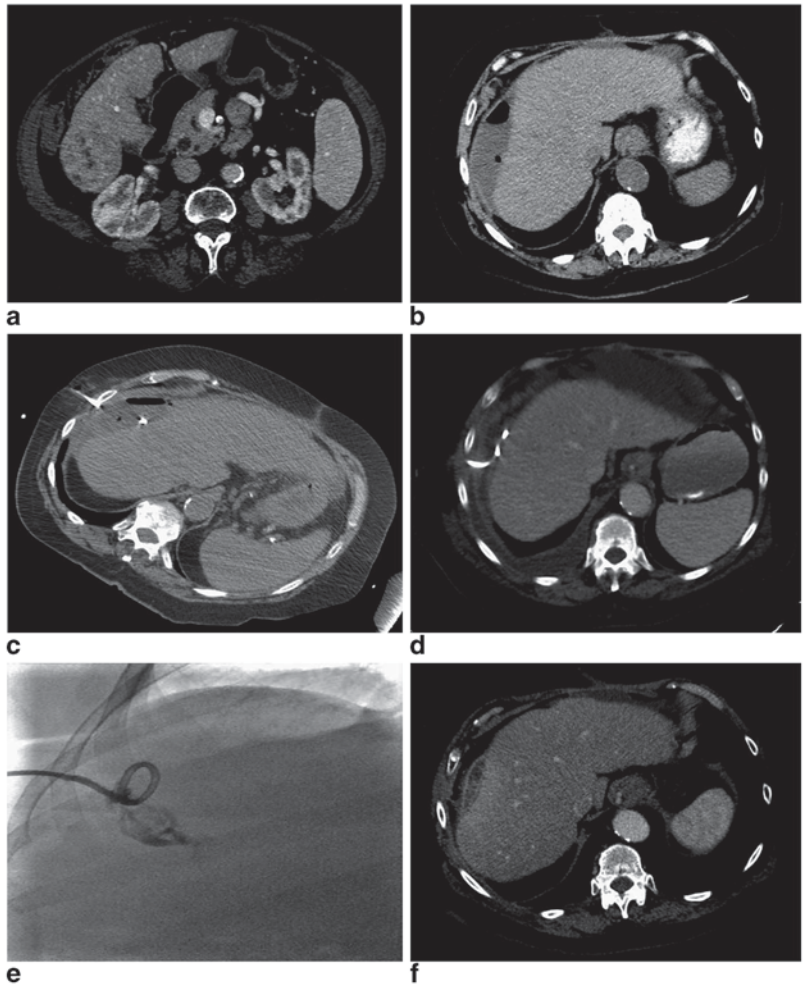

Fig. 22.2 A 68-year-old female with history of cirrhosis secondary to NASH and alcoholism, Child Pugh class A, insulin-dependent diabetes mellitus, and coronary artery disease who presented with a 5.6 cm arterially enhancing exophytic mass in segment 6 of the liver with portal venous washout consistent with hepatocellular carcinoma (**a**). The patient underwent an uneventful nonanatomic wedge resection, which revealed a well-differentiated HCC without vascular invasion. Her postoperative course was remarkable for postoperative bleeding which was managed with transfusion of two units of packed red blood cells and she was discharged on postoperative day number 8. She presented with increasing right upper quadrant pain approximately 8 weeks after surgery and laboratory evaluation revealed a normal white blood cell count. A CT of the abdomen and pelvis demonstrated a 10.8 × 3.5 cm rim enhancing hypoattenuating fluid collection with an air-fluid level along the right lateral liver (**b**). CT guidance was utilized for an intercostal approach into the collection and a 10 Fr locking loop drainage catheter was placed with aspiration of 60 mL of purulent fluid, which grew *Enterobacter cloacae* and *Escherichia coli* (**c**). She was discharged on appropriate antibiotic therapy, however, presented to the hospital 2.5 weeks after percutaneous drainage catheter placement with altered mental status. A CT examination demonstrated near-complete resolution of the abscess cavity; however, the drainage catheter was noted to cross the pleura and there was a new pleural effusion with enhancement (**d**). A diagnostic thoracentesis was performed with aspiration of 260 mL of serosanguinous fluid, which grew methicillin-resistant *staphylococcus aureus* (images not shown). The patient's antibiotic regimen was adjusted accordingly and an abscessogram was performed demonstrating no significant residual collection or evidence of biliary or bowel fistula and the catheter was removed (**e**). A follow-up CT examination 6 weeks status post drainage catheter removal demonstrates no residual pleural fluid and a small amount of residual inflammatory changes in the abscess cavity with no evidence of residual or recurrent disease (**f**)

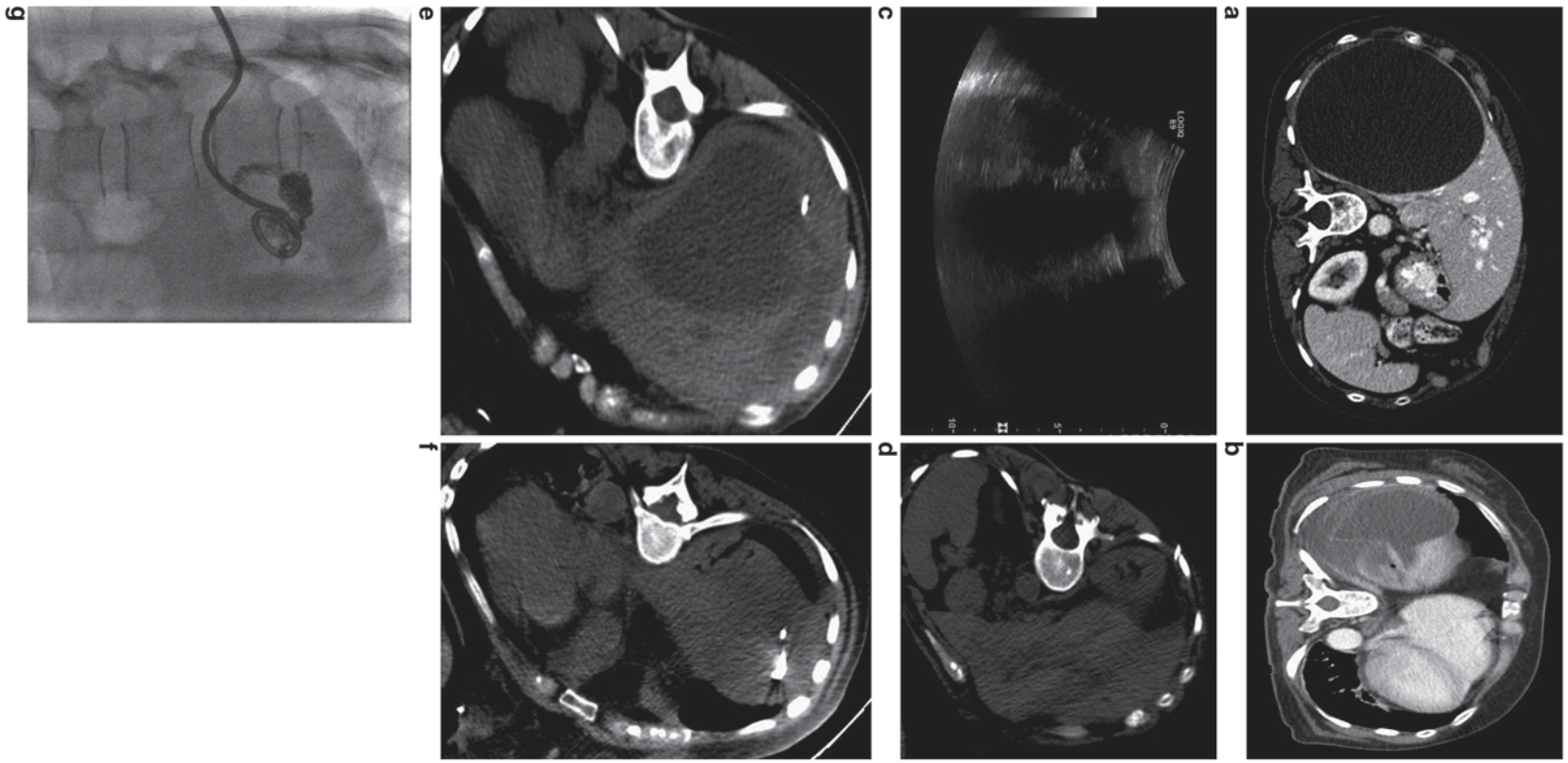

Fig. 22.3 A 67-year-old female presented with a large symptomatic simple appearing cyst (14.4 × 11.8 × 15.9 cm) in the dome of the liver (**a**) and underwent laparoscopic cyst wall fenestration and cyst wall fulguration. She was discharged home the next day but presented to the emergency department on postoperative day 7 with worsening right shoulder and flank pain with a leukocytosis of 12.8 K/uL. A CT of the abdomen and pelvis was obtained, which demonstrated a low attenuating fluid collection with a thin rim of peripheral enhancement adjacent to the site of prior laparoscopic cyst fenestration with a small focus of air (**b**). The fluid collection was accessed via an intercostal approach underneath the 11th rib posteriorly utilizing US guidance through the rib interspaces with aspiration of serosanguinous fluid (**c**). A limited noncontrast CT performed after placement of the needle under US guidance confirmed appropriate positioning of the needle and due to the concern for an infected collection, a 10 Fr locking loop catheter was placed (**d–f**). The aspirate grew *Escherichia coli* and the patient was treated with appropriate oral antibiotics. After 2 weeks of active catheter drainage, an abscessogram was performed, which demonstrated no significant residual collection or communication to the biliary system and the catheter was uneventfully removed (**g**)

drainage or is frankly purulent, a catheter can be placed in the same setting utilizing the Seldinger technique. Catheter drainage may also be performed utilizing the trocar technique and a multiside hole, locking catheter of various sizes can be placed. Abscess drainage catheter monitoring and care is of critical importance to ensure adequate drainage. Abscess catheters are usually flushed up to three times daily with sterile normal saline to prevent clogging. The output from the catheter should be recorded on a daily or per shift basis, and the presence of high outputs is suggestive of a fistula to the cavity. Clinical parameters such as drain output, hemodynamic status, leukocyte count, and culture results should be followed on a daily basis in the early postprocedure period to evaluate the patient's clinical progress. Catheters can be placed to either suction or gravity drainage. Passive drainage may minimize catheter occlusion secondary to aspirated debris within the abscess cavity; however, active drainage (suction) may result in more rapid evacuation of the abscess with opposition of the abscess cavity wall. Patients who do not respond clinically to percutaneous drainage catheter placement should be further evaluated with cross-sectional imaging, preferably CT, to assess the adequacy of catheter placement and/or the development of new potential sites of infection. In the event of catheter malfunction or inadequate drainage of the collection, the drainage catheter can be exchanged over a wire for larger bore catheters; however, in some cases of significant loculation or debris, more than one catheter may be required for adequate percutaneous management. Another option to aid in the success of percutaneous abscess drainage is the administration of thrombolytic agents through the abscess drainage catheter. If follow-up imaging demonstrates a persistent abscess cavity despite optimal drain placement and sizing, tissue-type plasminogen activator (tPA) can be instilled into the cavity to promote further drainage. Common practice is to dilute 4–6 mg of tPA in 25 mL of sterile 0.9% normal saline and infuse through the catheter and allow it to dwell for 30 min–1 h. Afterward, the drainage catheter is replaced to passive or active drainage, and the outputs from the catheter are monitored closely. This technique can be performed from once per day up to three times per day as long as it is effective. Thrombolytic therapy in abscess cavities can be effective due to the presence of a fibrin matrix within the cavity which when administered can result in breakdown of loculations and reduction of the viscosity of the fluid within the collection. Thrombolytic therapy has proved to be a safe and effective therapy even in the postoperative period with minimal to no risk of bleeding [45]. Drainage is usually continued until the patient demonstrates clinical improvement and drainage output is less than 10–20 mL/day [46]. The length of time required for successful percutaneous catheter drainage is highly variable and dependent on multiple patient and infection site factors. A fluoroscopic abscessogram can be performed prior to catheter removal to assess the residual size of the cavity and the presence of fistulization to the bowel or biliary system if indicated.

Success rates for image-guided needle aspiration of simple pyogenic liver abscesses less than 5 cm in size approach 100% with minimal complications [38, 41, 42]. Catheter drainage success rates have varied significantly in the literature from 66 to 100% likely secondary to abscess and patient factors. Higher failure rates have been associated with the presence of advanced malignancy, particularly necrotic infected tumors, and the presence of fistulization to an obstructed biliary system [39, 43]. Aggressive management of biliary obstruction/injury in the setting of postoperative abscess formation is of critical importance to ensure resolution. The risk of complications is minimal with complications such as pneumothorax, empyema, intraperitoneal hemorrhage, and mild pain being the most frequently reported.

Five Key Points on How to Avoid Complications

1. Assure well-perfused liver remnant following hepatectomy
2. Assure liver remnant has adequate biliary drainage following hepatectomy
3. Assure biliary-intestinal anastomoses are well perfused

4. Assure biliary-intestinal anastomoses are widely patent at the time of surgery
5. Limit biliary stents as much as possible

Five Separate Key Points on Diagnosing and/or Managing the Complication

1. Obtain contrasted CT or MRI for unexplained postoperative fever
2. Utilize interventional radiologic drainage whenever it is technically feasible
3. Utilize broad-spectrum antibiotics once diagnosed
4. Utilize surgical approach only for refractory cases
5. Multidisciplinary team input is critical

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Hepaticojejunostomy Anastomotic Strictures

23

François Cauchy and Jacques Belghiti

Introduction

For patients requiring bilioenteric anastomosis, Roux-en-Y hepaticojejunostomy (HJ) remains the procedure of choice in the vast majority of the cases. Several complications may occur following the creation of HJ. These include anastomotic strictures, stone formation, reflux of gastrointestinal content into the biliary tree, obstruction of the Roux-en-Y anastomosis [1], and both de novo [2] and recurrent malignant disease [3]. HJ anastomotic stricture, which is defined as the narrowing of the anastomosis leading to biliary obstruction and retention, accounts for more than 50% of these complications. Indeed, state-of-the-art hepaticojejunostomy requires precise creation of a (1) tension-free, (2) widely patent (3) mucosa-to-mucosa anastomoses using (4) well-vascularized bile ducts that (5) drain all parts of the liver. The lack of one or several of these conditions dramatically jeopardizes the quality of the anastomosis and puts the patient at risk of stricture development. HJ anastomotic strictures may cause recurrent cholangitis with life-threatening risks and, after several years, may also evolve toward biliary cirrhosis, hepatic failure, or even death. However, both diagnosis and treatment of HJ stricture may be difficult. While surgical repair was the treatment of choice several years ago, there has been growing interest in more conservative approaches with the development of balloon dilatation and stricture stenting. Hence, modern management of these strictures is often multimodal, requiring repeated therapeutic sessions and combined approaches.

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Diagnosis

Clinical and Biological Presentation

HJ stricture progressively leads to retention of contaminated bile. In this setting, any mild elevation of g-GT (gamma-glutamyl transferase) and trasnsaminase level and also transitory fever should highlight the possibility of a nascent anastomotic stricture. Once the stricture occurs, presenting symptoms are dominated by cholangitis in 80% of the cases, with isolated jaundice occurring in only 15% of the cases [1]. However, these symptoms are not specific and may be related to other causes of HJ malfunction, including intrahepatic stone formation without HJ stenosis, stenosis of the Roux-en-Y anastomosis, or the so-called sump syndrome, which is defined as the reflux of gastrointestinal content into the biliary tree because of inadequate length of the Roux-en-Y loop [4]. Likewise, in patients operated on for malignant disease, surgeons should also systematically rule out the possibility of loco-regional disease recurrence [3]. Finally, in transplanted

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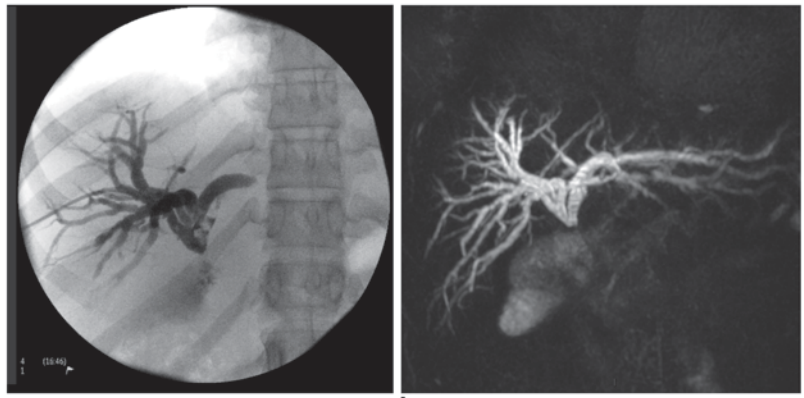

Fig. 23.1 Hepaticojejunostomy stenosis following early repair of a bile duct injury during laparoscopic cholecystectomy in a 27-year-old women. This patient was successfully managed using repeated sessions of percutaneous dilatation. **a** Percutaneous cholangiography. **b** Magnetic cholangiography

patients, impairment of liver functional tests or symptoms such as jaundice or cholangitis may account for non-anastomotic biliary strictures, graft rejection, viral infections, arterial complications, and recurrent primary disease. In this setting, diagnosis of HJ strictures should therefore be retained only after complete workup ruling out other complications has been performed.

Morphological Evaluation

Even though ultrasound (US) examination and computed tomography (CT) have no place in the direct visualization of anastomotic strictures, they should be routinely performed in the management of these patients. Indeed, both US and CT scan may be of value in the evaluation of nonspecific indirect signs of strictures and may allow for the assessment of differential diagnoses and stricture-related complications. Historically, diagnosis was achieved using percutaneous transhepatic cholangiography (PTC) (Fig. 23.1a), which may also allow for direct visualization of the strictures using cholangioscopy [5]. However, since this invasive procedure is associated with both risk of vascular injury in approximately 2 % of the cases [6] and septic complications, it should now be restricted to therapeutic purposes or rare situations of inconclusive magnetic resonance (MR) cholangiography. Indeed, MR cholangiography has become the standard morphological examination in the assessment of HJ stenosis and allows direct visualization of the strictures with a sensitivity reaching more than 90 % (Fig. 23.1b) [1]. Other anecdotal diagnostic modalities include endoscopic retrograde cholangiography, which has been reported to be feasible in 58–93 % of HJ patients [7–9], or percutaneous transjejunal endoscopy, which may be facilitated in patients with prior subcutaneous fixation of the Roux-en-Y loop [10, 11], but has been also successfully reported using US-guided puncture of non-fixed loops in experienced hands [12, 13].

Incidence and Risk Factors According to the Clinical Context

Since creation of HJ may be required in various surgical situations, both incidence and risk factors of HJ strictures widely vary according to the clinical context (Table 23.1).

Iatrogenic Bile Duct Injury

Since the description of the Hepp and Couinaud biliary-enteric anastomosis using the extrahepatic left hepatic duct [14], HJ has remained the standard procedure in the surgical management of most postcholecystectomy bile duct injuries.

Table 23.1 Incidence and risk factors of hepaticojejunostomy strictures according to the clinical situation

Indication for HJ	Incidence of strictures (%)	Risk factors
Bile duct injury	5–22	Sepsis during repair
		Absence of bile duct dilatation
		Postoperative biliary leakage
Liver transplantation (LT)		
Deceased donor	2–21	Primary sclerosing cholangitis
Living donor	6–22	Graft related factors:
		Steatosis, Prolonged cold ischemia time, donor age > 50 years
		Technical factors:
		Biliary anatomical variation, small ducts, no microsurgical repair
		Postoperative complications:
		Biliary leakage, arterial thrombosis, CMV infection
Pancreatic head resection	2.6	–
Choledochal cyst excision		
Children	0–6	Type Iva cysts
Adults	5–24	Short duration of symptoms
		Large-sized cysts
		Age > 10 years

In this setting, HJ anastomotic strictures nevertheless occur in 5–22 % [15–19] of the patients. The absence of bile duct dilatation has long been incriminated as the most prominent risk factor for the development of HJ stricture following bile duct injury repair [16], leading some authors to either postpone the intervention until bile duct dilatation was obtained or to routinely use transanastomotic stents on non-dilated bile ducts [20]. However, several studies have highlighted that early repair achieved similar results as delayed biliary reconstruction provided that the procedure was performed by a specialist hepatobiliary surgeon [21]. This clearly emphasizes the need for early diagnosis and referral to a specialized HPB unit. Other risk factors for the development of HJ stricture include the presence of biliary peritonitis at repair [22] and postoperative complications following the repair, especially biliary leakage [16], which both intuitively increase the risk of postoperative inflammatory stenosis. Finally, the impact of an associated right hepatic arterial injury in the occurrence of anastomotic stricture is still a matter of ongoing debate [15, 21, 22], with several arguments suggesting a role of arterial injury in favoring ischemia and retraction of the bile ducts and others supporting a rapid revascularization through the anastomosis. In our experience, routine CT scan with vascular reconstruction is always performed to preoperatively assess the arterial vascularization. Similarly, we believe that both operative evaluation of the biliary vascularization and confection of high anastomoses may help to prevent postoperative strictures. Finally, we consider that the existence of an associated vascular injury should probably lead to considering early repair with the utmost caution.

Liver Transplantation (LT)

In deceased donor liver transplantation (LT), HJ is more and more restricted to a limited number of situations including large disparity in size between the recipient's bile duct and the donor's bile duct, liver retransplantation, LT for primary sclerosing cholangitis, and biliary atresia. In these situations, the incidence of HJ strictures ranges from 2 %, in the case of liver retransplantation [23], to 21 % in patients with PSC [24]. In this latter setting, it has been recently suggested that duct-to-duct anastomosis (DDA) provided better long-term functional results than HJ [24] without increasing the risk of disease recurrence [25, 26], supporting that it should be probably preferred

over HJ. In living donor LT, no randomized study has yet documented the superiority of DDA over HJ. Hence, HJ is still performed in 20–40% of the cases [27, 28]. In this latter setting, biliary anastomotic strictures represent the Achilles heel of these procedures with reported rates ranging from 6 to 22% [29, 30]. The occurrence of HJ strictures may be the consequence of: (1) impaired graft quality as evidenced by increased rates of HJ strictures with significant steatotic grafts [31, 32] with prolonged cold ischemia time [33] or grafts from donors aged >50 years [30]; (2) technical factors including biliary anatomical variations [31] requiring >1 biliary anastomosis [30] and small donor right or left bile ducts; [31]; and (3) postoperative complications, mainly biliary leakage [30, 34], hepatic artery thrombosis [35], CMV infection [35], and acute cellular rejection [33]. Obviously, prevention of HJ strictures in patients undergoing LDLT may essentially be achieved by improving the selection of the grafts with the systematic use of preoperative donor liver biopsy but also with refinements in surgical technique. In this latter setting, Lin et al. have emphasized the value of routine microsurgical biliary reconstruction in decreasing the number of anastomotic strictures regardless of both types and number of ducts [27].

Pancreatic Head Resection

Biliary complications following pancreatic head resection are often neglected and overlooked by those involving the pancreatic anastomosis. Hence, only one study has to date specifically examined the incidence of biliary strictures after pancreaticoduodenectomy (PD) [3]. In this large single-center study analyzing 1595 patients undergoing PD over 8 years, 42 (2.6%) patients experienced HJ stricture and median time for stricture occurrence was 13 (median: 1-98) months. No significant risk factor for the development of strictures was observed with only marginal influence of preoperative biliary drainage and no impact of either common bile duct size or postoperative biliary leakage. Interestingly, the rates of strictures were also strictly similar in patients operated on for benign and malignant disease. In this latter context, less than 10% of the patients were found to have recurrent neoplastic disease involving the bilioenteric anastomosis. Of these, none were operated on for pancreatic or ampullary carcinoma supporting that development of a biliary stricture in these patients is usually benign. However, all patients with malignant anastomotic strictures carried a diagnosis of cholangiocarcinoma. This result, which is in line with the reported 16% rate of tumor recurrence at the proximal stump in patients operated on for extrahepatic cholangiocarcinoma [36], suggests that anastomotic tumor recurrence should be systematically ruled out in this subset of patients.

Choledochal Cyst

In the long-term follow-up of patients undergoing choledochal cyst excision, the development of postoperative HJ anastomotic stricture widely varies according to the age of the patient at the time of surgery. Indeed, the rates of HJ strictures range from virtually 0 to 6% in children [37, 38] when the anastomosis is performed on the hepatic hilum, while it may reach up to 24% in adults [39]. This finding is probably related to the fact that inflammation of the cyst wall is mild in children under 10 years of age and more severe in older children and adults, likely resulting from severe histological damage to the common hepatic duct used for a bilioenteric anastomosis [40]. Other risk factors for the development of HJ after choledochal cyst excision include shorter duration of symptoms [39], increased size of the cyst [39], and type IVa cysts [40] where inflammation is associated with histological damage of the common hepatic duct after HJ and may lead to severe scaring at the bilioenteric anastomosis [40]. Altogether, these results suggest that the balance between the risks of malignant transformation and the risks of invalidating symptoms following HJ stricture, especially in adults with type IVa cysts, should lead to cautious consideration of surgery on a case-by-case basis rather than on a systematic operative approach basis. In this situation, definition of a subgroup of patients

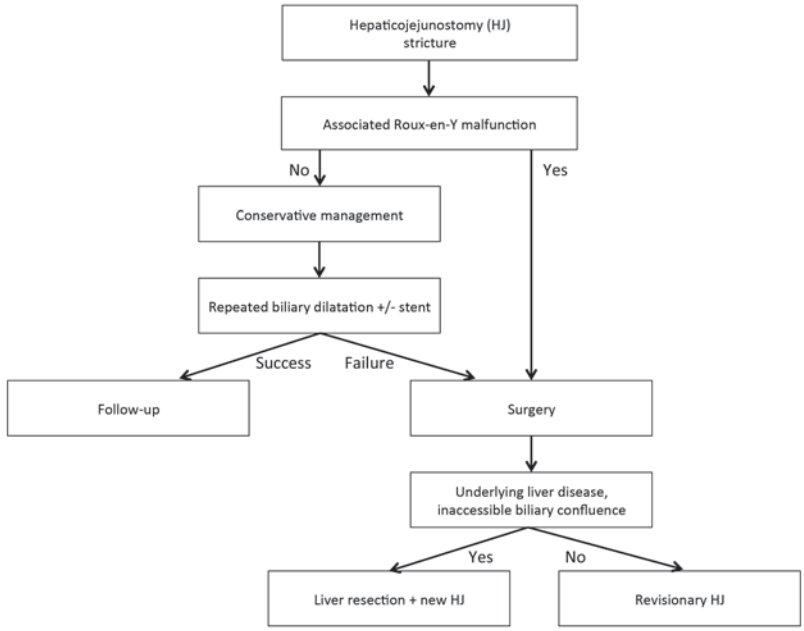

Fig. 23.2 Proposed management of patients with hepaticojejunostomy strictures. In patients with isolated HJ strictures, first-line treatment should be as much conservative as possible. Surgery should remain a second-line treatment after failure of well-conducted conservative management or in rare cases of associated Roux-en-Y malfunction

at low risk of malignant transformation would probably allow avoiding unnecessary procedures at extremely high risk of postoperative complications.

Therapeutic Options

In patients with HJ strictures, a multimodal and gradual management with repeated treatment sessions and a combination of several approaches is often required (Fig. 23.2). Treatment options, which include conservative management with endoscopic, percutaneous transhepatic, or transjejunal balloon dilatation and surgery from revisionary HJ to LT, depend on the clinical situation and the existence of associated complications. In this setting, the Terblanche classification [41], which was designed for the assessment of biliary repair following bile duct injury, stratifies the functional results of HJ into IV grades (Table 23.2) and may be of value in the analysis of the efficacy of the management of these strictures.

Conservative Management

Choice of the Approach

The percutaneous approach remains the approach of choice with reported therapeutic success rates reaching 90–100% [42, 43]. In this setting, a multistep strategy is generally undertaken. The first step usually consists in transhepatic cholangiography and external catheter drainage. A single-puncture technique is used whenever direct insertion of a thin wire offers a suitable approach to the biliary system. Otherwise, a common double-puncture technique is performed. Percutaneous transhepatic tracts are created to ensure complete drainage of all excluded territories. Once the bilioenteric stricture has been passed, insertion of one or several external cath-

Table 23.2 Classification of the functional results of hepaticojejunostomies. (Derived from Telbranche et al. [41])

Grade I. No biliary symptoms
Grade II. Transitory symptoms, currently no symptoms
Grade III. Clearly related symptoms requiring medical therapy
Grade IV. Recurrent stricture requiring correction or related death

eters allows drainage of the entire biliary tree above the stricture. When present, small biliary tract stones might be removed using irrigation with saline solution or may be pushed forward through the bilioenteric anastomosis [5]. On the other hand, large stones might be removed after percutaneous electrohydraulic lithotripsy under cholangioscopic guidance [5, 42]. The second step is usually performed between 3 and 7 days later. An angioplasty balloon catheter is inserted across the stenosis and inflated gradually. Thereafter, stenting is achieved using an internal–external biliary drainage or wall-stent placement. Control cholangiography with catheter exchange and complementary dilatations are performed every 6 weeks. When no residual stenosis is observed on at least two consecutive sessions, the catheter is removed and the patient is followed regularly to detect any recurrent stricture.

Recently, several teams have reported their results using endoscopic retrograde balloon dilatation. This approach, which may facilitate both multiple stent placement [7, 9] and use of lithotripsy, however, currently only provides success rates of 70% cases using single-balloon enteroscope [7]. Even though endoscopy may be facilitated with the use of short-limb Roux-en-Y [44] reconstruction or positioning of the Roux-en-Y loop on the duodenum, it should be restricted to experienced centers in the setting of therapeutic evaluation. The percutaneous transjejunal approach represents a valuable alternative to the endoscopic approach with satisfactory long-term results but is also restricted to very few experienced centers [12, 13]. Finally, the "rendez-vous" technique, which combines both endoscopic and percutaneous approaches, may be useful in complex situations. However, in a setting of HJ stricture, this strategy remains clearly marginal with only limited reported experience [45, 46].

To Stent or Not to Stent?

The rationale of using metallic wall-stent would be to allow limiting the number of procedures and decrease hospital stays [47]. However, despite initial promising results and high primary technical success rates [48, 49], long-term results of benign biliary stricture treatments by metallic stents have been tempered by high rates of late re-occlusion [50]. On the other hand, retrievable covered stent seems to be a good alternative to shorten treatment duration compared to interposition of an internal–external catheter. However, the risk of branching bile duct occlusion limits its use in the setting of living donor LT recipients owing to high frequency of complex biliary anastomotic strictures.

Periprocedural Management

Preanesthetic consultation and routine blood tests including a coagulation profile are systematically required. Similarly, the vast majority of the patients have contaminated bile, and it is mandatory to systematically start antibiotherapy prophylaxis before the procedure in order to prevent the occurrence of severe septic complications during manipulation of the bile ducts. Antibiotics are generally continued for at least 2–5 days following the procedure. Since most of the patients will require several therapeutic sessions, it is important to adapt the antibiotics to the microbiological findings of previous interventions. After the procedure, occurrence of blood in the drainages should lead to immediate elimination of vascular complications such as active hemorrhage, hematoma, or pseudo-aneurism on CT scan. Similarly, in patients with external drainage, tubes should be flushed daily with 5–10 ml of saline to ensure adequate bile outflow and bile loss should be rigorously compensated. If occlusion is suspected in the absence of bile outflow, proper fixation of

the drainage should be verified and tubes may be flushed with 5–10 ml of saline. In the persisting absence of bile outflow, radiological assessment of the drainage with standard X-ray, CT scan, or percutaneous cholangiography should be undertaken. Finally, when the internal–external drainage has been placed, occurrence of moderate fever or mild elevation of hepatic enzymes is common after first occlusion of the external part of the drain and should lead to its reopening. After a few days, a new attempt might be undertaken. In case of recurring symptoms, control of catheter placement should be undertaken.

Surgery

Revisionary Surgery

Revisional surgery should be considered only after well-conducted conservative management has failed or in rare situations of Roux-en-Y-loop-associated malfunction. These procedures, which are performed in a context of chronic sepsis and after a long history of percutaneous maneuvers, are hampered by the fact that biliary strictures are often found at a higher level than during the first attempt. Altogether, redo-HJs represent a real therapeutic challenge, which requires expertise in both liver and biliary surgery [51]. Operative identification of the anatomy and/or abnormalities may be difficult and requires systematic use of intraoperative cholangiography. When present, preoperative transhepatic cholangiography followed by transhepatic biliary drainage should be left in place before surgery as it may be useful in localizing the bile duct after removal of the HJ and dissecting the hilar plate to expose the primary biliary confluence. Finally, when the biliary confluence is not identifiable, a hepatotomy between segments 5 and 4 through of the bed of the gallbladder may be used to access the secondary right biliary confluence [51].

Liver Resection

Partial liver resection using left and right anterior or right hepatectomy has been proposed in patients with HJ stricture and anticipated complete biliary confluence destruction in order to perform a single-biliary anastomosis [52, 53]. Obviously, this situation mainly involves patients who initially underwent HJ for high and complex biliary lesions with frequently associated vascular injury. In a context of long-lasting biliary obstruction, partial liver resection also allows removal of atrophic liver parenchyma at high risk of secondary complication because of vascular or septic lesions. In our experience, this strategy was adopted for patients initially referred for LT in 20% of the cases and was feasible in the vast majority of our patients with success rates reaching 70% after a median follow-up of 8 years. Even though we did not experience any postoperative mortality, 61% of our patients experienced severe postoperative complications. This result is likely to be related to the fact that most of these patients with a long history of biliary obstruction often present with underlying parenchymal injury including severe (F3-F4) fibrosis in 50% of the cases. In this setting, we advise a systematic use of both preoperative biliary drainage of the future liver remnant and portal vein embolization of the resected lobe to increase the tolerance of these challenging procedures.

Liver Transplantation (LT)

LT is only indicated in patients with irreversible parenchymal damage due to secondary biliary cirrhosis and chronic liver failure. In patients primarily operated for benign disease, this situation represents a debatable option, which should be only considered after failure of all therapeutic strategies and should remain exceptional. In liver transplant recipients, this also raises the question of performing a highly risky procedure in a context of chronic sepsis, which is traditionally considered a contraindication to LT. In this setting, while obtaining bile sterilization and control of the sepsis during the pretransplant period is advisable, a certain degree of sepsis could probably be accepted in order not to delay the procedure to a point where it is not reasonably feasible anymore.

Key Points: How to Avoid HJ Stricture

1. For patients with bile duct injury following cholecystectomy, referral to another surgeon/specialty is mandatory to minimize further dramatic complications.
2. Repair of bile duct injury should only be attempted in the absence of ongoing sepsis regardless of the delay.
3. In patients undergoing LT for primary sclerosing cholangitis, duct–duct biliary anastomosis provides better functional long-term outcomes without increasing the risk of disease recurrence and should be preferred over HJ.
4. In living donor LT, optimal selection of the grafts and microsurgical HJ construction decrease the rate of postoperative anastomotic HJ strictures.
5. For patients operated on for choledochal cysts, definition of a subgroup of adult patients with type IVa cysts at low risk of malignant transformation could avoid unnecessary and highly risked hepaticojejunostomies.

Key Points: Diagnostic and Management

1. As much as 50 % of late-HJ-related complications are not anastomotic strictures and should be meticulously ruled out.
2. In patients primarily operated for malignancy, HJ anastomotic stricture is usually and requires a curative approach.
3. Percutaneous transhepatic biliary dilatation with or without stent placement is currently the approach of choice in the management of HJ strictures with high success rates.
4. The existence of a Roux-en-Y loop does not represent an absolute contraindication to the endoscopic approach.
5. Surgery should remain a second-line treatment since the vast majority of strictures can be managed conservatively with percutaneous or endoscopic dilatation.

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Stricture at Pancreatico-Jejunostomy or Pancreatico-Gastrostomy

24

Steven M. Strasberg and Daniel K. Mullady

The weakest point of pancreatoduodenectomy (PD) is the anastomosis between the pancreas and the jejunum or stomach. These anastomoses commonly fail in the immediate postoperative period and result in complications such as intraabdominal abscess and fistula. Even today, such events are responsible for a considerable proportion of complication burden following PD [1]. Pancreatico-jejunostomy (PJ) and pancreatico-gastrostomy (PG) may also fail chronically by becoming stenotic. The purpose of this chapter is to describe current understanding of the incidence, pathogenesis, and management of postoperative anastomotic stenosis and hopefully bring some order to the terminology and classification in order to guide the reader through the literature on the subject. As will be shown, the ability to treat symptomatic strictures by minimally invasive endoscopic is improving as a result of the introduction of new ingenious ways to enter the pancreatic duct and advances in endoscopic instrumentation. An overview of endoscopic techniques and their results occupies a major section of the chapter, but does not intend to provide a detailed manual of instruction in these methods.

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Defining Pancreatico-Jejunostomy Strictures (PJS) and Pancreatico-Jejunostomy Strictures (PGS) by Symptoms, Morphology and Function

PJS and PGS have been classified symptomatically, morphologically, and functionally. Patients may have no symptoms, suffer mainly from exocrine insufficiency manifested by diarrhea/steatorrhea without pain or with readily manageable degrees of pain, or complain of severe, often intractable pain. The last is often associated with evidence of pancreatitis and is also usually accompanied by steatorrhea. Many more patients have exocrine insufficiency due to strictures than have a degree of pain requiring anastomotic revision. Thus, from the clinical perspective these strictures may be placed in three groups: (1) asymptomatic, (2) symptomatic causing exocrine insufficiency, and (3) symptomatic causing severe pain (and exocrine insufficiency).

Attempts to classify the degree of stricture morphologically have been recently attempted. This has been made possible almost entirely by the introduction of dynamic MRI using secretin by Takahera et al. in 1996 **(**Fig. 24.1**)** [2]. Anastomoses have been classified as patent, partially obstructed, and completely obstructed based on the degree to which fluid enters the intestine. Some sub-categorization of the extent of stenosis

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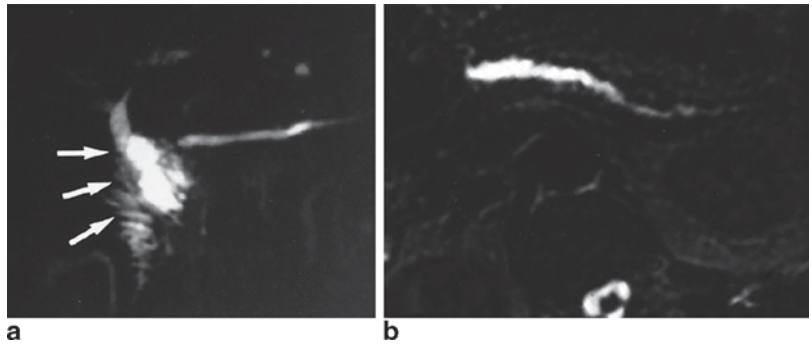

Fig. 24.1 Secretin-stimulated MRI. **a** Normal result showing normal diameter duct with free flow into jejunum (*arrows*) indicating no obstruction at the pancreatico-jejunostomy anastomotic (*PJA*). (With permission from [3] © Elsevier). **b** Abnormal result with distended duct and no flow into jejunum indicating obstruction at the PJA. (With permission from [4] © Elsevier)

has been attempted [3, 4] but the evaluations are descriptive rather than quantitative and depend mostly on the degree of distension of the jejunum in response to secretin. There is no consensus method of grading degree of stenosis.

Strictures may also be classified potentially by their functional effect on pancreatic exocrine function. While there are many tests that have been used to accomplish this, fecal elastase-1 concentration seems to be most useful in doing so [4, 5].

Exocrine Function of the Pancreas After Pancreato-Jejunostomy or Pancreato-Gastrostomy

Many patients who have PD develop pancreatic exocrine insufficiency and require pancreatic enzyme replacement. The principal putative causes are obstruction of at the pancreatic anastomosis to the jejunum or stomach, the resection of functional pancreatic parenchyma, and underlying diseases of the exocrine pancreas such as chronic pancreatitis or atrophy secondary to malignant obstruction. Until recently, there has been little work in sorting out these causes. As noted above, the use of dynamic MRP to evaluate patency of pancreatic anastomoses to jejunum or stomach and fecal elastase-1 concentration to measure exocrine function have furthered our understanding.

Sho et al. studied 34 post-PD patients who had pancreatojejunostomy with secretin MRP [3]. Secretion into the jejunal loop after secretin stimulation was graded as poor, moderate, or good (Grades 1–3 respectively) by two radiologists. Distention of the jejunal loop in the good secretors was obvious. Patency of the anastomosis could also be seen directly. About one-third of patients were in each group. Symptoms such as diarrhea and pain were present only in 1 of 11 patients in the "good" group, but 10/24 of the patients in the other groups had symptoms. This study established the potential usefulness of secretin MRP in evaluating post-PD symptoms and demonstrated some correlation between the diarrhea/steatorrhea and partial or complete obstruction at the anastomosis. Obviously the ability to differentiate between stenosis at the pancreatico-jejunostomy anastomotic (PJA) and parenchymal hypofunction as the cause of symptoms would be useful in directing therapy.

Pessaux et al. combined secretin MRP and fecal elastase measurements in 19 patients who had had PD with pancreatogastrostomy [4]. Fecal elastase-1 was reduced in almost all patients possibly because of inactivation by gastric acid. Six of 19 patients had significant stenosis or obstruction at the PG and these had the lowest fecal elastase-1 levels. It is unclear whether any of the patients were symptomatic as a result of loss of exocrine function.

Nordback et al. investigated exocrine function in 26 patients who had pancreatic head resection including a few Beger procedures [5]. The anastomotic technique was a two layer invaginating anastomosis with the inner layer picking up duct wall. Patients were evaluated by dynamic MRP using secretin, 3–76 months postoperatively.

Pancreatic function was evaluated by measurement of fecal elastase-1 concentration. More than 90% of patients had severe exocrine insufficiency as assessed by fecal elastase-1 concentration. 66% had moderate or severe diarrhea. The severity of diarrhea was associated only with a hard pancreas (usually associated with chronic pancreatitis or pancreatic cancer) on multivariate analysis. 16 patients could have the anastomosis evaluated by dynamic MRP and these split almost evenly between total obstruction, partial obstruction, and patent anastomosis. The last had the highest fecal elastase-1 levels recorded. Not surprisingly, anastomosis to smaller ducts was associated with a higher incidence of obstruction. The authors conclude that pancreatic insufficiency under these circumstances is due to a combination of stenosis at the anastomosis and loss of functional parenchyma.

In summary, three studies in a limited number of patients using secretin MRP have described stenosis at the PJA or PGA in some patients. In two of these studies, pancreatic exocrine insufficiency was more prominent in the patients with greater degrees of stenosis and in two of the studies symptoms were also related. However, even patients with patency of the anastomosis usually have some degree of pancreatic insufficiency after PD that seems attributable to loss of parenchymal function. Variations in outcome of such studies are probably attributable to the underlying diagnosis, the time after PD that patients are studied, and whether symptomatic or asymptomatic patients are selected. Nonetheless, this seems to be a potentially fruitful area for future research particularly as endoscopic treatment of PJ strictures is improving and while stenosis of the PG or PJ is usually only one factor in exocrine insufficiency, it is potentially correctable.

Management of Intractable Pain Due to PJA or PGS Stenosis in Surgical Case Series

Several papers have described a small number of patients treated in some cases by operative means.

Reid-Lombardo et al. from the Mayo Clinic followed 122 patients who had PD for benign disease [6]. Selecting patients with benign disease allowed for long follow-up of the group and eliminated the possibility that symptoms were due to recurrence of cancer. Four required treatment for severe pain accompanied by exocrine insufficiency, and in one case pancreatitis accompanied by a pseudocyst for an incidence of 3% and a cumulative probability rate over 5 years of 4.6%. Three of the four patients presented in the 1st year after PD. Only one had had a PJA leak after PD. 40% of the patients had PD for chronic pancreatitis and only one of these developed a stricture at the PJA. Two patients were treated surgically and two endoscopically. Pain was relieved in all four, as was steatorrhea in the three in whom it was present preoperatively.

Morgan et al. from the Medical University of South Carolina, in the largest case series on this subject, reported on 27/237 (11%) patients who had revisional surgery for stricture at the PJA after PD for benign disease [7]. Their case series is notable for the very high percentage of patients who had PD for chronic pancreatitis—70% of 237 patients. Also, 89% of the 27 PJA strictures were in the patients with chronic pancreatitis. The predominance of patients with chronic pancreatitis is different from the reports of Reid-Lombardo et al. [6] and Demirgian et al. [8] (see below). The patients presented with intractable pain and pancreatitis at a mean of 12 months after PJ. Secretin MRP detected a stricture at the PJA in 18 patients. Nine other patients with normal imaging were diagnosed on the clinical grounds of pain and recurrent pancreatitis. Three patients had attempted treatment by ERP and all failed. All 27 had surgical revision of the anastomosis in most cases using the original jejunostomy limb. The pancreatic duct was opened on the anterior surface of a variable distance and reanastomosed to jejunum. There were no postoperative deaths but four patients died in long-term follow-up of causes not directly related to the revisional surgery. More concerning is that only 6 of the remaining 23 patients reported good relief of pain and two of these still used narcotic analgesics frequently. Also two of the patients with a good result were in the group of nine patients diagnosed only on the basis of symptoms (personal communication from first author).

Demirjian et al. described seven patients who developed PJS out of 357 PDs performed over 8 years [8]. 60% of patients had PD for malignancy and 14% for chronic pancreatitis. The incidence was 1.4% in PDs done in their institution. Diagnosis was also by secretin MRP. Unlike the report from the Mayo Clinic, 6/7 patients had had a pancreatic fistula. On the other hand, there did not seem to be correlation to duct size or gland texture at the time of the PD. Only 2/49 cases (4%) had had PD for chronic pancreatitis. Average time to presentation was more than 3 years. Endoscopic correction was attempted but failed in every case. Reconstruction was attempted in all. Four had reconstruction of the PJ after re-resection of the anastomosis and two had a lateral pancreatojejunostomy. In one case, the procedure was abandoned because of operative difficulty. In mean follow-up of about 2 years, 4/7 remained pain free of pain.

In summary, only a small number of case series regarding the surgical management of intractable pain due to stenosis at the PJA are available for review. The series are not particularly comparable as they differ in the type of patient studied (benign disease, mainly chronic pancreatitis and all patients having PD). Reoperation to correct stenosis at the PJA is technically difficult. It seems that it is less likely to be successful when it is performed in patients who have had PJA for the treatment of chronic pancreatitis. It is likely to be supplanted as first-line therapy by evolving endoscopic techniques (see below).

Pancreatico-Jejunostomy vs Pancreatico-Gastrectomy and Anastomotic Stricture

There have been a number of studies comparing these methods of anastomosis including some randomized trials, but most including the randomized trials have focused on the early results rather than comparisons of late outcomes such as strictures at the PJA vs PGA. Tomimaru et al. studied 42 patients 2 years after pancreatoduodenectomy, 28 who had had PGS and 14 who had had PJS [9]. They noted that pancreatic duct diameter tended to increase more and that pancreatic atrophy was more severe after PGS [9]. Schmidt et al. studied QOL after PGS and PJS at a mean time of 6.4 years after surgery in about 100 patients [10]. In the PG group, there was an increase in steatorrhea as well as intolerance to certain foods. There was no difference in need for enzyme replacement or in onset of diabetes, and global QOL was also not different in the two groups. Ishikawa et al. studied glucose tolerance in 51 patients over a 7-year period. The patients were about equally divided between PJS and PGS. The decline in glucose tolerance after PG was not associated with type of pancreatic anastomosis. Konishi performed a prospective randomized trial of PGS vs PJS and followed the patients for 2 years [11]. They found no difference in change of pancreatic duct diameter or glucose tolerance but the study population was made up of only 25 patients. These results address the problem of stricture only tangentially but they suggest that there probably is not an advantage of one type of anastomosis over the other in retention of pancreatic exocrine function. The data regarding pancreatic endocrine function are probably more reflective of remaining parenchyma than anastomotic stricture.

Endoscopic Techniques for Management of PJA Strictures

Endoscopic retrograde pancreatography (ERP) has been the traditional endoscopic approach for treatment of symptomatic post pancreatoduodenectomy PJA strictures. It has had limited technical success. More recently, however, multiple additional novel techniques involving direct transgastric puncture of the pancreatic duct under endoscopic ultrasonography (EUS) guidance have been described with much better technical and clinical success. In this section, we describe the various endoscopic techniques to treat symptomatic PJA stenoses, the obstacles involved, and the technical and clinical results.

Endoscopic Retrograde Pancreatography (ERP)

The traditional ERP approach involves accessing the pancreatojejunostomy anastomosis (PJA) retrograde through the afferent loop of the gastroenterostomy. There are several challenges involved

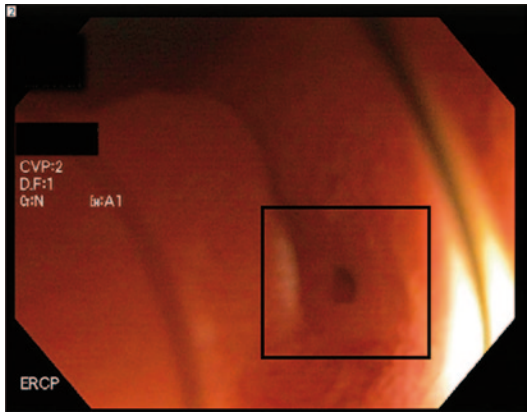

Fig. 24.2 Close-up endoscopic view of a stenotic pancreatojejunal anastomosis (*box*). This was located behind a fold. The estimated diameter is 1 mm. (Courtesy of Susana Gonzalez, MD)

in performing ERP through the afferent loop for treatment of PJA stenosis, which limit technical success.

First, successfully advancing the endoscope to the PJA is challenging. The afferent limb is often difficult to engage with the side-viewing duodenoscope. Also, the afferent limb may be of variable length (depending on surgeon preference and location of jejunal loop in relation to the transverse mesocolon), sometimes making it impossible to reach the PJA with a standard duodenoscope (124 cm long). In these situations, forward-viewing instruments are required, typically either a pediatric or adult colonoscope (168 cm long) or enteroscope (234 cm long) with or without a balloon overtube. Using a forward-viewing instrument poses several difficulties. First, these instruments lack an elevator, that is, a metal lever at the distal tip of the working channel that provides an extra degree of motion to instruments exiting the tip of the scope. Second, the longer working channel length of colonoscopes and enteroscopes compared to duodenoscopes limits the number and type of instruments, which can be utilized during the procedure. Third, pediatric colonoscopes and enteroscopes have smaller diameter working channels, which limits the caliber of stents that can be used.

The second major difficulty encountered is that a stenotic PJA can be difficult to visualize (Fig. 24.2). The PJA is usually 15–20 cm beyond the usually well-visualized choledochojejunostomy and can be located at the stump of the afferent limb or, more commonly, approximately 5 cm proximal to the stump. Visualization of the anastomosis also depends on whether it is an end-to-end or end-to-side anastomosis, the latter being usually more difficult to visualize. When the PJA cannot be visualized, there are ways to help localize it. One method is to administer intravenous secretin and observe for a gush or trickle of pancreatic juice. However, another challenge is transparency of pancreatic juice. Visualization of the juice can be enhanced by spraying the mucosa with a dye, such as methylene blue.

Once the PJA is identified, a variety of catheters and wires may be utilized to achieve deep cannulation of the pancreatic duct. Usually, due to the pinhole size of the PJA, the smallest available 3-4-5 F taper tip catheter loaded with an 0.021″ caliber wire is used. Once the PJA is carefully engaged with the catheter, contrast is injected and retrograde opacification of the pancreatic duct is observed fluoroscopically. The wire is then advanced deeply into the pancreatic duct. Another approach is to attempt passage of a wire through the anastomosis prior to injection of contrast. Following wire placement deep into the pancreatic duct (Fig. 24.3), passage or balloon dilation of the PJA is performed. Cautery is avoided to reduce the risk of perforation at the PJA. Following dilation, a plastic stent is placed (Fig. 24.4). There are multiple different stent types of varying lengths, diameters, and shape (straight versus pigtail). Generally, stents are removed in 6 weeks, and the need for repeat dilation or stenting is assessed at that time (Fig. 24.5). However, the optimal duration of stenting is not well established and not evidence based.

Technical Clinical Results for ERP

Given the limitations described above, technical success rates of ERP for treating PJA strictures are low. Farrell et al. described their technical success with ERCP in 29 patients who were postpancreatoduodenectomy [12]. The afferent limb was successfully intubated in 92 % of cases. Among these patients, ten had pain attributed to a stenotic PJA. Within this group, successful identification of the PJA was achieved in five patients

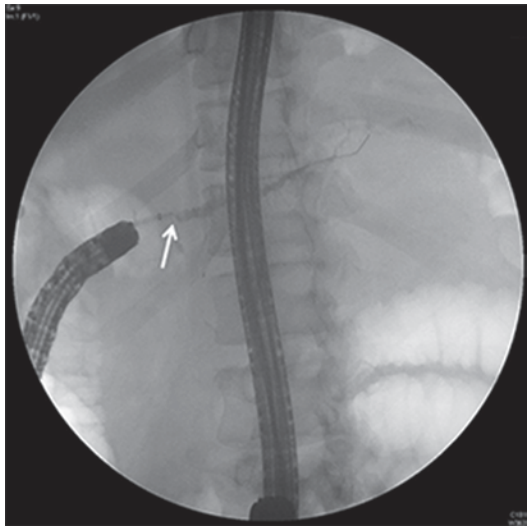

Fig. 24.3 Retrograde pancreatogram reveals a mildly dilated and irregular main pancreatic duct and a stenotic PJA (*arrow*). A guidewire is then inserted through the stenotic PJA into the pancreatic duct over which balloon dilation and stent placement can be performed**.** (Courtesy of Susana Gonzalez, MD)

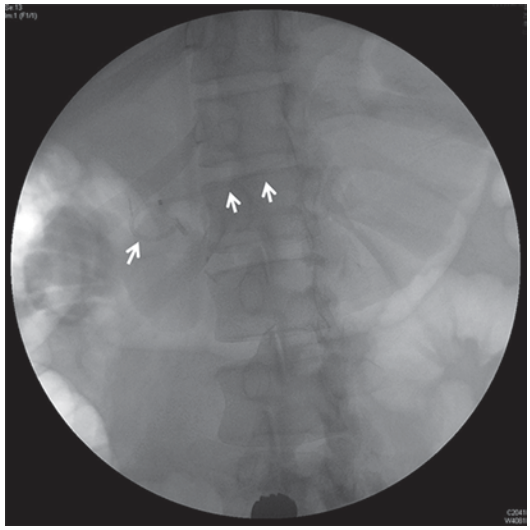

Fig. 24.4 A transanastomotic 5 F plastic stent has been placed into the pancreatic duct (*double arrow*). The intraluminal portion of the stent has a pigtail to prevent migration into the pancreatic duct (*arrow*). (Courtesy of Susana Gonzalez, MD)

(50%), three of which had PJA stenosis and underwent stenting with palliation of pain. Chahal et al. reported their experience in 51 patients with

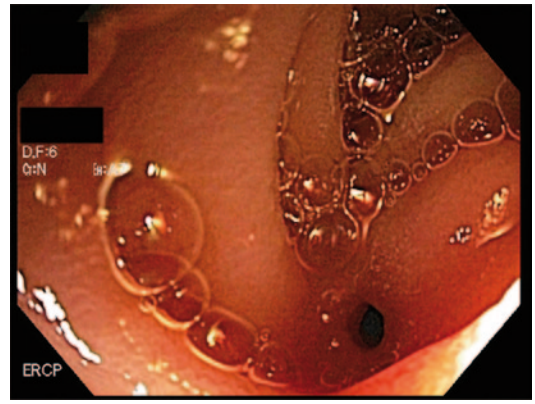

Fig. 24.5 Widely patent pancreatojejunostomy following stent placement. (Courtesy of Susana Gonzalez, MD)

pancreatoduodenectomy anatomy [13]**.** Among the 37 patients in this series undergoing ERCP for pancreatic indications, technical success was achieved in only three (8%). Technical success in both series was much higher for biliary indications at approximately 80%. Long-term clinical outcomes regarding palliation of pain and incidence of restenosis were not provided.

Little data exist regarding the appropriate duration of stenting to achieve durable patency of the PJA. Anecdotally, most experts will leave the initial stent in for a maximum of 6 weeks (to avoid stent induced changes in the pancreatic duct) and reassess for persistence of PJA stenosis at the time of stent removal. If the stricture persists, retreatment with balloon dilation and stenting continues every 6 weeks until resolution.

EUS-Guided Access and Drainage

EUS has evolved from a purely diagnostic procedure to one with increasingly more therapeutic applications. The development of curvilinear echoendoscopes allowed for ultrasound visualization of instruments passed through the tip. The initial application was EUS-guided fine-needle aspiration. Increasingly more EUS-guided therapeutic procedures are being developed for various pancreatobiliary and luminal indications. EUS-guided pancreatography was first described in 1995 by Harada et al. [14]**.**

In this section, we describe several procedures that involve EUS-guided access and drainage to treat symptomatic PJA stenosis. The close proximity of the pancreas to the posterior wall of the stomach facilitates EUS-guided drainage. All variations of these procedures depend on accessing the main pancreatic duct by direct puncture through the posterior wall of the stomach under EUS guidance. All EUS-guided techniques also require fluoroscopic imaging. EUS-guided procedures can be performed when traditional ERP fails or as the initial procedure with better technical success than traditional ERP.

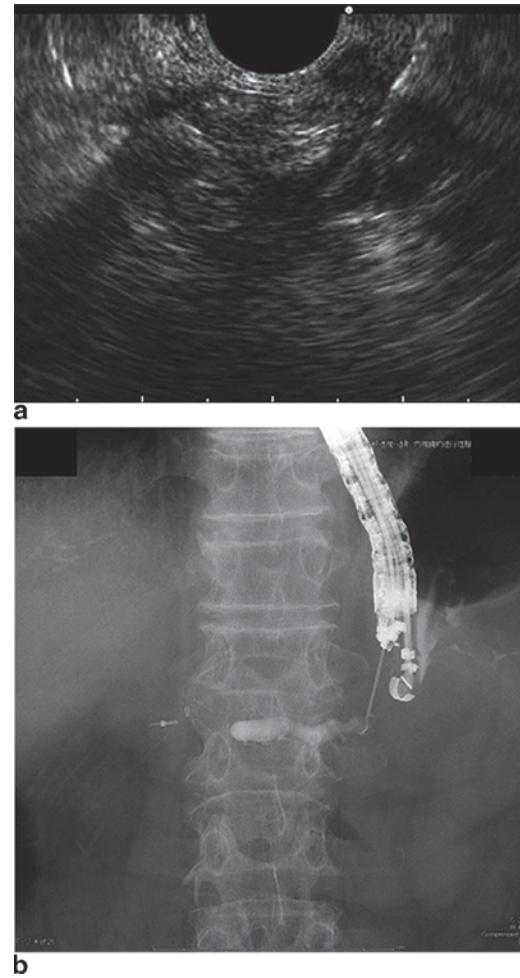

Fig. 24.6 EUS-guided transgastric puncture (**a**) and subsequent opacification of a dilated main pancreatic duct (**b**). Contrast does not flow antegrade through the PJA, indicative of a high-grade stricture. (With permission from [15] © Moseby)

EUS-Guided Rendezvous

During EUS-guided rendezvous, the pancreatic duct is punctured. Contrast is then injected through the needle to opacify the pancreatic duct visualized fluoroscopically **(**Fig. 24.6**)** [15]**.** A guidewire (usually 0.035″ or 0.025″) is then advanced through the needle and into the pancreatic duct. Attempts are then made to advance the guidewire antegrade through the PJA, and successful completion of the rendezvous procedure depends on being able to pass a guidewire through the stenotic PJA. The echoendoscope is removed, while leaving the wire in place. An endoscope is then advanced alongside the wire into the afferent loop of the gastroenterostomy to the site of the PJA. The wire is then grasped with a forceps or snare and pulled through the channel of the scope. A passage or balloon dilator is advanced over the guidewire to dilate the PJA followed by placement of a temporary plastic stent **(**Fig. 24.7**)** [15].

Pancreatic Antegrade Needle Knife (PANK) Technique

A modification of the rendezvous procedure is the pancreatic antegrade needle knife (PANK) technique. The PANK procedure is one option when the wire cannot be passed antegrade through the PJA. To perform the PANK procedure, it is necessary to have demonstrated access to the PJ anastomosis through the afferent loop for reasons of safety and also to ensure feasibility to effect stent change. The initial steps of the PANK procedure are the same as for the rendezvous procedure. In this situation, a needle knife catheter is advanced over a guidewire into the MPD until it reaches the PJA, identified by proximity of the catheter tip to the air-filled jejunum or indentation of the air-filled jejunum is demonstrated when pushing the catheter under fluoroscopic visualization **(**Fig. 24.8**)** [16]. When the catheter is in contact with the anastomosis, the needle is advanced from the tip of the catheter and blended cautery is used while the catheter is pushed antegrade across the anastomosis. The guidewire is then advanced deeply into the jejunum while the

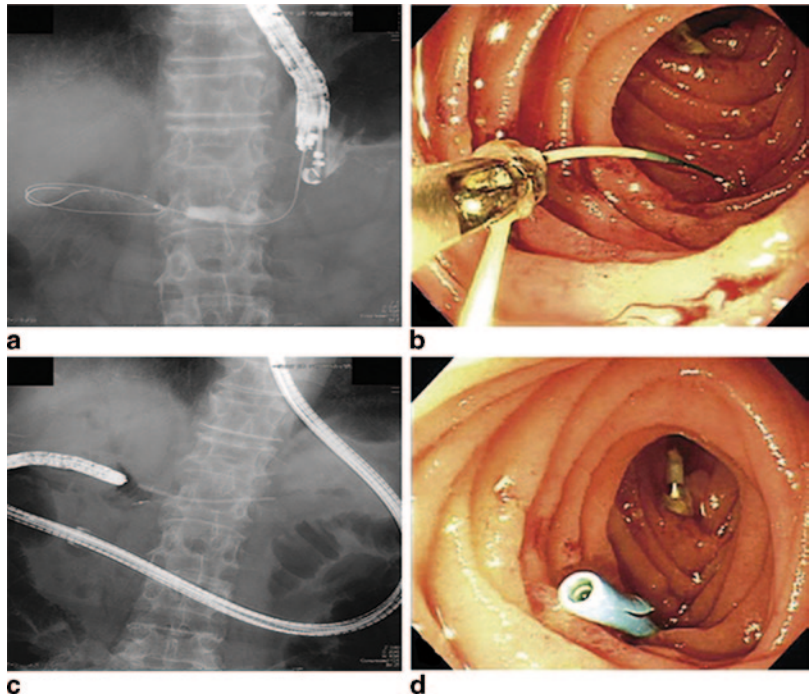

Fig. 24.7 EUS-guided rendezvous procedure. **a** Successful antegrade passage of a guidewire through the stenotic PJA and coiled within the jejunum. **b** Leaving the wire in place, a scope is advanced to the PJA. The wire is then grasped with a forceps and pulled through the scope. **c** Fluoroscopic and **d** endoscopic visualization of a transanastomotic pancreatic duct stent placed in retrograde fashion. (With permission from [15] © Moseby)

needle knife catheter is withdrawn. Once the wire has been successfully advanced into the jejunum, a gastropancreatojejunal stent is placed **(**Fig. 24.9**).** Initially, the stent is not fully internalized into the pancreatic duct to avoid a pancreatic duct leak since the catheter produces a larger defect in the pancreatic duct than a needle. Approximately 4–6 weeks later, the stent is removed and replaced with a transanastomotic pancreatic duct stent at ERP.

EUS-Guided Pancreatogastrostomy

EUS-guided pancreatogastrostomy results in placement of a stent between the MPD and stomach, resulting in pancreatic drainage into the stomach. This is performed in a similar way as the other techniques. This is an alternative to EUS-guided rendezvous or is an option when the guidewire cannot be passed antegrade across the PJA **(**Fig. 24.9**)**. If stent migration occurs, the pancreatogastric fistula might remain patent. However, if stenosis of the fistula occurs, a repeat procedure may be necessary.

Technical and Clinical Results for EUS-Guided Procedures

To date, there have been eight case series of EUS-guided pancreatic duct access and drainage procedures (each with more than five patients) with a total of 177 patients reported in the world literature [17–24]**.** There have been numerous case reports of EUS-guided drainage procedures [25]. Fujii et al. published the largest case series to date of EUS-guided pancreatic duct drainage in 45 patients with postoperative anatomy [23]. The series included both rendezvous technique and direct MPD drainage. Twenty-five patients in this series had undergone prior pancreatoduodenectomy. The indication for MPD drainage in the majority of these patients was recurrent acute pancreatitis or abdominal pain associated with a PJA stricture and a dilated main pancreatic duct. EUS-guided drainage was performed in 21/25 patients following failed ERP and was the initial procedure of choice in the remainder. EUS-guided MPD drainage was successful in 17

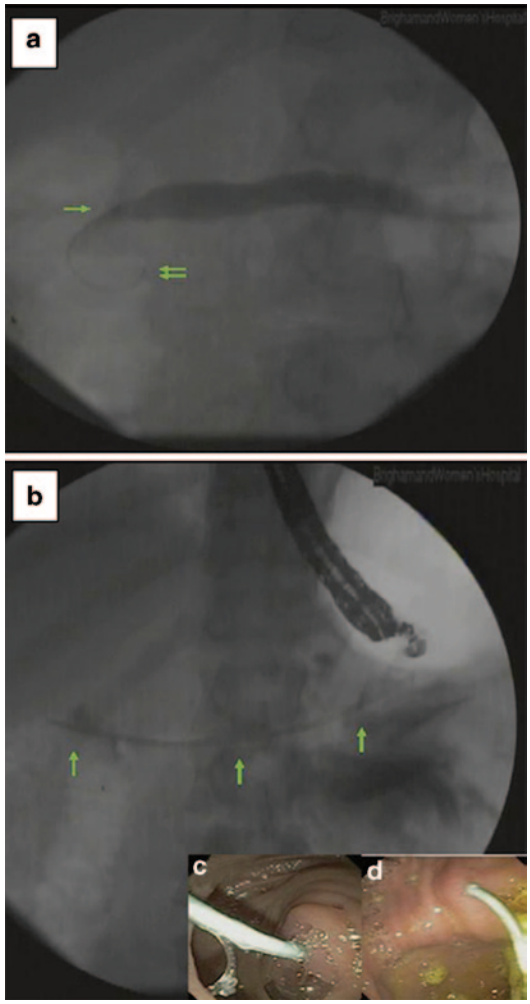

Fig. 24.8 PANK procedure. **a** *Single arrow* demonstrates the needle knife catheter tip advanced antegrade through the stenotic PJA and *double arrow* demonstrates guidewire looped within the air-filled jejunum. **b** Fluoroscopic image of gastropancreatojejunal stent; **c** jejunal and **d** gastric endoscopic views of the stent. (Modified with permission from [16] © Moseby)

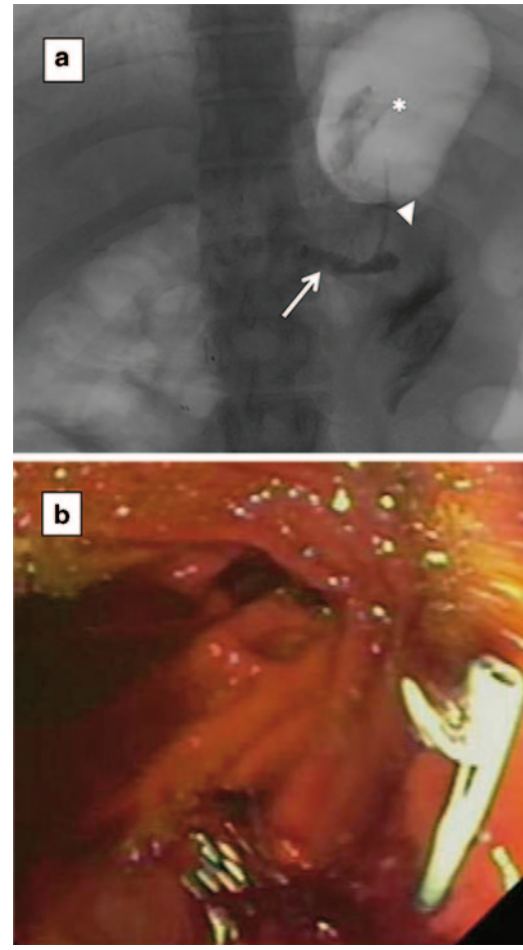

Fig. 24.9 **a** Fluoroscopic view of pancreatogastrostomy stent (*arrowhead*) spanning the stomach (*) and pancreatic duct (*arrow*); **b** endoscopic image of stent traversing the gastric wall**.** (Courtesy Vladimir Kushnir, MD)

patients (76%). Major adverse events, including stent migration, pancreatic duct leak, and abscess requiring drainage, occurred in 5.8% patients.

Itoi et al. described successful rendezvous procedure using a single balloon overtube in two patients who had undergone prior unsuccessful ERP due to inability to reach the PJA with a colonoscope [15].

Kikuyama et al. reported a series of 14 patients who had undergone pancreatoduodenectomy (eight with PJA) who required endoscopic intervention for recurrent acute pancreatitis or pancreatic duct fistula [26]. All patients initially underwent attempted ERP, which was successful in two of the eight patients (25%) with PJA. Of the six patients with failed ERP, three underwent successful EUS-guided rendezvous and three underwent ultrasound-guided percutaneous pancreatic duct stent placement.

Ergun et al. described their experience with EUS-guided direct pancreatic duct drainage in 20 patients, 10 of whom were postpancreatoduodenectomy [27]. The major indication for pancreatic duct drainage was pain in the setting of a dilated

duct. All ten patients underwent attempted pancreatogastrostomy, and technical success was achieved in 90 %. Long-term relief of pain (median follow-up 36 months) was achieved in eight patients.

Regarding the PANK technique, Ryou et al. described three patients postpancreatoduodenectomy who developed pain in the setting of PJA stenosis [16]. There was radiologic evidence of main pancreatic duct dilation. Secretin-enhanced MRCP in two failed to show further dilation of the pancreatic duct and there was absence of flow into the jejunum suggesting diminished exocrine function. The rendezvous technique had been attempted and had failed in all three. The PANK technique succeeded in cannulating the PJ anastomosis in all three with short-term relief of pain. One patient who also required removal of a pancreatic duct stone developed mild pancreatitis. All three had a 60 % reduction in pancreatic duct diameter at follow-up MRCP done after 8 months on average. All remained stent free at 2-year follow-up and two remained pain free. The third patient described episodic epigastric pain. None of the three have had pancreatitis or required further procedures or hospital admission.

In summary, endoscopic treatments for postpancreatoduodenectomy PJA strictures are in evolution. Exciting advancements in EUS-guided techniques for drainage of the main pancreatic duct have increased technical success, now approximately 75 %. It also appears that there is good long-term palliation of symptoms based on available case series. In an editorial on this paper, Giovannini states "it is very difficult to define today the place of EUS-guided pancreatic duct drainage; in our experience, the best indication is anastomotic stenosis after pancreatoduodenectomy procedure for benign pancreatic lesions" [28]. However, there are several questions that remain. One is regarding the optimal interval for stent exchange, size and number of stents, and total stenting duration. Another involves the indication for the procedure given the risks and benefits involved. The most obvious indication is pancreatic type pain associated with imaging demonstrating a dilated MPD to the level of the PJA. Pain without significant MPD dilation, exocrine insufficiency, and asymptomatic MPD dilation are marginal indications. Additionally, though endoscopic intervention is much less invasive than surgery, there has been no comparative study looking at outcomes between endoscopic and surgical therapy for symptomatic post-PD PJA strictures.

Jejunal Stenosis Mimicking PJA Stenosis

It is well known that development of a stenosis of the jejunum between the PJA and the gastroenterostomy may result in abdominal pain and elevation of pancreatic enzymes [29]. Usually the stricture is due to recurrence of pancreatic carcinoma involving that portion of the jejunum. The fact that the problem is not due to a PJA stricture is rarely in doubt because the narrowing is also beyond the hepaticojejunostomy, with resulting bile duct dilation and abnormal liver function tests. This type of obstruction is usually treated with enteric stent and access is often transhepatic and retrograde through the hepaticojejunostomy. Theoretically the stricture could lie between the PJA and the hepaticojejunostomy and occur without bile duct dilation and abnormal liver function tests. More than 20 years ago, Howard reported two patients who had recurrent bouts of pancreatitis without jaundice due to this type of stenosis [30]. The problem was corrected surgically in both cases.

Conclusions

This is an area with a paucity of studies. Strictures at the PJA or PGA occur frequently but are often asymptomatic. When they are symptomatic, they present predominantly as pancreatic exocrine insufficiency, but may sometimes present with intractable pain. Objective diagnosis has been aided by the introduction of dynamic MRI using secretin and to a lesser extent fecal elastase-1 measurement. Ideally, diagnostic measures should accurately measure the degree of steatorrhea and the anatomic extent of the stricture. This

would allow the clinician to determine the severity of the problem and the extent to which the stricture contributes.

Surgical reconstruction of PJA and PGS for intractable pain has been successful but these operations are quite difficult. Endoscopic results were initially not impressive but have recently evolved due to the advent of EUS-guided transgastric access to the pancreatic duct. Currently it may be stated that surgical correction of strictures should be reserved for cases in which endoscopic attempts have failed. Also, as endoscopic techniques improve in terms of success and decrease in morbidity there may be a role for their use in milder forms of the problem such as steatorrhea without severe pain. This might reduce or eliminate lifelong need for pancreatic enzyme replacement. Of course, the benefit of such strategies will have to be tested in appropriate trials.

Key Points

1. Stricture at the pancreatojejunostomy or pancreatogastrostomy after pancreatoduodenectomy is fairly common.
2. Stricture at the pancreatojejunostomy or pancreatogastrostomy frequently contributes to pancreatic exocrine insufficiency.
3. Stricture at the pancreatojejunostomy or pancreatogastrostomy sometimes is associated with the debilitating attacks of pancreatic pain and pancreatitis.
4. Diagnosis is best achieved by secretin-stimulated MR pancreatography.
5. Fecal elastatse-1 measurements can evaluate pancreatic exocrine insufficiency.
6. Surgical reconstruction has been used for recurrent severe pain but the procedure is difficult and results are mixed.
7. Endoscopic treatments of PJA strictures have advanced rapidly in the recent past and are now the first-line therapy.

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Postoperative Portal, Mesenteric, and Splenic Vein Thrombosis

25

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Introduction

Acute postoperative portal-mesenteric and splenic venous thrombosis (PMS-VT) is an uncommon, potentially lethal, and often overlooked condition reported after several open and laparoscopic HPB procedures. It is defined as the presence of a thrombus in the portal vein/superior mesenteric vein, and/or in the splenic vein [1]. The thrombosis may extend proximally to the left or right hepatic branches, distally to the superior mesenteric vein branches, or both. Acute PMS-VT develops within 30 days from the index operation, without evidence of chronic portal hypertension or of porto-portal collaterals on imaging studies. It includes a wide spectrum of clinical presentations ranging from incidental findings in an asymptomatic patient to life-threatening bowel infarction, and accounts for 5–15% of all mesenteric ischemic events [2]. The low incidence of acute PMS-VT may depend on the absence of symptoms, and on the fact that in many institutions, routine cross-sectional imaging is not performed postoperatively in patients devoid of clinical concern. Thus, PMS-VT is most often found when chronic changes have occurred. These include portal hypertension, splenomegaly, and formation of esophageal varices with possible bleeding [3, 4].

In HPB surgery, the procedures that have been shown to be associated with postoperative PMS-VT include liver transplantation, hepatectomy, pancreaticoduodenectomy, and distal pancreatectomy [5–10]. Potentially, any other intervention can lead to PMS-VT, including central pancreatectomy, autologous islet cell transplantation, percutaneous, and intraoperative RFTA [11, 12]. PMS-VT has been also reported after various laparoscopic operations without injury to the portal venous system [13]. The dissemination of the use of laparoscopic surgery, and the greater availability of modern diagnostic imaging methods, have likely contributed to and increased awareness and observation of this possible complication.

In general, most medical literature that concerns splanchnic venous thrombosis relates either to chronic superior mesenteric vein/portal vein thrombosis (as in hepatic cirrhosis or chronic pancreatitis), or to acute thrombosis in the setting of hypercoagulable states or hematologic diseases. Reports of acute PMS-VT are scattered, and generally they are composed of either case reports or very small series of patients with heterogeneous pathologic conditions. This chapter outlines the current evidence on the pathophysiology, the diagnosis, and the different treatment strategies of acute PMS-VT after major HPB procedures.

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Pathophysiology

The development of venous thrombi is a multifactorial process, and a combination of systemic and loco-regional prothombogenic factors may be causative in PMS-VT. Systemic predisposing factors include inherited thrombophilia (e.g., antithrombin III deficiency, protein C and S deficiencies, factor V Leiden deficiency, G20210A prothrombin mutation, and hyperhomocysteinemia), and various acquired prothrombotic states (including sepsis, pregnancy, oral contraceptive use, myeloproliferative disorders, and others) [14, 15]. Local predisposing factors to PMS-VT include abdominal malignant neoplasm, abdominal inflammatory diseases (e.g., pancreatitis, appendicitis, diverticulitis, and inflammatory bowel disease), and factors that create stasis of the portal blood flow, such as previous portal thrombosis [16]. The surgical maneuvers that might increase the risk of PMS-VT include intraoperative vessel manipulation, ligation of major portal tributaries (such as the splenic vein during distal pancreatectomy), venous resections (either with venorraphy or with venous resection), and inadvertent trauma to the portal venous system [8–10, 17].

The clamping of the hepatoduodenal ligament (Pringle maneuver), which is very often required in patients undergoing hepatectomy, can result in portal vein endothelial injury, and the duration of the Pringle maneuver is a significant risk factor for PPV thrombosis [9]. Furthermore, a correlation between a small volume of the liver remnant and an increased von Willebrand factor/disintegrin ratio and metalloproteinase with thrombospondin type 1 motif (ADAMTS13) has been recently reported. These disturbances may thus enhance thrombogenesis [18]. Acute PMS-VT is a particularly serious event after liver transplantation, because the subsequent liver ischemia may result in extensive parenchymal necrosis and graft failure, requiring re-transplantation. It has been shown that portal vein thrombosis affects only approximately 3% of liver transplantations and that liver ischemia or infarction may result from portal vein abnormalities or from non-physiological reestablishment of portal flow (cavoportal hemitrasposition, renoportal anastomoses, mesoportal jump graft) [7].

Portal vein-superior mesenteric vein resections are now performed more commonly during pancreaticoduodenectomy, which extends the indications for resection in patients with carcinoma of the pancreatic head and venous involvement. The incidence of PMS-VT after pancreaticoduodenectomy with venous resection seems to be high, ranging from 2 to 17% in the immediate postoperative period. The higher percentage of PMS-VT was observed in patients who underwent venous resection with interposition graft. In particular, a PTFE interposition graft was associated with an incidence of thrombosis up to 33% [8]. These data suggest that mesenteric venous thrombosis is a substantial problem after SMV-PV resection, with the potential for serious consequences.

Apart from intraoperative vein manipulation, postoperative collections in the resection bed due leaks (e.g., pancreatic or biliary) may contribute to an inflammation of the vein wall, with subsequent partial to complete thrombosis. This concept has been well described by Yoon et al. in spleen-preserving distal pancreatectomy. In patients with postoperative collections, the patency of the splenic vein tended to decrease over time, with the risk of splenic vein occlusion, left-sided portal hypertension, and perigastric varices. Splenic perfusion did not seem to be affected [17]. In a recent paper by Kang et al., the overall incidence of PMS-VT after minimally invasive distal pancreatectomy was 38%, with a significantly greater incidence in patients undergoing associated splenectomy who developed clinically relevant postoperative pancreatic fistula (79%) [19].

Loco-regional factors particular to laparoscopic procedures may contribute to the development of PMS-VT. In animal and human studies, insufflation of the abdomen and increased intraabdominal pressure led to decreased mesenteric and portal venous flow via direct pressure-induced compression [13]. Most studies found a dose-dependent relationship between insufflation pressures and venous stasis. Insufflation with carbon dioxide has been shown to cause a more substantial decrease in venous flow than insufflation with other inert gases [20]. Transperitoneal diffusion of carbon dioxide into the circulation can cause hypercapnia, which in turn has been implicated in decreasing splanchnic blood flow related to

mesenteric vasoconstriction [21]. Another possible explanation is that a prolonged reverse Trendelenburg position (such as may be necessary for various laparoscopic procedures) may exacerbate laparoscopy-associated portal venous stasis, as observed in experimental models [22]. In addition, intraoperative surgical manipulation may damage the splanchnic endothelium and lead to local thrombus formation that may then propagate throughout the portal venous system.

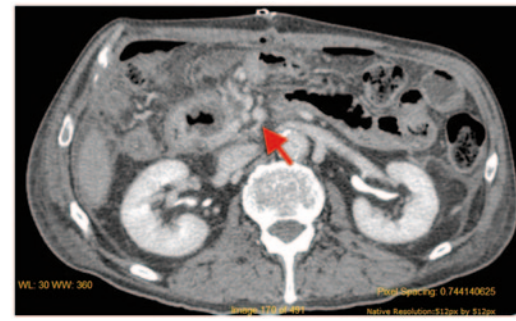

Fig. 25.1 Contrast-enhanced computed tomography (*CT*) of the abdomen, especially when coupled with thin cuts through the porta hepatis, has a high sensitivity (90 %) and specificity (99 %), as well as a more accurate delineation of the portal vein anatomy that contains thrombus

Diagnosis: Clinical Manifestations and Blood Tests

Clinical symptoms of acute PMS-VT are mostly unspecific and variable, which makes an accurate clinical diagnosis difficult. The wide spectrum of clinical presentations ranges from incidental findings to life-threatening bowel infarction. Patients may be initially seen with non-specific abdominal pain (90 % of patients), nausea (54 %), vomiting (77 %), or diarrhea (36 %) [23]; other findings may include anorexia, colicky pain, or low-grade fever [1–3]. When ischemia develops, clinical signs are similar to those observed in postoperative pancreatitis or hemorrhage, namely peritoneal signs, hypotension, tachycardia, and oliguria, that requires an inordinate volume of intravenous fluid to maintain an adequate mean arterial blood pressure and hourly urine output [24]. These physiologic disturbances are caused by the massive gut fluid sequestration that occurs in the edematous bowel as a consequence of mesenteric venous obstruction. Ascites is an uncommon and transient presenting sign, indicating that collateral circulation has not yet developed. Otherwise, the presence of ascites denotes chronic liver dysfunction [4].

Laboratory values might not be useful, because liver function tests might be normal. Yoshiya et al. demonstrated that patients with portal vein thrombosis after hepatectomy had a significantly lower serum albumin level, higher serum total bilirubin level, and higher PT-INR than patients without thrombosis. There were no significant differences between patients with and without portal vein thrombosis regarding the aspartate aminotransferase level or alanine aminotransferase level [9]. Sharp increases in liver function tests should raise the suspicion of the potential for PMS-VT, especially when taken in the context of other signs and symptoms. Decreased white blood cell and platelet count may also be present when associated with hypersplenism, but an increased white blood cell count in the presence of metabolic acidosis, increased abdominal pain, and hemodynamic instability should warrant further diagnostic imaging as the potential for bowel ischemia is great [1–3, 9]. Serum lactate is unspecific and a late parameter and is therefore not reliable as a marker for bowel ischemia [24].

Diagnosis: Imaging Tests

Several imaging modalities have been employed to establish the diagnosis of postoperative PMS-VT. Ultrasonography with color Doppler is able to visualize the thrombus and the local venous flow, but it is extremely user-dependent, and may be limited by the body habitus or by the overlying bowel gas. Furthermore, an acute thrombus may not be visualized correctly because of its non-echogenic nature. However, the fact that ultrasonography is non-invasive and inexpensive makes it a valuable screening tool [25]. The sensitivity and specificity for color Doppler to detect portal thrombosis range from 89 to 93 % and 92 to 99 %, respectively [26]. Contrast-enhanced computed tomography (CT) of the abdomen (Fig. 25.1), especially when coupled with thin cuts through the

porta hepatis, has a high sensitivity (90%) and specificity (99%), as well as a more accurate delineation of the portal vein anatomy that contains thrombus [26]. In particular, contrast-enhanced CT scan is useful in case of uncertain findings of Doppler ultrasound or for better visualization of the extent of remnant thrombotic material in mesenteric and portal veins. A single study showed that it is reasonable to screen patients with CT scan on postoperative day 7 (after major HPB procedures) because those with PMS-VT did not have symptoms indicating mesenteric ischemia at that time [9]. Magnetic resonance angiography (MRA), although costly and time-consuming, can provide exquisite detail of the portal anatomy, including flow direction and disturbances. In regard to acute PMS-VT, MRA is not usually required, but is instead more useful in the chronic state of thrombosis, that is seen in patients with liver failure who may be considered for liver transplantation [6]. Historically, the gold standard for the diagnosis of PMS-VT has been portal venography. Not only this examination allows diagnosis, but also treatment of the thrombus, although it is more invasive and associated with significant complications. In a small series, portal venography was correlated had a sensitivity of 100% and specificity of 90% [26]. After the diagnosis, follow-up can be performed daily with Doppler ultrasound (if technically feasible) to assess perfusion of the portal vein during in-hospital stay.

Treatment

The goal of the treatment of acute PMS-VT is the permanent recanalization of the portal vein/superior mesenteric vein and their large branches, with sufficient transhepatic blood flow to prevent development of portal venous collaterals and portal hypertension. Treatment of PMS-VT is dictated by the acuity of the clinical picture and by the associated complications.

Anticoagulation

Patients with documented PMS-VT need to be treated with intravenous or subcutaneous heparin to prevent propagation of the thrombus. First, even in the early postoperative period, the risks of clot propagation or complete superior mesenteric vein/portal vein occlusion far outweighs the risk of bleeding. Second, based on findings from observational studies, spontaneous recanalization of the portal vein is uncommon, and cavernous transformation develops in most patients without treatment [27]. However, randomized trials comparing patients under anticoagulation with patients without anticoagulation are lacking. Nonetheless, anticoagulant therapy has become standard of care for the treatment of acute PMS-VT. Both the American Association for the Study of Liver Diseases guidelines and American College of Chest Physicians Evidence-based Clinical Practice Guidelines recommend treatment with anticoagulants [28, 29]. Interestingly, the recanalization rates under anticoagulation differ between studies. In the one prospective multicenter trial with > 100 patients enrolled, anticoagulation resulted in a recanalization rate of the main portal vein and its left or right branch of 39% [30]. Obstruction of the portal vein persisted in the rest of the patients, and portal cavernoma already had developed in 40% of the patients by the end of follow-up, which put them at risk for permanent portal hypertension. In a study by Plessier et al. [31], anticoagulation treatment was less effectivwwe in inducing recanalization of complete PVT than in preventing extension of thrombosis to or from the portal vein. It seems that the thrombus burden also has an effect on response to anticoagulation therapy and should be taken into account when selecting patients for anticoagulation alone in the treatment of acute PMS-VT. In particular, complete recanalization was achieved more frequently in cases where the thrombosis involved only the portal vein or the superior mesenteric vein, rather than in patients with more extensive involvement of the portal venous system [32]. At the authors' institution, unfractionated heparin is initially given IV with target-activated partial thromboplastin time between 1.5 and 2.5. Oral anticoagulant therapy with warfarin for 3–6 months should follow, targeting a prothrombin time–international normalized ratio (PT-INR) between 2 and 3.

The incidence of PMS-VT may be influenced by the lack of clear recommendation regarding anticoagulation following "high-risk" surgery procedures (i.e., major venous reconstruction, extended hepatic resection, pancreaticoduodenectomy). In particular, some surgeons delay or completely withhold routine venous thromboembolism prophylaxis following major hepatectomy, because it is believed that these patients are at risk for postoperative liver insufficiency, leading to the concern they are already anticoagulated. This belief is often supported by the resulting laboratory derangements in measurable liver function, including elevations in the prothombin time/international normalized ratio (PT/INR) and partial thromboplastin time (PTT), as well as occasional thrombocytopenia. Because of that, many surgeons carefully observe patients with portal vein thrombosis following hepatectomy and initiate anticoagulation therapy only when the thrombus extended to the superior mesenteric vein or reduced portal venous flow. In contrast with this practice, Ejaz et al. showed that despite having alterations in platelets, PT/INR, and PTT, patients with liver insufficiency actually often have significant increased risk for venous thrombosis, leading to the routine use of thromboprophylaxis in these patients [33].

Interventional Techniques

Because anticoagulation only leads to a recanalization of the PMS-VT in nearly 40 % of patients, alternative and more aggressive treatment strategies are used by some centers. During the last decade, several treatment modalities have been used, including percutaneous transhepatic thrombolysis, mechanical thrombectomy, and percutaneous transhepatic balloon angioplasty and/or stent placement without thrombolysis or thrombectomy. Advancements in interventional radiologic techniques have made it possible to administer thrombolytic agents in the proximity of the clot. Local infusion of thrombolytic agents (urokinase 15,000–30,000 IU/h or recombinant tissue plasminogen activator 1.8 mg/h, for 4–5 days.) has been reported to achieve recanalization in 60 %, up to 100 %, of patients [34–36]. The effect of thrombolysis can be visualized with angiographies via the catheter on a regular basis or, if clinically indicated, until the catheter is removed. Removal is conducted under fluoroscopy. However, positioning a radiologic catheter adjacent to clot might be technically problematic (especially in patients with complete intra- and extrahepatic thrombosis), and thrombolysis might be prohibitively hazardous in the early postoperative period after major HPB procedures, due to the risk of major bleeding [36]. Most clinicians therefore consider pharmacologic thrombolysis as therapy reserved for patients with severe disease with propagation of thrombus or without improvement of symptoms. Furthermore, catheter-directed thrombolytic therapy may fail, especially in the setting of acute thrombus superimposed on chronic thrombus [35, 36]. To avoid the drawbacks of thrombolysis, several investigators have successfully treated the cases of postoperative PMS-VT by mechanical percutaneous thrombectomy [37]. Venous thrombectomy is generally considered to be less successful than arterial thrombectomy because of difficulties in removing adherent clot from the thin, delicate vein wall. In the acute setting, however, percutaneous venous thrombectomy may be technically easier, because the clot has not yet become adherent to the vein wall [38].

By debulking the thrombus burden, mechanical percutaneous thrombectomy may reduce the duration and the total dose of thrombolytic agents, thereby reducing the bleeding risk for the patient. However, thrombectomy has potential risks of embolism, intimal trauma, and re-thrombosis [39]. Balloon angioplasty and/or stent placement for treating postoperative PMS-VT has several advantages. The procedure can restore the patency of the portal vein-superior mesenteric vein (if there is no thrombosis in the intrahepatic portal vein) without the need for prolonged thrombolysis, reducing the bleeding risk in this group of postoperative patients [40]. When balloon angioplasty and/or stent placement without thrombolysis or thrombectomy are used to treat thrombotic vessels, there is a risk that the thrombus will prolapse through the stent mesh,

causing re-occlusion or distal embolism. Balloon angioplasty or stent placement also has several potential limitations. First, there is a risk of suture dehiscence during balloon angioplasty if the patient has thrombosis in the early postoperative period and has undergone venorraphy during the surgical treatment. The use of a balloon catheter with a smaller diameter relative to that of the patent portal vein or superior mesenteric vein and careful under-inflation of a balloon catheter relative to the diameter of the deployed stent may prevent this complication. Second, the long-term patency rate is not excellent, although these results are limited to small case series [40–42].

Surgery

Surgical exploration must be undertaken when clinical, biochemical, and radiologic signs of bowel infarction are detected, in order to eradicate the source of septic shock. The first report of a successful portal vein/superior mesenteric vein thrombectomy for acute PMS-VT was provided in 1968 by Mergenthaler and Harris [43]. However, surgeons have been historically hesitant to embrace this approach. The surgical principles are simple: the superior mesenteric vein can be accessed at the inferior border of the pancreas, whereas the portal vein is accessed and controlled dissecting the hepatoduodenal ligament. Once the involved vessel has been isolated and taped proximally and distally to the thrombosis site, a venotomy is performed, and thrombotic material is mechanically removed with forceps and a surgical suction device [24]. Recently, a combined surgical/interventional approach has been described. After conventional surgical thrombectomy, a guiding sheath is inserted into the superior mesenteric vein or in the portal vein via the venotomy, and radiologic interventional mechanical thrombectomy is performed. An important advantage of the combined approach is the possibility to remove thrombi in both directions (antegrade and retrograde) and in formerly inaccessible areas as the intrahepatic portal vein branches. To keep the portal vein patent after successful thrombectomy, it seems to be essential to have sufficient blood inflow from the mesenteric and splenic veins and downstream into the liver parenchyma [24].

Conclusion

The ability to diagnose and, therefore, to treat PMS-VT is of paramount importance in order to prevent the catastrophic case of mesenteric ischemia resulting from this complication. Awareness of the potential for PMS-VT thrombosis will allow for early detection and immediate anticoagulation. Overall, prognostic factors for recanalization are needed and have to be validated to define the best possible therapy in the individual patient. It must be assessed which patients should be treated more aggressively to achieve patency of the portal vein and which patients have good chances for recanalization by mere anticoagulation treatment. According to the current knowledge, the treatment of PMS-VT should be determined by the individual clinical situation of the patient, the pathophysiology involved, and the available expertise. It is important to search for the causes of PMS-VT after the treatment. In many patients, coagulation disorders can be found that impact on the additional postoperative or postinterventional course. Specialists in hematology should therefore be involved in the care of these patients. For extensive interventional and surgical procedures, experienced interventional radiologists and surgeons with hepato-pancreatic-biliary and vascular expertise are definitely necessary.

Key Points for Diagnosis

1. Clinical symptoms of acute PMS-VT are mostly non-specific and variable and clinical presentations range from incidental findings in an asymptomatic patient to life-threatening complications.
2. Due to the absence of symptoms in many patients, PMS-VT is often found when chronic changes including portal hypertension, splenomegaly, and formation of esophageal varices with possible bleeding have occurred.

3. Ultrasonography with color Doppler is a valuable screening tool to visualize the thrombus and the local venous flow, but it is user-dependent and may be limwited by the body habitus or by the overlying bowel gas.
4. Contrast-enhanced CT of the abdomen is highly sensitive and specific and provides a better visualization of the extent of PMS-VT and an accurate delineation of the portal vein anatomy that contains thrombus.
5. Portal venography allows for diagnosis and also treatment of the thrombus, although it is more invasive and associated with risks of bleeding in the early postoperative period.

Key Points for Treatment

1. Treatment of PMS-VT should be determined by the individual clinical situation of the patient, the pathophysiology involved, and the available expertise.
2. The goal of the treatment of acute PMS-VT is the permanent recanalization of the portal vein/superior mesenteric vein and their large branches, with sufficient transhepatic blood flow to prevent the development of portal venous collaterals and portal hypertension, and is dictated by the acuity of the clinical picture and by the associated complications.
3. Patients with documented PMS-VT need to be treated with intravenous or subcutaneous heparin in order to prevent propagation of the thrombus as the risks of clot propagation or complete superior mesenteric vein/portal vein occlusion far outweighs the risk of bleeding.
4. Advancements in interventional radiologic techniques have made it possible to administer thrombolytic agents in the proximity of the clot or balloon angioplasty and/or stent placement. However, these interventions can pose increased risks of major bleeding in the postoperative period, suture dehiscence, poor long-term patency, and re-occlusion or distal embolism and therefore are generally reserved for patients with severe disease with propagation of thrombus or without improvement of symptoms.
5. Surgical exploration is undertaken when clinical, biochemical, and radiologic signs of bowel infarction are detected.

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Postpancreatectomy Hemorrhage: Early and Late

26

Albert Amini, Kathleen K. Christians and Douglas B. Evans

Introduction

The mortality rate after pancreaticoduodenectomy (PD) has decreased markedly over the last several decades. However, the morbidity rate has not decreased to the same extent; complications continue to occur in 30–40 % of patients who undergo pancreatectomy (PD or distal pancreatectomy) [1, 2]. Postpancreatectomy hemorrhage (PPH) is one of the major causes of morbidity and can result in mortality after PD or distal pancreatectomy [3, 4]. In particular, late PPH is associated with a high mortality rate because the diagnosis may not be apparent, the patient may no longer be an inpatient and the hemorrhage may present as abrupt, massive bleeding [5, 6].

PPH occurs between 1 and 8 % of all pancreatic resections and accounts for 11–38 % of overall mortality [3, 7–9]. This wide variation is caused by different definitions used by authors in the reporting of results. The International Study Group of Pancreatic Surgery has clinically graded PPH based on onset, location, and severity [10]. Generally, PPH can be divided into early and late postoperative bleeding. *Early PPH* is that which occurs within 24 h of surgery. It often is caused by technical failure to achieve appropriate hemostasis during the index operation or an underlying perioperative coagulopathy. *Late PPH* occurs more than 24 h after the operation, and usually after 7–10 postoperative days. Late PPH typically results from complications of the operation and becomes clinically apparent several days or even weeks after surgery. For example, late PPH may occur following the diagnosis of an intra-abdominal abscess, erosion of a peripancreatic vessel secondary to a pancreatic fistula or an intra-abdominal drain, ulceration at the site of an anastomosis, or in association with an arterial pseudoaneurysm. Late PPH or delayed bleeding is one of the most feared postoperative complications because it is often not accurately diagnosed and therefore not treated effectively. Late PPH under these circumstances is associated with a high mortality rate because of the already poor condition of the patient [11].

PPH may originate from arterial or venous vessels, suture lines, areas of resection (pancreatic stump, retroperitoneum), gastric/duodenal ulcer or diffuse gastritis, eroded and ruptured pseudoaneurysms, or hemobilia from previously placed endobiliary stents [10] (Table 26.1). Vascular structures that may be the source of PPH include the stump of the gastroduodenal artery (GDA; most common and well known cause of late PPH), splenic artery, branches of the superior mesenteric artery (SMA) (e.g., inferior

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Table 26.1 Location, onset, diagnosis, and management of postpancreatectomy hemorrhage (PPH)

Location	Onset	Diagnosis/management
Vessel		
Gastroduodenal artery stump	Usually late	Angiography and embolization/stent
Hepatic artery	Late	Angiography and embolization
Inferior pancreaticoduodenal artery	Early	Reoperation following PD
Inferior pancreaticoduodenal artery	Late	Angiography and embolization/stent as this usually presents as a pseudoaneurysm
Splenic vein stump	Early	Reoperation following distal pancreatectomy
Splenic artery stump	Late	Angiography and embolization following distal pancreatectomy
Intrapancreatic arteries (smaller un-named)	Early or late	Early—reoperation Late—angiography and embolization
Anastomoses		
Hepaticojejunostomy	Early	Reoperation
Pancreaticojejunostomy	Early	Reoperation
Gastrojejunostomy	Early or Late	Endoscopy or reoperation

Early refers to the first 24–48 h after surgery; late most commonly refers to after the first postoperative week
PD pancreatodudenectomy

pancreaticoduodenal artery especially in the setting of a clinically significant pancreatic anastomotic leak), the splenic vein stump, or, rarely, an intrapancreatic artery. In addition, PPH can be grouped into intraluminal and extraluminal; intraluminal PPH manifests itself as hematemesis, bleeding from the nasogastric tube, or melena, and extraluminal PPH is characterized by bleeding from intra-abdominal drains, an abdominal wound, or intra-abdominal hemorrhage. True extraluminal bleeding has an extraluminal source. False extraluminal bleeding is a manifestation of primary intraluminal bleeding that becomes extraluminal owing to coexisting anastomotic disruption [12–14].

Early PPH (within 24 h after surgery) is most commonly the result of technical failure to properly secure the inferior pancreaticoduodenal arteries (IPDAs). One can also see bleeding at any of the three anastomotic suture lines (following PD) and rarely a GDA stump hemorrhage due to failure to properly secure this vessel. If the SMA dissection is performed sharply with direct identification and ligation of the IPDAs at their origin from the SMA, this complication can largely be avoided. Intra-abdominal hemorrhage from poorly secured IPDAs would present as early postoperative intra-abdominal hemorrhage and would require immediate reoperation. Bleeding from the post-PD reconstruction (pancreatic, biliary, or gastric anastomosis) is very uncommon, and the anastomosis of greatest risk is the pancreaticojejunostomy if an invagination anastomosis is performed. With this type of anastomosis, the cut surface of the pancreas is open to the inside of the jejunum and small vessels which are partially cauterized may retract at the time of pancreatic transection only to bleed when the patient is in the recovery room or during the first postoperative night. Hemorrhage from the biliary anastomosis should not occur, and bleeding from the gastrojejunostomy is also very uncommon in the absence of a technical error. Marginal ulceration at the gastrojejunostomy, if it were to occur, presents months or years after the date of surgery. Yekebas et al. presented an analysis of 1669 consecutive pancreatic resections and in their experience, early PPH was due to 3 causes: (1) technical failures in terms of inadequate hemostasis in the operative field always associated with extraluminal PPH (IPDAs being the most common involved vessels); (2) suture line of gastroenteric or one of the enteroenteric anastomoses leading uniformly to intraluminal PPH on the first or second postoperative day; and (3) resection cavity or transection surface of the pancreas resulting in PPH originating from the pancreatico-enteric anastomosis [15].

Late PPH may occur from a gastrointestinal source but more commonly originates from an

intra-abdominal site often associated with intra-abdominal infection or abscess formation due to leakage of an anastomosis (most commonly the pancreaticojejunostomy). Intra-abdominal infection is thought to be the major cause of late PPH due to erosion into ligated vessels, most notably the GDA. Bleeding from a disrupted anastomotic suture line can also be caused by intra-abdominal infection and can mimic bleeding from major vessels [7, 8, 16]. Finally, some patients may present with bleeding from the wound after a wound infection but significant hemorrhage from this etiology is uncommon.

The core difference between the etiology of early and late PPH is the association of late PPH with pancreatic fistula and intra-abdominal infection. This finding is consistent throughout the surgical literature which notes an elevated risk of late PPH in patients with pancreatic fistula as well as a near 100% prevalence of pancreatic fistula in patients who exhibit late arterial bleeding [16, 17]. Surgical reports are consistent in describing a sequence of events at the beginning of which pancreatic fistula causes erosions, pseudoaneurysms, and other vascular irregularities, which eventually result in clinically significant hemorrhage. Clearly, the majority of postoperative pancreatic fistulas do not result in late PPH and the cause of PPH within the population of patients who have a pancreatic leak is likely multifactorial. Extended lymphadenectomy or the need for concomitant adjacent organ resection (resulting in a large retroperitoneal space), soft texture of the pancreatic remnant in the setting of a complete anastomotic disruption, or insufficient drainage of pancreatic fistula (failure to obtain source control) may be the cofactors increasing the risk of fistula-induced vascular injury and PPH [16–18].

Possible pathophysiologic explanations for pancreatic anastomotic leak-associated late PPH include enzymatic digestion of the blood vessel wall by trypsin, elastase, and other pancreatic exocrine enzymes, intra-abdominal infection/abscess with direct involvement of the vessel wall, and/or vascular injury at the time of operation that leads to pseudoaneurysm formation [3]. Most reports and anecdotal clinical observations favor the theory of local sepsis resulting from pancreatic fistula as the main cause of late PPH. Local sepsis may erode the vascular wall and adjacent bowel. This mechanism of injury may result in acute arterial bleeding with or without arterial pseudoaneurysm formation, which typically occurs days to weeks after the operation [19]. There is minimal data regarding the impact of newer energy devices, especially when using them for ligating the IPDAs arising from the SMA; however, anecdotal experiences with such situations have generated reason for caution. Many of us have managed PPH in patients where the use of such energy devices close to arterial structures has been implicated in the etiology of late PPH.

Skeletonization of the hepatic artery and SMA which is performed with PD, and similar dissection of the celiac artery and splenic artery stump associated with distal pancreatectomy make these vessels vulnerable to pseudoaneurysm formation due to local sepsis arising from the pancreatic fistula, anastomotic leakage, or intra-abdominal abscess [20]. In a series reported by Lee et al., of 27 patients with PPH, 26 had an antecedent pancreatic fistula, as shown by drain amylase level and computed tomography (CT) findings. This report confirms the association between late PPH and pancreatic fistula. The onset of the infectious complication ranged from 7 to 13 days but the hemorrhage developed after postoperative day 28 in 9 patients. The high frequency of late-onset (after 4 weeks from the date of operation) hemorrhage in this study led the authors to conclude that PPH can occur more than 4 weeks postoperatively, particularly in patients with pancreatic fistula and/or a complicated initial postoperative course [21].

Prevention of Late PPH

The Falciform Ligament

When opening the abdomen, we carefully preserve the falciform ligament (obliterated umbilical vein) for later use as coverage of the GDA

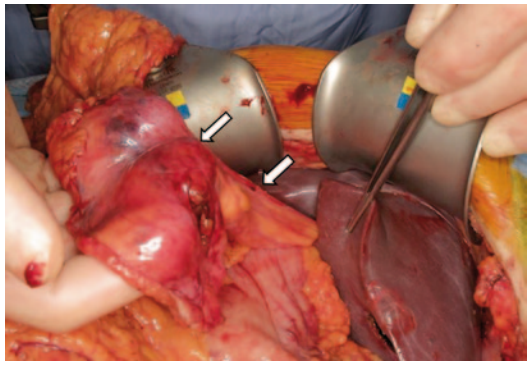

Fig. 26.1 Intraoperative photograph of preserved falciform ligament pedicle flap. Debakey forceps are retracting the liver. *White arrows* point to the falciform flap

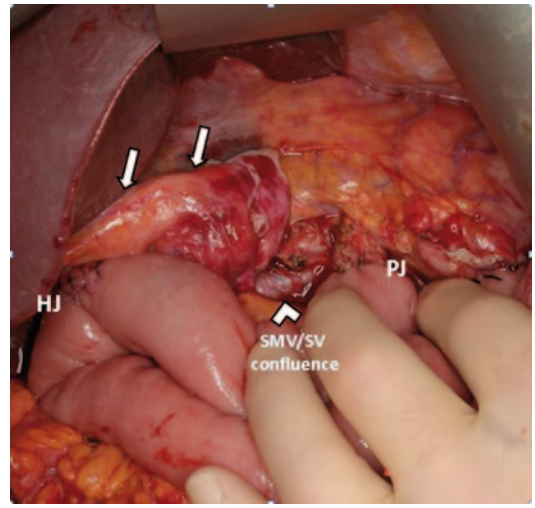

Fig. 26.2 Intraoperative photograph of completed pancreaticoduodenectomy. The falciform ligament pedicle flap (*white arrows*) completely covers the common hepatic artery and GDA stump from any possible *PJ* leak. *HJ* hepaticojejunostomy, *PJ* pancreaticojejunostomy, *SMV* superior mesenteric vein, *SV* splenic vein

stump, vascular anastomoses, or other peripancreatic vessels [22]. A pedicled falciform ligament is easily and rapidly obtained during a midline abdominal incision. After incising the linea alba, the preperitoneal fat is dissected laterally (to the left) when incising the peritoneum. The falciform ligament is mobilized by dividing it near the umbilicus and incising its anterior peritoneal reflections along the posterior rectus sheath. An additional length is obtained by continuing the anterior incision cephalad to the anterior surface of the liver. The pedicled falciform ligament is completed by taking down the attachments of the liver until just the obliterated umbilical vein remains attached. Note that the pedicled falciform ligament (Fig. 26.1) normally reaches the space between the pancreaticojejunostomy and the major vessels exposed during resection. After completion of the pancreatectomy, the pedicled falciform ligament is spread widely anterior to the common/proper hepatic artery with special attention to coverage of the GDA stump. A robust flap usually also covers the superior mesenteric vein (SMV), portal vein (PV), and splenic vein confluence effectively separating the vessels from the afferent jejunal limb (Fig. 26.2). When a distal pancreatectomy is performed, the pedicled falciform ligament can be fixed with 4-0 prolene sutures to the remnant pancreas thereby reinforcing the pancreatic closure. This procedure enables the complete separation of these vessels from the pancreas in the event that a pancreatic fistula and associated abscess were to develop.

The Portal Dissection

The portal dissection is initiated by removing the lymph node that lies directly anterior to the common hepatic artery (CHA) proximal to the right gastric artery and GDA. This facilitates exposure of the CHA proximal and distal to the GDA. The right gastric artery is ligated and divided followed by the GDA. Dissection of the hepatic artery should be performed with gentle, sharp dissection, especially in patients who have received prior chemotherapy or chemoradiation and in those with extensive peritumoral inflammation from a previous laparotomy or stent-related pancreatitis. Blunt dissection at the GDA origin can result in intimal dissection of the hepatic artery. Division of the GDA allows mobilization of the hepatic artery and exposure of the anterior surface of the PV directly posterior to the inferior border of the CHA. The PV should always be

exposed in this way before dividing the common hepatic duct. Care during this critical step in the performance of PD can minimize trauma to the hepatic artery and allow for a secure closure of the GDA stump [22].

GDA Ligation

Occasionally, ligation of the GDA is complicated by close proximity of the pancreatic tumor. If the tumor extends to within a few millimeters of the GDA, our technique is to obtain proximal and distal control of the hepatic artery and then divide the GDA flush at its origin. The resulting arteriotomy can be closed primarily with interrupted 6-0 prolene sutures. If 2 mms of GDA origin is available, we often use a small vascular pledget, as the hepatic artery can be quite fragile in this location; if the arteriotomy is flush with the CHA, a pledget cannot be used. When the tumor extends to the GDA origin, we divide the GDA prior to any form of ligation of the distal GDA on the specimen side. The GDA on the specimen side is suture ligated with 4-0 Prolene after it is divided; control of back-bleeding from this vessel is easily accomplished with simple hand pressure if a complete Kocher maneuver was performed earlier in the operation. This maneuver decreases trauma and handling of the GDA and decreases chances of intimal dissection of the hepatic artery [22]. When adequate length of GDA allows for a simple ligation, we usually use a 0-silk tie on the hepatic artery side with a 4-0 Prolene suture on the specimen side (so as to avoid unnecessary mobilization which is often needed to place a tie distally on the specimen side).

Reinforcing the Pancreatic Transection Site (Distal Pancreatectomy)

When performing a distal or subtotal pancreatectomy, the remnant pancreas can lead to a potential pancreatic fistula and subsequent PPH from a splenic artery pseudoaneurysm. We routinely divide the pancreas and perform the pancreatic closure either with Gore-Tex reinforced staples

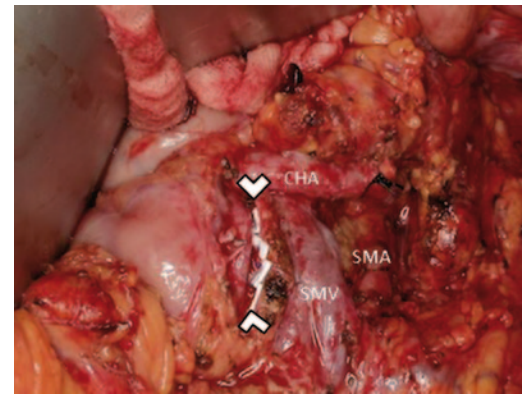

Fig. 26.3 Intraoperative photograph of a completed distal pancreatectomy. *Arrowheads* point to the cut margin of the pancreas closed with pledgeted sutures. *CHA* common hepatic artery, *SMA* superior mesenteric artery, *SMV* superior mesenteric vein

or with pledgeted sutures. The limitation to using the stapler is in proximal neck/body tumors where there is limited room (due to the proximity of the intrapancreatic bile duct) for achieving an adequate margin. In addition, as one moves to the patient's right of the pancreatic neck (and enters the region of the pancreatic head), the pancreas becomes too thick for a staple line. In this scenario, after confirming a negative margin, we identify the pancreatic duct and close it directly with a horizontal mattress suture. We then close the remaining pancreas with additional horizontal mattress sutures with a pledget on both the posterior and anterior surfaces (Fig. 26.3). The first such pledgeted suture is placed at the site of the pancreatic duct so that the duct closure is covered by the location of the pledget. Both a stapled closure and a suture closure with pledgets are done to minimize the risk of pancreatic fistula, which can increase the risk of PPH.

Diagnosis of Late PPH

Symptoms/Signs

The occurrence of a sentinel bleed is a key sign and symptom of late PPH [8, 16]. Sentinel bleeding refers to isolated bleeding, usually from the gastrointestinal tract or an abdominal drain/drain

site. It implies the presence of a structural vascular defect and requires immediate evaluation [23]. Sentinel hemorrhage, as mentioned previously, is often associated with local sepsis and an anastomotic leak; it is uncommon to see late PPH in a patient who has had a completely uneventful postoperative course [24]. Patients who develop a sentinel bleed, as defined as a low volume of hemorrhage in a patient who is hemodynamically stable at the time of the event, are at high risk of developing massive hemorrhage and should undergo diagnostic and therapeutic intervention as soon as possible [7, 8, 16]. The second episode of bleeding may follow in minutes or hours and is often severe, being accompanied by hemodynamic instability and a high risk of mortality. Vigilance is critically important, as up to 90% of patients who experience PPH have been through a turbulent postoperative period characterized by some form of intra-abdominal infection. Those patients who have had conservative management or radiological interventions for intra-abdominal fluid collections are at particularly high risk, and therefore, a sentinel hemorrhage in this setting warrants immediate attention [7, 16].

Imaging for Late PPH

Management of the exsanguinating patient with late PPH is unlikely to be successful and therein lies the rationale for immediate action in the setting of a sentinel bleed. A patient presenting with a sentinel bleed should undergo immediate angiography. If the diagnosis of a sentinel bleed is less clear, for example, the blood in the drain may have been associated with accidental traction on the drain, or the issue of a possible melanotic stool is in question, then CT imaging prior to angiography is quite reasonable. Ultrasound imaging may depict a false aneurysm but has no role in the investigation of acute bleeding. CT angiography may reveal the cause, site, and nature of bleeding if contrast extravasation is seen or a pseudo-aneurysm is visualized. A triple-phase examination (unenhanced, arterial, and venous phases) is performed with iodinated contrast material. Images are reviewed with multiplanar reformatting, which contributes to the diagnosis and aids in the planning of endovascular or surgical intervention. Unenhanced scans depict collections and high attenuation from beam-hardening and streak artifacts that can mimic bleeding. The arterial phase may reveal active contrast extravasation from the arterial anatomy. The venous phase may show contrast pooling and other complications that can follow a Whipple procedure [25, 26].

If CT imaging does not yield a focus for the bleeding and the patient becomes unstable or an unequivocal sentinel bleed were to occur, the patient should move directly to selective angiography without delay. Caution should be taken in interpreting the results of angiography if a bleeding site is not seen, as a negative examination does not rule out a late PPH. The intermittent nature of the bleeding can hamper detection by angiography even in patients with severe stigmata of bleeding. The importance of angiography cannot be overstated: first, embolization can be performed if the bleeding site is located and second, the alternative treatment to consist of reoperation is unlikely to be successful [27]. Emergent reoperative laparotomy in an effort to expose the GDA stump in an unstable patient stands a very low likelihood of being successful even if performed by a very experienced surgeon. The main (and perhaps only) hope for a good patient outcome rests in the interventional radiology suite, not the operating room. If the site of bleeding is uncertain, angiography of the celiac axis and SMA should be performed. Active contrast extravasation and pseudoaneurysms can be managed therapeutically when the diagnosis is made. Spasm and irregularity of a vessel are indirect signs of a source of bleeding. If extravasation from the expected sites is not seen, selective/superselective angiography can be performed [27].

Management of PPH

Early PPH

Management of early PPH should consist of resuscitation and in general, emergent return to

the operating room for laparotomy. Very rarely, gastrointestinal hemorrhage early in the postoperative period can be managed endoscopically. Therapeutic endoscopy may permit the successful management of a bleeding point in the gastrojejunostomy, which would be the only indication for endoscopy early in the postoperative setting. However, the pancreaticojejunostomy would be more likely to be the source of hemorrhage rather than the gastrojejunostomy. Patients with intra-abdominal bleeding, whether evident from a surgically placed drain or due to progressive expansion of the abdomen on examination, require re-operation, and a delay should not occur [12–14].

Late PPH

Patients with late PPH should undergo emergent selective angiography and if the source is found, embolization of the bleeding vessel should be performed. Embolization is successful in up to 80% of patients although this complication is uncommon and reports are largely anecdotal or consist of small series from large referral institutions. As noted previously, the key to preventing mortality is rapid recognition and prompt management. Postoperative gastrointestinal or drain tract bleeding should prompt immediate evaluation with arteriography. Gastrointestinal or drain tract bleeding represents a true medical emergency as the only patients likely to survive are those in whom the diagnosis is made immediately. Although individual surgeon experience with this complication is largely anecdotal, stenting of the hepatic artery or the more conventional embolization of the hepatic artery may both be successful. In the setting of a normal bilirubin, the liver will usually tolerate hepatic artery embolization when it is performed a few weeks after the hepaticojejunostomy. Multisystem organ failure and death usually result from the infectious complications and the excessive blood loss which may accompany/often accompanies this complication [22].

Embolization sacrifices distal blood flow but is the only alternative for areas where anatomy is complex and vessels are small [27]. The embolic materials used are coils, glue, thrombin, and absorbable gelatin sponge. Coils are commonly used and suitable when there is a single feeding vessel which can be sacrificed. It is essential to embolize both the inflow and outflow vessels or bleeding may recur. Balloon occlusion can be used for protection of distal circulation but tissue infarction is more likely than with coils. Stent grafting preserves distal perfusion, such as that to the liver and spleen, but can be impossible in tortuous and small vessels. Intentional dissection is an option if the bleeding site cannot be reached selectively for embolization [28, 29].

Pseudoaneurysms that persist after embolization can be managed with percutaneous injection of thrombin under ultrasound or CT guidance [16, 29]. The GDA stump is the most common cause of active extravasation or pseudoaneurysm formation. A bleeding source in the common or proper hepatic arteries can also occur as the result of a pancreatic leak. Covered stents are useful and have the added benefit of preserving distal perfusion. Celiac axis erosion is uncommon, and endovascular stent grafting is an option for management although this procedure may involve sacrificing either the hepatic or the splenic artery. An alternative is to embolize the whole vessel to ensure that there is no back filling from the celiac axis branches [30].

Splenic artery pseudoaneurysm is uncommon and when it occurs, is once again usually secondary to a pancreatic leak or intraoperative infection. Management depends on the site of extravasation and the tortuosity of the splenic artery. A covered stent can be used in straight arteries; in tortuous vessels, embolization is required. Proximal lesions can be embolized with preservation of splenic perfusion via the short gastric arteries as the left gastric artery is preserved and remains the main source of gastric perfusion. Embolization of distal lesions increases the risk of splenic infarction.

IPDA pseudoaneurysms are rarely seen after the Whipple procedure but when they occur, they are the result of a local infection (pancreatic leak) or abscess formation adjacent to the SMA. If bleeding is present, the problem can be managed with embolization or stenting.

Hemobilia due to a hepatic artery pseudoaneurysm with involvement of the residual common bile/hepatic duct in the inflammatory process can manifest itself as false extraluminal bleeding. The hepatic artery can be managed with embolization [29–31].

Conclusion

Complication rates for pancreatectomy still persist due to the large magnitude of the operation which is usually performed in patients of advanced age with associated comorbidities. PPH is one of the major causes of morbidity and mortality after PD. PPH can be divided into early and late postoperative bleeding. Early PPH is that which occurs within 24 h of surgery. It often is caused by technical failure of appropriate hemostasis during the index operation (failure to perform the SMA dissection correctly and to identify and ligate the IPDAs) or by an underlying perioperative coagulopathy. Late PPH occurs more than 24 h after the operation and typically one or more weeks from the date of surgery. Late PPH is associated with more common complications of the operation, most notably a leak from the pancreaticojejunostomy. Local sepsis from a pancreatic fluid collection or intra-abdominal abscess may erode the vascular wall adjacent to a loop of bowel leading to PPH. Prevention of PPH depends both on careful dissection of the portahepatis and the hepatic artery/GDA and on creation of a pedicled falciform ligament flap to protect the vessels from possible pancreatic fistula and fluid collections. For patients who receive a distal pancreatectomy, reinforcement of the pancreas transection site with Gore-Tex or pledgeted sutures can also be followed with falciform ligament flap coverage. The occurrence of a sentinel bleed is a key sign which often occurs before the onset of late PPH. Patients who develop a sentinel bleed, especially those who have had a complicated/septic postoperative period have a high risk of developing imminent massive hemorrhage and should undergo immediate diagnostic and therapeutic angiography.

Management of early PPH depends on whether the bleeding is located intraluminally or extraluminally. Interventional endoscopy is occasionally indicated when intraluminal PPH is suspected to originate from the gastrojejunostomy; reoperation is usually the treatment of choice for early PPH and in all cases where the blood is intra-abdominal (extraluminal). In the case of a late PPH usually associated with pancreatic fistula formation, angiography is the intervention of choice and should be performed without delay. If the source cannot be found at the first attempt at angiography, re-angiography may be performed within 6–24 h. The best solution to the problem of late PPH is prevention—a carefully performed operation and use of vascularized tissue to separate the hepatic artery from the afferent jejunal limb to include careful coverage of the GDA stump.

Key Points to Avoid Complications

1. Preserve the falciform ligament (obliterated umbilical vein) for use as coverage of the GDA stump, vascular anastomoses, or the splenic artery stump (in the case of a distal pancreatectomy).
2. When a distal pancreatectomy is performed, the falciform ligament can be sutured to the remnant pancreas allowing for complete separation of the adjacent vessels from the pancreas in the event of a pancreatic fistula.
3. Dissection of the hepatic artery should be performed with gentle, sharp dissection. Blunt dissection, especially at the GDA origin, can result in intimal dissection of the hepatic artery.
4. If the tumor extends to within a few millimeters of the GDA origin, our technique is to obtain proximal and distal control of the hepatic artery and then divide the GDA flush at its origin.
5. We routinely reinforce our remnant pancreatic transection with stapled Seamguard (Gore, Newark, DE) or pledgeted sutures.

Key Points to Diagnose/Manage

1. The occurrence of a sentinel bleed is a key sign, which often signals the onset of a significant PPH.
2. A patient presenting with an obvious sentinel bleed (acute blood loss of gastrointestinal (hematemesis or melena) or drain-site origin) should undergo immediate angiography in search of a pseudoaneurysm.
3. If the presence or absence of a sentinel bleed is not obvious (trace amount of blood at a drain site or a drop in hemoglobin in the absence of hematemesis or melena), a contrast-enhanced CT scan is indicated.
4. Patients who are found to have extraluminal PPH (most commonly the GDA stump) should undergo embolization or stent placement.
5. Splenic artery pseudoaneurysms are uncommon and most often secondary to a pancreatic leak or intraoperative trauma.

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Major Disruptions of Pancreaticojejunostomy

27

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Introduction

Modern series of pancreaticoduodenectomy (PD) operations consistently report mortality of well under 5% and morbidity of 30–50% in selected high-volume centers [1]. These outcomes are possible as a result of advances in surgical technique as well as in the perioperative care of patients who are more complex and have greater comorbidity than patients undergoing PD in prior eras. Patient selection and preparation are essential in order to maximize the potential for good outcomes. Wolfgang et al. have examined predictors of mortality following PD in over 1500 cases. They found that age, male sex, preoperative albumin, tumor size, and total pancreatectomy predicted 30-day mortality [2]. Of these factors, preoperative nutrition is the only modifiable risk factor.

Preoperative malnutrition and micronutrient deficiency may be severe in patients with pancreatic or periampullary malignancy, particularly in the setting of biliary obstruction, which may lead to significant deficiencies in fat-soluble vitamins A, D, E, and K. Careful assessment of preoperative weight loss, difficulties with alimentation (i.e., anorexia, early satiety, gastric outlet obstruction, and steatorrhea), and duration of jaundice aid in identifying patients with significant malnutrition who are at risk for major perioperative complications. Preoperative biliary decompression is often a consideration and should be generally avoided if definitive operation is planned within 7–10 days [3]. For patients in whom operation will be delayed, endoscopic biliary stenting with a plastic stent or short metal stent is currently the preferred modality for biliary decompression [4]. Finally, cardiopulmonary risk stratification and management of medical comorbidities is essential.

Arguably the single most important aspect of successful PD is performing the pancreatic–enteric anastomosis. Pancreatic leak is the major component of morbidity and mortality in every series and is often referred to as the "Achilles heel" of PD. The definitions and classification of postoperative pancreatic fistula/anastomotic leakage has been established by an international consensus conference as an abnormal communication between the pancreatic ductal epithelium and another epithelial surface containing pancreas-derived, enzyme-rich fluid. The clinical criterion is output via an operatively placed drain (or a subsequently placed, percutaneous drain) of any measurable volume of fluid on or after postoperative day 3, with an amylase content greater

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Table 27.1 International study group on pancreatic fistula (*ISGPF*) classification. (Modified from [5])

ISGPF parameters for postoperative pancreatic fistula grading			
Grade	A	B	C
Clinical condition	Well	Often well	Ill-appearing/bad
Specific treatment[a]	No	Yes/no	Yes
US/CT (if obtained)	Negative	Negative/positive	Positive
Persistent drainage (after 3 weeks)[b]	No	Usually yes	Yes
Re-operation	No	No	Yes
Death related to POPF	No	No	Possibly yes
Signs of infection	No	Yes	Yes
Sepsis	No	No	Yes
Re-admission	No	Yes/no	Yes/no

US ultrasound, *CT* computed tomography, *POPF* postoperative pancreatic fistula. *ISGPF* International Study Group on Pancreatic Fistula definition

[a] Partial (peripheral) or total parenteral nutrition, antibiotics, enteral nutrition, somatostatin analogue, and/or minimal invasive drainage

[b] With or without a drain in situ;

than three times the upper normal serum value [5]. By definition anastomotic leakage requiring re-operation is classified as grade C and is the topic of discussion for this chapter (Table 27.1).

Given the fragile nature of the pancreatic anastomosis and its propensity to leak, many variations have been described with various advantages and disadvantages touted for each. Despite numerous studies comparing the type and style of anastomosis (pancreaticojejunostomy vs. pancreaticogastrostomy, [6–9] duct-to-mucosa vs. invagination technique, [10] pancreatic duct stent vs. no stent [11–13], the choice for management of the distal pancreatic remnant is still largely a matter of surgeon preference and comfort. The authors prefer a modified Blumgart two-layer pancreaticojejunostomy with an outer layer of 2-0 silk horizontal mattress sutures and an inner duct-to-mucosa layer of 5-0 polydioxanone (PDS) performed end-to-side. However, in an experienced pancreaticobiliary surgeon's hands, several approaches may have similar outcomes.

Anastomosis begins by dissecting 2–3 cm of the pancreatic stump from surrounding tissues (Fig. 27.1a–c). The jejunal limb is brought through the duodenal hiatus or another retrocolic window is made in the transverse colon mesentery and positioned to allow creation of a tension-free end-to-side anastomosis. Interrupted horizontal mattress sutures of 2-0 silk are placed using transpancreatic bites of pancreas and seromuscular bites of jejunum (Fig. 27.1a). The needles are left on these sutures and used for the anterior seromuscular buttressing layer later. Care must be taken not to suture the pancreatic duct; thus, a temporary 5F or 7F Hobbs ERCP stent (Hobbs Medical, Stafford Springs, CT) is placed in the duct to help prevent inadvertent occlusion. Three sutures are required for the posterior row: one superior, one straddling the pancreatic duct, and one inferiorly. The middle stitch is placed while moving the stent in the duct to assure the knot is not tied too tight. Next, a 2–3 mm enterotomy is made in the jejunum, and the inner suture line is constructed with interrupted 5-0 PDS. Beginning at the superior aspect of the gland, the suture line incorporates the pancreatic duct and full-thickness jejunum. Depending on the size of the duct, it is usually possible to place three to five sutures in a duct-to-mucosa fashion in the anterior and posterior rows, each. After the posterior suture line is complete, it is tied down and the Hobbs stent is inserted into the pancreatic duct with the curved end inserted into the jejunum (Fig. 27.1b). The anterior suture line is formed. Finally, the anterior row of 3-0 silk mattress sutures are placed using seromuscular bites of jejunum secured to the capsule of the pancreas. In tying the sutures, take extreme care to avoid pulling the sutures through the tissue when attempting to imbricate the jejunum over the anastomosis, particularly when the pancreas is soft (Fig. 27.1c). A #19 round channel

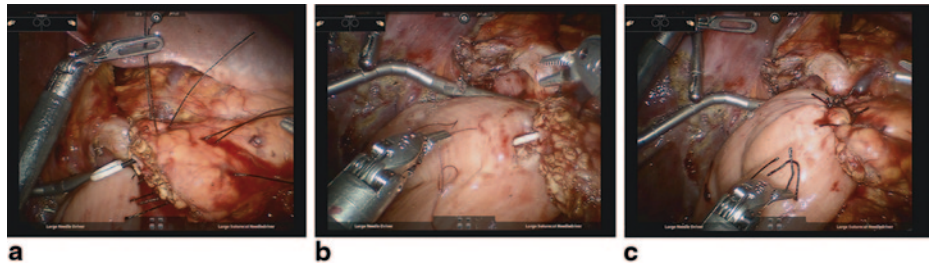

Fig. 27.1 **a** Completed posterior row of 3-0 silk stitches. **b** Posterior row of 5-0 PDS duct-to-mucosa stitches and pancreatic duct stent in place. **c** Completed pancreaticojejunostomy

drain is placed in the region of the anastomosis to help detect leakage and manage smaller leaks in the postoperative period. Although not classically described in the literature, in the opinion of the authors, attention should also be paid to the placement of the biliary anastomosis with respect to the pancreatic anastomosis. Whenever possible, at least 10–15 cm should be left between the two anastomoses to prevent reflux of biliary fluid into the pancreatic anastomosis. Although little clinical evidence exists to support this practice, it is an important anecdotal observation that may decrease the incidence of massive pancreatic anastomotic disruption.

There exists some debate on the use of closed suction drains following PD. Drainage of the pancreatic anastomosis may be associated with greater likelihood of pancreatic fistula, and some have advocated abandoning the use of drains routinely following PD [14, 15]. It is the opinion of the authors that drains should be placed following most, if not all PD and clinical trials support this. A recent randomized multicenter trial comparing routine placement of operative drains to no drains following PD provides level-one evidence that routine use of closed suction drains should be standard of care. In this study, all-cause mortality was higher in the no drain group and there was an increased number and mean severity of complications when operative drains were not placed. There was no increase in the incidence of pancreatic fistula between the two groups [16]. It is likely that the excess mortality seen in the no drain group reflects the consequences of undrained pancreatic fluid in the small number of patients who develop significant compromise to the integrity of the pancreaticojejunostomy, resulting in the development of multisystem organ failure (MSOF) and death.

Despite compelling data supporting the routine use of drains, an emerging consensus also suggests that they represent a double-edged sword and can lead to an increased incidence of pancreatic fistula when left in situ for a prolonged period of time. Prospective data indicate that amylase activity of drain effluent less than 5000 U/L predicts a low likelihood of clinically significant pancreatic fistula [17]. In these patients with a low risk of pancreatic fistula, drains may be safely removed early in the postoperative period without relying on standard metrics of drainage character or volume. A prospective randomized study investigating early removal of operative closed suction drains in patients with postoperative day 1 drain that amylase values of less than 5000 U/L found significantly fewer complications, including pancreatic fistulae in the early removal group (postoperative day (POD) 3 vs. ≥ POD 5) [18]. Several caveats should be noted in this study including the fact that the authors did not use closed suction drains and subjects were only randomized if they showed "no adverse clinical metrics."

It is the author's opinion that closed suction drains are important in the early postoperative period to assist in management of major disruptions of the pancreatic anastomosis. However, persistent application of negative pressure can clearly lead to persistence of a "nuisance" low-grade fistula. Since 2008, we have adopted a modified "Verona" protocol: One or two #19 channeled closed suction drains are placed near the pancreatic anastomosis and drain amylase activity is measured on POD 3. For patients who

are clinically improving and have drain amylase activity of less than two to three times the serum amylase on POD 4, the drain(s) is/are removed. In our experience, this approach has resulted in a very low rate of uncontrolled pancreatic leaks while also minimizing clinically insignificant "nuisance" low-grade fistulae.

Major anastomotic disruptions typically present early in the postoperative course (POD 3–5) though they may occur later, as in the case of an operative drain that has eroded tissues, thus creating an anastomotic dehiscence. Often, the first recognized indications of a major disruption of the pancreatic anastomosis will be deteriorating clinical indices such as tachycardia, hypotension, fever, and oliguria. Delayed return of bowel function and/or delayed gastric emptying is also common, though nonspecific findings. Leukocytosis/leucopenia, electrolyte abnormalities (i.e., acidemia, hypokalemia), thrombocytopenia/thrombocytosis, coagulopathy, and anemia are frequent laboratory findings. In cases of grade C fistula, patients may meet criteria for systemic inflammatory response syndrome (SIRS)/sepsis and many experience some degree of MSOF involving cardiac, respiratory, renal, hepatic, and other organ systems.

Management of major pancreatic anastomotic disruption should progress in a logical, stepwise fashion (Fig. 27.2). The two primary clinical goals in the early setting of a massive pancreatic anastomotic failure are goal-directed resuscitation to maintain end-organ perfusion and establishment of a controlled pancreatic fistula. Intravenous fluids (either crystalloid or blood, as indicated) to maintain euvolemia and correct acidosis should be administered. Adequate vascular access including central venous catheter(s), arterial catheter, and/or pulmonary artery catheter may be indicated.

In attempting to diagnose and characterize pancreatic fistulae, computed tomography (CT) scans of the abdomen have limited ability to assess the integrity of the pancreatic anastomosis and are only used to assess for the presence of undrained pancreatic fluid collections (Fig. 27.3). Patients are often acutely ill, and the decision of whether and when to transport to the radiology department should be carefully considered. Given that most patients with significant SIRS have disruptions in regional blood flow to the kidney and are at significant risk of contrast-induced nephropathy, intravenous (IV) contrast should rarely be used.

An attempt at nonoperative management is warranted and is successful in a vast majority of instances in the experience of the authors. For situations where a surgical drain was not placed, the patient demonstrates clinical SIRS, and a major pancreatic anastomotic disruption is suspected, an attempt at image-guided percutaneous drainage is worthwhile in all but the most unstable patients. Most patients will demonstrate significant and rapid clinical improvement with successful establishment of a controlled fistula via a percutaneous drain. In patients with existing surgically placed drains, a noncontrast CT scan can be considered to rule out displacement of the drain and/or presence of undrained collections.

Once drainage is accomplished, the character of the drain fluid should be noted: Classically, thin, cloudy, gray "dishwater" fluid is observed in situations of major disruptions. It is important to note that drain fluid from major pancreaticojejunostomy disruptions is often bilious. Bile may leak retrograde from the hepaticojejunostomy through a disruption in the pancreaticojejunostomy if it is not draining antegrade through the efferent jejunal limb. Considering that the hepaticojejunostomy is a more structurally robust anastomosis, bilious drainage can be considered the more likely result of a leaking pancreaticojejunostomy than vice versa. As was noted above in the section on constructing a pancreaticojejunostomy, this bile reflux may be more significant when there is insufficient length between the hepaticojejunostomy and pancreaticojejunostomy and, in the opinion of the authors, contributes to development of severe pancreatic fistulae.

Bloody drainage is a particularly ominous sign as this may indicate hemorrhage from a ruptured pseudoaneurysm of the gastroduodenal artery or other visceral arterial branches exposed during the course of dissection. Most cases of pseudoaneurysm rupture appear later in the course of a significant pancreatic leak, often 2–3 days after

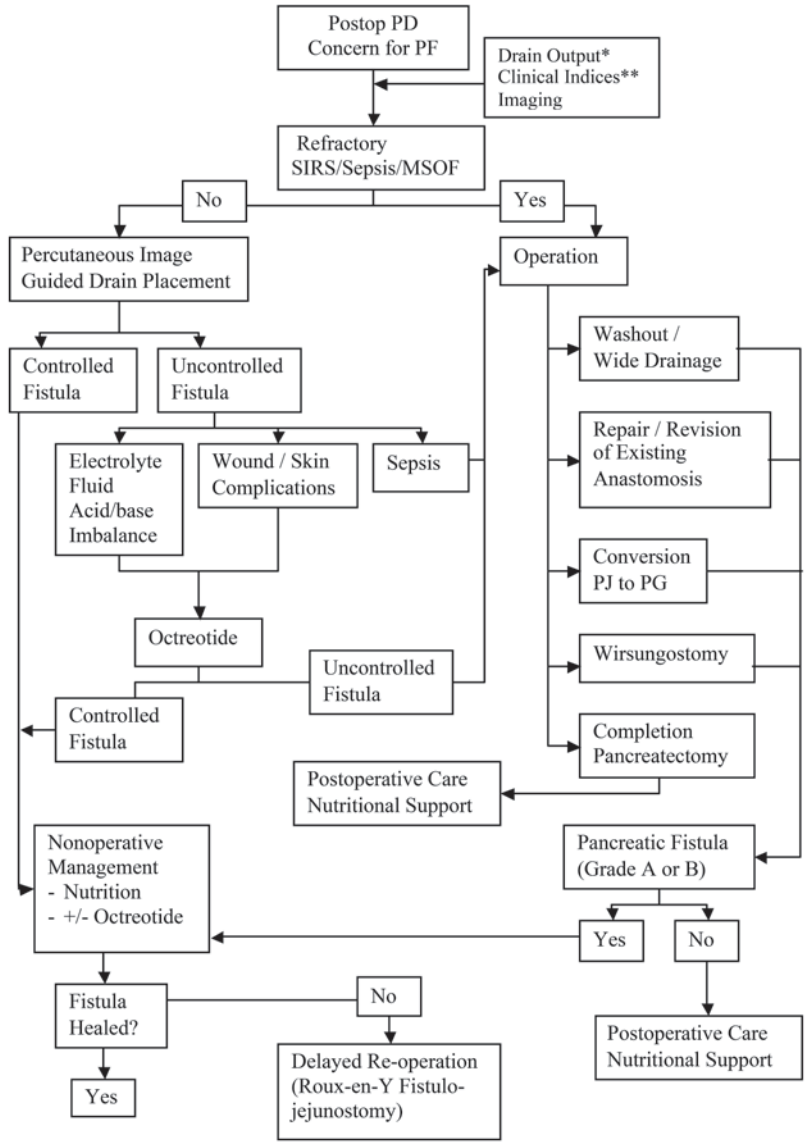

Fig. 27.2 Diagnostic/therapeutic algorithm for pancreaticojejunostomy dehiscence. *Single asterisk* drain output: bilious, "cloudy/dishwater", bloody; *double asterisk* clinical indices: tachycardia, fever, leukocytosis, abdominal pain; *PD* pancreaticoduodenectomy, *PF* pancreatic fistula, *SIRS* systemic inflammatory response syndrome, *MSOF* multisystem organ failure

recognition of the leak when the patient has recovered from the initial insult. As with pancreatic fistula, an international study group classification of postpancreatectomy bleeding has been established (Table 27.2, 27.3) [19].

Empiric broad-spectrum antibiotics are often indicated and should cover Gram-negative (*Escherichia coli, Klebsiella pneumoniae, Enterobacter*), enteric Gram-positive (*Enterococcus*), and possibly fungal (*Candida*) organisms. Bile cultures obtained at the time of index operation have been advocated as helpful in this scenario, particularly if preoperative biliary stenting was performed.

The decision to re-operate is based on the presence of refractory and progressively worsening

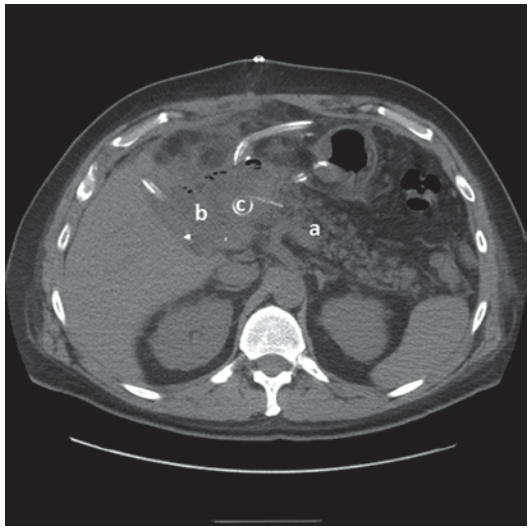

Fig. 27.3 Computed tomography scan showing pancreaticojejunostomy leak. a - pancreatic remnant, b - peripancreatic fluid collection, c - pancreatic duct stent

SIRS in the presence of apparently adequate drainage. It should be stressed that re-operation for major pancreatic anastomotic disruptions is and should be an extremely rare event. As noted above, an overwhelming majority of these situations can be managed with nonoperative percutaneous drainage and aggressive critical care management (Fig. 27.2).

Once the abdomen is opened, retractors are placed, and exploration of the abdomen is commenced, the pancreatic, biliary, and enteric suture lines are inspected. Evacuation of pancreatic ascites/fluid collection(s) should be performed along with copious irrigation of the peritoneal cavity. As most of these re-explorations occur in the early postoperative period, there are rarely intense adhesions. Great care should be taken not to disrupt the fragile hepaticojejunostomy and gastrojejunostomy during exploration. Once the disruption of the pancreatic anastomosis is identified, the relative condition of the pancreatic tissues and bowel is taken into consideration when determining the next step. Several interventions can be considered and the pros and cons of each are carefully weighed with the patient's condition (Table 27.4). Most often there is a marked inflammatory response to pancreatic leakage

Table 27.2 International Study Group on Pancreatic Surgery (*ISGPS*) definition of postpancreatectomy hemorrhage. (Adapted from [19])

Definition of postpancreatectomy hemorrhage (PPH)
Time of onset
Early hemorrhage (≤24 h after the end of the index operation)
Late hemorrhage (>24 h after the end of the index operation)
Location
Intraluminal (intraenteric, e.g., anastomotic suture line at stomach or duodenum, or pancreatic surface at anastomosis, stress ulcer, pseudoaneurysm)
Extraluminal (extraenteric, bleeding into the abdominal cavity, e.g., from arterial or venous vessels, diffuse bleeding from resection area, anastomosis suture lines, pseudoaneurysm)
Severity of hemorrhage
Mild
Small or medium volume blood loss (from drains, nasogastric tube, or on ultrasonography, decrease in hemoglobin concentration <3 g/dL)
Mild clinical impairment of the patient, no therapeutic consequence, or at most the need for noninvasive treatment with volume resuscitation or blood transfusions (2–3 units packed cells within 24 h of end of operation or 1–3 units if later than 24 h after operation)
No need for re-operation or interventional angiographic embolization; endoscopic treatment of anastomotic bleeding may occur provided the other conditions apply
Severe
Large volume blood loss (drop of hemoglobin level by ≥3 g/dL)
Clinically significant impairment (e.g., tachycardia, hypotension, oliguria, hypovolemic shock), need for blood transfusion (>3 units of packed cells)
Need for invasive treatment (interventional angiographic embolization, or relaparotomy)

Table 27.3 International Study Group on Pancreatic Surgery (*ISGPS*) classification of postpancreatectomy hemorrhage. (Adapted from [19])

Classification of PPH: clinical condition, diagnostic, and therapeutic consequences				
Grade	Time of onset, location, severity, and clinical impact of bleeding	Clinical condition	Diagnostic consequence	Therapeutic consequence
A	Early, intra- or extraluminal, mild	Well	Observation, blood count, US and, if necessary CT	None
B	Early, intra- or extraluminal, severe *or* Late, intra- or extraluminal, mild[a]	Often well/intermediate, very rarely life-threatening	Observation, blood count, US, CT, angiography, endoscopy[b]	Transfusion of fluid/blood, ICU, therapeutic endoscopy[b], embolization, relaparotomy for early PPH
C	Late, intra- or extraluminal, severe	Severely impaired, life-threatening	Angiography, CT, endoscopy[b]	Localization of bleeding, angiography, embolization, (endoscopy[b]) *or* relaparotomy, ICU

US ultrasound, *CT* computed tomography, *ICU* intensive care unit, *PPH* post-pancreatectomy hemorrhage
[a] Late, intra- or extraluminal, mild bleeding may not be immediately life-threatening to patient but may be a warning sign for later severe hemorrhage ("sentinel bleed") and is therefore grade B
[b] Endoscopy should be performed when signs of intraluminal bleeding are present (melena, hematemesis, or blood loss via nasogastric tube)

Table 27.4 Options for surgical management of major pancreatic anastomotic disruptions

Options for surgical management of major pancreatic anastomotic disruptions
Conversion of pancreaticojejunostomy to pancreaticogastrostomy
Wide local drainage with or without pancreatic duct ligation
Wirsungostomy or "bridge stent"
Completion pancreatectomy

causing edema, hyperemia, and friability of the tissues. For this reason, simple suture repair of the leaking anastomosis is doomed to failure and should almost never be considered.

One option in a clinically stable patient with completely viable pancreas is to convert a pancreaticojejunostomy to pancreaticogastrostomy. We feel this option must be considered with great caution given there is a substantial likelihood of this second anastomosis leaking. In the instance of a re-operation where debridement of the pancreatic neck and jejunal limb is required to obtain healthy tissues, there will usually be insufficient bowel length to create a tension-free anastomosis between the pancreatic remnant and efferent jejunal limb. An intact biliary anastomosis should not be reconstructed in order to gain more jejunal length in this setting. Therefore, due to the mobility of the stomach and its proximity to the pancreatic stump, a pancreaticogastrostomy may be constructed. The anastomosis is performed to the posterior wall of the stomach in two layers as described by Yeo et al. [7] Briefly, the distal 2–3 cm of pancreatic remnant is dissected and a 2–3 cm gastrotomy is made. An outer layer of 3-0 silk and inner layer of 3-0 or 4-0 PDS is used with the inner layer incorporating pancreatic duct and mucosa where feasible. Alternatively, the anastomosis may be performed in a single layer [20]. The excess jejunal limb upstream of the biliary anastomosis is brought to the skin as an ostomy, oversewn, or resected depending on tissue viability, length of remnant, and/or condition of the patient. A feeding jejunostomy should be placed as well. Salvage pancreaticogastrostomy was found to be associated with less postoperative diabetes (25 vs. 100%), one grade B pancreatic fistula managed nonoperatively (25%), and no mortality when compared retrospectively with completion pancreatectomy [21]. Randomized

controlled data are lacking (and likely impossible to obtain due to the rarity of this complication); however, this approach appears to be a safe operative strategy in selected patients.

When a disruption of the anastomosis that is not amenable to reconstruction is discovered at the time of re-exploration or there is a marked inflammatory response, more definitive measures must be taken to obtain a controlled fistula. In situations where the anastomosis appears to be largely intact, consideration can be given to establishing better evacuation and irrigation of the pancreatic fluid with larger closed suction drains or irrigating catheters (i.e., Axiom). One may also place a pedicled omental or falciform flap over the visceral vessels to prevent pseudoaneurysm formation though clinical evidence to support this is based on anecdotal/observational data. At the very least, there seems to be little downside to this approach, warranting its consideration [22]. Another possible approach is to deconstruct the pancreatic anastomosis and ligate the main pancreatic duct. Neither wide drainage alone nor ligation of the pancreatic duct is preferred due to the unavoidable adverse consequences of ongoing pancreatic leakage (sepsis, electrolyte disturbances, loss of exocrine function, nutritional deficiency, ongoing major pancreatic fistula) or pancreatic duct ligation (acute pancreatitis and long-term pancreatic atrophy with complete loss of exocrine and endocrine function). However, if the patient is in extremis at the time of re-operation, a "damage control" approach may be warranted in order to limit operative time with an open abdomen and its attendant physiologic consequences (hypothermia, fluid losses, coagulopathy, etc.).

A variation of local drainage of the pancreatic bed that can avoid the undesirable consequences of pancreatic duct ligation or completion pancreatectomy (see below) is Wirsungostomy. Drainage of the pancreatic duct can be performed expeditiously in patients with significant physiologic derangement without concern for breakdown of a second, high-risk pancreatic anastomosis. After dismantling the dehiscent pancreatic anastomosis and debridement of the distal pancreatic stump as necessary, a 6–10F silastic tube with end and side holes is inserted into the main pancreatic duct and exteriorized through the right flank. A pancreaticojejunostomy is then performed later once the fistula is controlled, infected fluid is drained, sepsis is resolved, and the patient has recovered completely from operation (mean 130 days after re-operation in one study) [23]. This is usually done with a Roux-en-Y limb of jejunum to the fistula tract rather than directly to the pancreatic duct itself. Mortality was 17% and the function of the pancreatic remnant was preserved in 75% of patients (though no biochemical/objective measures of exocrine or endocrine function were made) [23]. Alternatively, a "bridge stent" using a similar silastic tube sutured in place to the jejunum and pancreatic stump may be used to bridge the gap resulting from pancreaticojejunostomy dehiscence. This technique diverts pancreatic fluid away from the peritoneum and preserves the pancreatic remnant, avoiding pancreatic endocrine and exocrine dysfunction or loss [24].

The most definitive operation to correct disruption of the pancreatic anastomosis is completion pancreatectomy [25]. This is usually performed in conjunction with splenectomy though the spleen may be preserved [26]. Certainly, completion pancreatectomy is required when the pancreatic remnant is found to be nonviable at the time of re-operation, which can be observed in rare cases of postpancreatectomy pancreatitis. Clearly, ischemic or necrotic bowel should be resected to viable tissue. If the initial pancreatic reconstruction was with a pancreaticogastrostomy, the gastrotomy can be oversewn in one or two layers. Sump drainage of the stomach with a nasogastric tube is generally indicated following repair. Finally, tube jejunostomy should be performed for postoperative nutritional support. Careful attention to postoperative glycemic control is paramount for these critically ill patients. Loss of both insulin and glucagon secretion precipitates wild swings in blood glucose that may be difficult to manage, particularly in the setting of sepsis. Consultation with an endocrinologist may be warranted for acute management as well as to establish long-term follow-up care.

Outcomes following completion pancreatectomy for major pancreatic duct disruption

following PD are generally poor, as might be expected [26]. Undoubtedly, this is in large part due to the emergent nature of operation in a profoundly ill patient, often with serious underlying comorbidity (i.e., pancreatic malignancy, malnutrition, other).

As was described following Wirsungostomy, relaparotomy to establish a pancreatic-enteric anastomosis in patients managed with long-term catheter drainage of a persistent pancreatic fistula may be performed months later [27]. In the author's personal experience, at least 6 months are necessary to allow resolution of the inflammatory changes, restitution of nutrition, and maturation of the fistula track. As is the case in patients with major pancreatic duct disruption following acute pancreatitis, it is often not feasible, nor desirable, to dissect out the pancreatic parenchyma in order to fashion an anastomosis to the bowel. The preferred approach in these situations is to create an anastomosis of the fibrotic drain tract to a Roux-en-Y limb of jejunum [28, 29]. The jejunal–fistula tract anastomosis should be made as close as possible to the pancreatic parenchyma to prevent closure of the fistula tract. Anastomosis should not be made to a matured pseudocyst wall or abscess cavity as this is associated with surgical failure and recurrent fistula [30]. Technique for fistula–enteric anastomosis is quite variable: The authors approach it much the same way as a conventional pancreatic anastomosis. An outer layer of interrupted seromuscular jejunum with 2-0 silk to the fibrotic tissues surrounding the drain tract followed by a duct to drain tract layer with 4-0 PDS. It may be advisable to leave a drain in the fistula tract and create a Witzel tube jejunostomy through the Roux limb to the abdominal wall, particularly if the drain tract was not robust [24].

Generally patients will require a period of care in the intensive care unit for further resuscitation and management of ongoing sepsis, hemodynamic monitoring, and MSOF. Empiric antibiotics begun preoperatively should be continued until culture data allow for narrowing of antimicrobial coverage. Ongoing "prophylactic" antibiotics should not be utilized without some objective data indicating the presence of infection (positive culture, ongoing fevers, continued SIRS without alternative explanation, etc.). Operative drains are maintained on closed suction drainage or continuous irrigation (Axiom type) as appropriate.

Nutritional support should be instituted as soon as possible. Protein catabolism in the postoperative period can be severe and some degree of hyperalimentation may be necessary to maintain nutritional balance. Caloric needs should be calculated and titrated based on nitrogen balance and nutritional indices such as prealbumin, albumin, ferritin, and body weight. Initially, total parenteral nutrition (TPN) is likely to be required until postoperative ileus has resolved, vasopressors are weaned, and gut perfusion allows enteral alimentation. As soon as is feasible, enteral nutrition, preferably via jejunostomy tube placed at the time of re-operation or nasojejunal tube, should begin. For patients with ongoing pancreatic fistula following re-operation, a randomized controlled trial of enteral versus parenteral nutrition showed increased rates of fistula closure at 30 days in patients maintained on enteral nutrition [31]. Additionally, for critically ill patients, there are fewer infectious complications and a trend toward improved survival in patients treated with enteral nutrition [32]. Nasogastric tube (NGT) feeding is suboptimal as an enteral feeding route due to risks of aspiration, long-term NGT complications (dislodgement, aspiration, sinusitis, erosion of nasal mucosa), and the high incidence of delayed gastric emptying (DGE) associated with pancreatic fistula following PD. When the patient is able to begin oral alimentation, this should be initiated keeping in mind that nutritional supplementation with tube feedings may be required for some time as oral intake is increased. This can often be accomplished by continuous nocturnal jejunostomy feeds.

An important consideration in patients who are tolerating oral alimentation is pancreatic enzyme supplementation. For patients undergoing completion pancreatectomy, pancreatic exocrine function is absent and enzyme supplementation is mandatory. The same is true for patients with significant postoperative fistulas as the diversion

of pancreatic fluid creates an essentially apancreatic state in terms of exocrine function. For the remainder of patients, enzyme supplementation is initiated based on symptomatic postprandial diarrhea/steatorrhea and should be treated with pancrealipase 60,000 U with meals and may be titrated upward for continued symptoms. Generally, smaller, more frequent meals (5–6/day) are better tolerated and should be recommended. We do not check fecal elastase or fecal fat levels routinely as these values are difficult to interpret and do not predict the need for enzyme supplementation in postpancreatectomy patients.

Somatostatin analogues may be helpful to decrease the volume of drainage from recurrent/persistent pancreatic fistulae though data are lacking on their efficacy in promoting complete healing or spontaneous closure [33]. The authors employ somatostatin as a three-times daily (TID) subcutaneous injection of 150 mcg in patients with high-output pancreatic fistulas with associated electrolyte abnormalities and/or skin excoriation. The TID regimen can be converted to a depot dose of 20–30 mg intramuscular monthly. The effect of therapy is assessed by volume of output after 3 days, and if there has not been a $\geq 50\,\%$ decrease in fistula output, therapy is discontinued. Otherwise, therapy is continued indefinitely until spontaneous fistula closure or definitive therapy to close the fistula is successful.

Occasionally, major pancreaticojejunostomy disruptions will manifest as a pancreatic–cutaneous fistula rather than through well-controlled drain tracks. In these situations, skin excoriation and breakdown can be severe and difficult to manage, particularly when combined with an open-wound and high-output fistula drainage. CT scan of the abdomen should be performed to look for undrained intra-abdominal fluid collection(s) and, if found, these should be drained percutaneously. We find vacuum-assisted/negative pressure wound dressings are particularly helpful as they collect wound drainage and prevent skin damage while facilitating wound granulation. Grossly infected wounds should be debrided prior to placing VAC dressings and careful examination for fascial dehiscence performed. In cases where fascial dehiscence is noted and bowel is visible below, care must be taken not to apply the VAC sponge directly to the bowel as negative pressure may precipitate an enteric fistula.

Conclusion

Major pancreaticojejunostomy disruption is a dreaded complication of PD that has significant attendant morbidity and mortality. Despite the seriousness of the complication, there are multiple options for management. We advocate a thoughtful, deliberate approach that utilizes non-operative techniques such as image-guided percutaneous drain placement first and re-operation only for recalcitrant leaks or the sickest patients. Utilizing this management strategy maximizes the chances for a successful outcome following a major operative complication.

Key Points: How to Avoid Complications

1. Patient selection
2. Duct-to-mucosa anastomosis
3. Tension-free, well-vascularized anastomosis
4. Use of closed suction drains
5. Early removal of closed suction drains when appropriate

Key Points: Diagnosis/Management

1. Clinical parameters
2. Imaging
3. Resuscitation
4. Operation
5. Postoperative management

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Persistent Pancreatic Fistula

28

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Introduction

In 1898, Halsted performed the first local excision of a carcinoma of the ampulla of Vater [1]. The pancreatic resection of periampullary tumors was popularized in a 1935 classic paper by Whipple et al. [2]. Their two-stage pancreatoduodenectomy consisted of posterior gastroenetrostomy, ligation, and division of the common bile duct and cholecystogastrostomy in the first stage, followed by resection of the duodenum and pancreatic head in the second stage. The pancreatic stump was closed with sutures, without a pancreaticoenteric anastomosis. Whipple later described the procedure performed in a single stage in 1940. The reconstruction was modified in 1942 to include pancreaticojejunostomy, due to the high rate of pancreatic fistula after the closure of the pancreatic stump [3]. This may represent the first modification of a surgical procedure to prevent pancreatic fistula.

By the mid-1990s, improvements in anesthesia, perioperative management, and the regionalization of care had decreased the surgical mortality in most major centers to less than 5% for both pancreaticoduodenectomy and distal pancreatectomy [4, 5]. Unfortunately, the postoperative morbidity remains high and still approaches 50% even in large series [5, 6, 7]. The key determinant of outcome after pancreatoduodenectomy remains the pancreaticoenteric anastomosis. Although many pancreatic fistula are self-limited problems that resolve over time, sepsis and hemorrhage, due to a pancreatic leak can be associated with mortality of 20–40% and result in prolonged hospitalization and increased hospital costs [8]. Therefore, the management of pancreatic fistula after a major operation requires an evidence-based multidisciplinary approach to "rescue" many patients from life-threatening complications. Finally, in the cases with persistent fistulas, defined as fistulas present for greater than 6 weeks, definitive treatment may be necessary.

Definition of Pancreatic Fistula

In general, a pancreatic fistula is defined as leakage of enzyme-containing fluid from the pancreatic parenchyma or duct regardless of origin and cause. Pancreatic parenchymal or ductal disruptions may be iatrogenic or due to progression of disease. Iatrogenic pancreatic fistulas usually result from operative trauma, resection of a portion

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of the pancreas, or from the complications of endoscopic interventions usually during endoscopic retrograde cholangiopancreatography (ERCP). Noniatrogenic fistulas typically result from either acute or chronic pancreatitis, caused most frequently by cholelithiasis or alcohol. A pancreatic fistula can drain either internally or externally. An internal pancreatic fistula is usually seen in patients with a history of pancreatitis, where leakage is not controlled by the inflammatory response. Such fistulas may manifest as pancreatic ascites or a pancreaticopleural fistula. An external pancreatic fistula or pancreaticocutaneous fistula usually occurs after percutaneous drainage of a pancreatic fluid collection/pseudocyst, following pancreatic debridement, or after a pancreatic resection usually via an operatively placed drain. With regard to the postoperative pancreatic fistula, the leakage from the pancreatic anastomosis or the stump is usually observed in the early days after a resection.

In the past, authors have described pancreatic fistula using nonstandardized definitions. Inherent to the problem of defining pancreatic fistula was that complications from leakage of pancreatic fluid present in multiple ways and can carry multiple diagnoses including peripancreatic collection or intra-abdominal abscess. Documentation, that the fluid is rich in amylase, will define the complication as a pancreatic leak and once drained externally, is by definition a pancreatic fistula.

Until 2005, 26 different definitions of postoperative fistula were used, resulting in a variety of confusing scoring systems with limited clinical value. Furthermore, the reported incidences of fistula of 2–50% in different studies were not comparable, making a scientific approach to address this problem difficult. In 2005, the International Study Group on Pancreatic Fistula (ISGPF) consensus paper defined a postoperative pancreatic fistula as the existence of any fluid output via an intraoperatively placed or postoperatively inserted drain on or after postoperative day 3 with an amylase content greater than three times the upper normal serum value [9]. After the diagnosis of fistula has been established from this simple laboratory finding, it should be further classified regarding the clinical condition, specific therapeutic measures, the duration of treatment, consecutive complications, and the outcome of the patient (Table 28.1). According to ISGPF stratification of pancreatic fistulas, grade A (low grade) resolves spontaneously and needs no intervention; grade B (medium grade) requires change in management or adjustment of the clinical pathway, but patients are not severely ill. Grade C fistula (high grade) is a refractory postoperative pancreatic fistula that requires a major change in the clinical management and aggressive clinical intervention and is associated with systematic illness and sepsis.

With this three-category system, a standardized definition was established, which was widely accepted, validated, and used worldwide by

Table 28.1 ISGPF grading system of postoperative pancreatic fistula. (Adapted from [44])

Criteria	Grade A fistula	Grade B fistula	Grade C fistula
Clinical conditions	Well	Often well	Ill-appearing/bad
Specific treatment	No	Yes/no	Yes
Ultrasound/CT scan	Negative	Negative/positive	Positive
Persistent drainage (>3 weeks)	No	Usually yes	Yes
Signs of infection	No	Yes	Yes
Sepsis	No	No	Yes
Reoperation	No	No	Yes
Readmission	No	Yes/no	Yes/no
Death related to fistula	No	No	Yes

Drain output of any measurable volume of fluid on or after postoperative day 3 with an amylase content greater than three times the serum amylase activity

ISGPF International Study Group On Pancreatic Fistula, *CT* computed tomography

all major study groups for the categorization of patient data. Pratt et al. prospectively analyzed postoperative complications in 176 patients after pancreaticoduodenectomy [10]. In this study, there were 53/176 patients (30%) confirmed fistula—26 (15%) type A, 21 (12%) type B, and 6 (3%) type C. Patients with grade A fistula had shorter hospital stays and less secondary complications than patients with grade B and C fistula. Compared to patients with grade B fistula, patients with grade C fistula had a longer hospital stay, a higher frequency of intensive care unit (ICU) admissions, and more blood transfusions. This study served to validate the ISGPF classification scheme in demonstrating minimal clinical impact of type A fistulas, while showing more complications and costs in patients with type B and C fistula.

Procedure-Specific Incidence and Risk Factors for Pancreatic Fistula

The occurrence of a pancreatic fistula is highly dependent on the type of surgical procedure performed and the underlying pancreatic pathology. Soft pancreatic tissue texture without pre-existing fibrosis is regarded as a risk factor for fistula development in all pancreatic procedures.

Pancreaticoduodenectomy

Pancreaticoduodenectomy is the treatment of choice for patients with resectable carcinoma of the pancreatic head and periampullary region. In recent years, the mortality rate of pancreaticoduodenectomy has declined to <5%. However, the overall morbidity remains at approximately 50% with the pancreatic fistula occurring in 5–40% of patients [6, 7]. In an attempt to understand pancreatic fistula after pancreaticoduodenectomy, several risk factors have been identified. These include patient risk factors (age, sex, bilirubin level, and comorbid conditions), pancreas risk factors (pancreatic texture, pancreatic duct size, underlying patient pathology and blood supply to the pancreatic remnant) and operative risk factors (operative time, blood loss, anastomotic techniques, and stent usage). Evaluation of these risk factors led to the generally accepted theory that a fibrotic pancreatic remnant facilitates the pancreaticoenteric anastomosis, whereas, a soft pancreatic remnant frequently results in a higher pancreatic fistula rate.

Recently, a single 10-point fistula risk score (FRS) was developed, for the prediction of critically relevant postoperative pancreatic fistula (CR-POPF) after pancreaticoduodenectomy using risk factors from the ISGPF classification [11]. Based on an extensive analysis of pre- and intra-operative variables, four distinct factors were discovered: pancreatic duct size smaller than 3 mm; soft pancreatic parenchyma; ampullary, duodenal, cystic, or islet cell pathology; and excessive intraoperative blood loss (Table 28.2). An aggregate of 0–10 points subsequently determines a patient's fistula risk profile. Patients with 0 points have a negligible risk to develop a biochemical fistula or CR-POPF. Patients with 1–2 points have low-risk (14%) of developing any fistula with less than one-third developing CR-POPF. Patients who accumulate between 3 and 6 points are in intermediate risk and 25% can be expected to develop pancreatic fistulas, which are twice as likely to be clinically relevant. Finally, patients who acquire 7 or more points are considered high risk, because the incidence of CR-POPF approaches 90%. This FRS has been internally and externally validated by a multi-institutional study that confirmed that the FRS was a strong prognostic tool for predicting the development of CR-POPF after pancreaticoduodenectomy [12].

Distal Pancretectomy

Distal pancreatectomy is performed for all kinds of pancreatic pathologies, including chronic inflammation and benign and malignant tumors. Pancreatic fistulas are merely leakage of pancreatic fluid from the cut margin of the pancreatic remnant. The average reported pancreatic fistula rates following distal pancreatectomy are approximately 20–25% ranging from 0 to 40% with approximately 97% of these being type A or type B fistulas [13, 14, 15]. Many different factors like surgical stump management, spleen preservation, tissue texture, or extent of surgical

Table 28.2 Fistula risk score for prediction of clinically relevant pancreatic fistula after pancreaticoduodenectomy. (Adapted from [11])

Risk factor	Parameter	Points[a]
Pathology	Pancreatic adenocarcinomaor pancreatitis	0
	Ampullary, duodenal,cystic, islet cell	1
Gland texture	Firm	0
	Soft	2
Intraoperative blood loss, mL	≤400	0
	401–700	1
	701–1000	2
	>1000	3
Pancreatic duct diameter, mm	≥5	0
	4	1
	3	2
	2	3
	≤1	4

[a] Total 0–10 points. 0 points (negligible risk); 1–2 points (low risk); 3–6 points (intermediate risk); 7–10 points (high risk) to develop clinically relevant postoperative pancreatic fistula

procedure can have an impact on fistula development and have been investigated in numerous studies. The technique of stump closure after distal pancreatectomy remains the subject of an ongoing debate. All approaches including fibrin glue, sealants, patches, stapler closure, electrocautery, and suture have been tested in numerous studies. In an analysis by Ferrone et al. of 462 patients, fistula rates were 19–31% considering all approaches without significant advantages for any method [14]. The recently completed DISPACT trial included 352 patients that were randomly assigned to a stapler or hand-sewn closure of the pancreatic remnant. Both groups showed identical fistula rates of 30 and 36% on postoperative day 7 and 30, respectively [15].

The role of splenic preservation on fistula development is also controversial. An analysis of 211 patients by Shoup et al. showed that splenectomy was associated with a higher risk for clinically-relevant fistula [16]. In contrast to this publication, the two large series by Kleeff et al. including 302 patients and by Lillemoe et al. with 235 patients, failed to confirm splenectomy as an independent risk factor for fistula development [17, 18].

In recent years, laparoscopic distal pancreatectomy for benign as well as malignant disorders has gained acceptance. In a multicenter study of 96 laparoscopic distal pancreatectomies, the overall fistula rate was 17% [19]. In contrast, a meta-analysis published in 2009 which included 28 studies, found an overall fistula rate of 29% [20]. When compared to the open approaches in a multicenter study of 142 laparoscopic versus 200 open resections, a rather high fistula rate (26% laparoscopic vs. 32% open) was reported [21]. Currently, there is no evidence supporting the laparoscopic procedure over the open procedure with regard to postoperative fistula development.

Duodenum-Preserving Pancreatic Head Resection/Lateral Pancreaticojejunostomy

Duodenum-preserving pancreatic head resection (DPPHR) and lateral pancreaticojejunostomy (Puestow procedure) are the procedures used in the surgical treatment of chronic pancreatitis. These patients usually show a fibrotic tissue texture which facilitates surgical tissue handling and is associated with a reduced risk for anastomotic leak. Although all of these procedures require anastomotic suture line of extensive length, the fistula rates are low ranging from 0 to 6% [22]. There are no clear advantages with regard to fistula development for any of the common DPPHR modifications (Frey or Beger) or the Puestow procedure which supports the fact that fistula development is mainly dependent on the fibrotic pancreatic texture, not on the surgical

technique or the extent of resected tissue in these procedures.

Pancreatic Pseudocyst Drainage/ Pancreatic Necrosectomy

Acute necrotizing pancreatitis is the most severe and potentially life-threatening form of acute pancreatitis. As many cases involve infection of the necrotic tissue, almost all will require percutaneous drainage of peripancreatic fluid collections or a surgical procedure for the debridement of necrosis (necrosectomy) (Fig. 28.1a, b). In acute necrotizing pancreatitis, the pancreatic duct often disrupted by the necrosis, results in creation of a pseudocyst or either a sterile or an infected collection consisting of pancreatic juice and necrotic tissue. Any procedures to address these fluid collections by external drainage will result in an external pancreatic fistula.

Howard et al. have classified external pancreatic fistulas anatomically into end and side fistulas. Side fistulas can be further classified as postoperative and inflammatory [23]. End external pancreatic fistulas are leaks from the pancreatic duct which have no continuity with the gastrointestinal tract. The most common anatomic configuration in these is the "disconnected duct syndrome" due to necrosis of the midpancreatic body along with the ductal epithelium, with no communication between the external pancreatic fistula and the proximal pancreatic duct. The distal remnant of the pancreas is an isolated pancreatic segment draining only via the fistula. All such end fistulas will require either internal drainage or resection in order to close.

A pancreatic fistula following percutaneous drainage of a pseudocyst occurs approximately 15 % of the time [23]. Persistent drainage is often the result of an obstructing stricture within the main pancreatic duct, causing the pressure within the duct to be abnormally high. Patients with pancreatic necrosis secondary to acute pancreatitis often present with pancreatic duct disruption. At the time of the initial surgery, the goal is to debride all necrotic tissue and perform wide drainage. Most duct disruptions go on to seal with time and drainage, however 10–56 % continue to have persistent drainage that may require more definitive management [24].

Other Pancreatic Resections

Middle segmental pancreatic resections are tissue-sparing procedures usually employed for benign pancreatic neoplasms. Current literature reporting results from nearly 300 patients, reports fistula rates between 10 and 40 % with most series having rates higher than 25 % [25, 26]. This high rate is explained by the existence of two cut pancreatic surfaces, which are either closed by an anastomosis or by duct/parenchyma closure comparable to distal resections.

Tumor enucleations of the pancreas represent another type of resection with a rather high reported fistula incidence. In a 61-patient study by Crippa et al. fistula incidence was 23 %, while smaller series report fistula rates of approximately

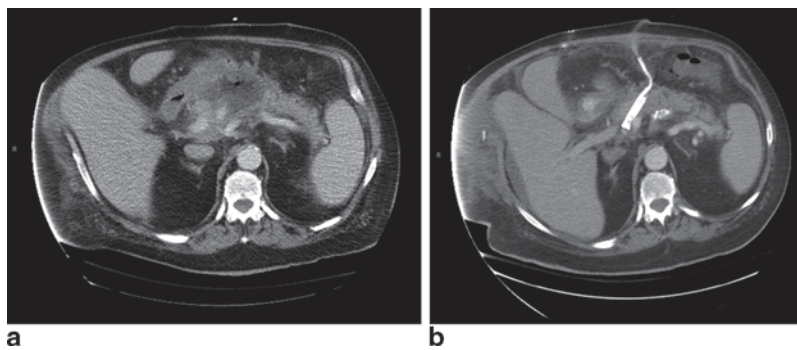

Fig. 28.1 **a** Patient with infected pancreatic necrosis. **b** Same patient after operative debridement and drainage of pancreatic necrosis

40% [27, 28]. Despite these rather high overall fistula rates, associated complications are low in all studies. Grade C fistulas range between 0 and 4%, showing that enucleation-associated fistula are rare and treated by drainage without further specific therapy.

The pancreatic fistula after operative trauma is usually isolated to the tail of the pancreas following splenectomy, left nephrectomy/adrenalectomy, and mobilization of the splenic flexure during colectomies. Reported fistula rates range from 0 to 2% after these operations [27].

Prevention of Pancreatic Fistula

Given the frequency of pancreatic fistulas following pancreatic resection, extensive research has been employed to prevent the occurrence of pancreatic fistula. The strategies include pharmacologic manipulation, modifications and refinements in surgical technique regarding pancreatic anastomosis, pancreatic anastomotic stents, and perianastomotic drainage post pancreatic resection.

Octreotide, a synthetic somatostatin analogue inhibits pancreatic exocrine secretion. The use of octreotide and its analogues to prevent postoperative fistula is an approach which has been used since the 1990s [29, 30]. Despite 20 years of clinical use and evaluation in numerous studies, a recent Cochrane meta-analysis concluded that evidence is still lacking to give clear guidelines [31]. While early randomized controlled trials (RCTs) favored the use of octreotide and showed a 50% reduction of fistula rates, these findings were not confirmed in later studies [30, 32, 33]. From these results, it was concluded and supported by the Cochrane review that routine use of octreotide was not indicated, but should be used in a risk-dependent manner in a presumed "critical" anastomoses due to soft pancreatic tissue texture. Although the overall fistula rates have been reduced, somatostatin analogues failed to reduce the incidence of clinically relevant (grade B/C) fistula or re-operation rates and mortality. Finally, postoperative octreotide administration for postoperative fistula has failed to show any improvement in the rate of fistula closure [34]. Despite the lack of effect on fistula closure rate, the octreotide may help lower fistula output and make fistula control easier. Recently, a single-center, randomized, double-blind trial was published showing pasireotide, a new somatostatin analogue, decreased the rate of clinically significant postoperative pancreatic fistula, leak, or abscess [35]. While the initial results are promising, further studies need to be conducted to prove whether pasireotide is beneficial.

Modifications in surgical technique to prevent pancreatic fistula have been evaluated for decades with conflicting results. Following a pancreaticoduodenectomy, there has been an ongoing debate of whether a pancreaticogastrostomy or pancreaticojejunostomy has a lower postoperative fistula rate. Within each of these techniques, several different technical modifications, including single or double layer sutures, invagination and purse-string sutures have been compared with regard to the surgical complications and especially postoperative fistula frequency. Unfortunately, there have been no level 1 evidence-supported techniques that have been universally adopted. Following distal pancreatectomy, there are numerous studies comparing sutures, staplers, patches, fibrin glue, and sealants to handle the distal stump of the pancreatic remnant that have been reported [13, 14], and no convincing evidence exists to support the superiority of any one technique.

The placement of pancreatic duct stents and the potential role in prevention of postoperative pancreatic fistula has been investigated for both right and left pancreatic resections. The principle of internal drainage of the pancreatic duct following pancreaticoduodenectomy to achieve a diversion of the pancreatic secretion from the suture site has been hypothesized; however, the stent may also cause problems via irritation of the duct and the suture lines as well as the obstruction or migration. In available studies, the outcome shows a great deal of variability. Earlier studies demonstrated a beneficial effect of anastomotic stenting in lowering the postoperative pancreatic fistula rate [36, 37]. A randomized trial by Poon et al. among 120 patients, which used long stents

across the pancreaticjejunostomy anastomosis and drained externally, showed that the stented group had a significantly lower pancreatic fistula rate compared to the nonstented group (6.7 vs. 20%, respectively) [37]. Despite these encouraging results, the technique has not been universally adopted. In contrast, the largest randomized study, published in 2006 by Winter et al., which used short internalized stents (6 cm long plastic pediatric feeding tube) included 234 patients who underwent pancreaticoduodenectomy with stent ($n=115$) or without stent ($n=119$) placement into the pancreatic duct [38]. Winter showed an overall fistula rate of 7.6% (no stent) vs. 11.3% (stent), concluding no benefit for stenting of the pancreatic duct. The most recent study, published in 2012 by Sachs et al. where 59/444 patients had an intraoperatively pancreaticojejunal stent placed actually had greater rates of critically relevant postoperative pancreatic fistula, major complications, greater length of stay, and total costs [39].

There are very few studies analyzing the effect of preoperative or intraoperative stents in the distal pancreatectomy setting. In a 23-patient collective, Fischer et al. described a prophylactic intraoperative transampullary stent placement as an open surgical procedure that resulted in a significant reduction in postoperative pancreatic fistula rates [40]. However, Okamoto et al. observed a stent-related morbidity of 57%, including pancreatitis and stent obstruction [41]. Reider et al. had no postoperative pancreatic fistula in stented patients; however, in this study a sphincterotomy was performed in addition to the placement of preoperative stents prior to distal pancreatectomy [42].

The routine use of intraperitoneal drains following elective pancreatic surgery remains an area of debate regarding whether drains prevent or exacerbate pancreatic fistulas. The first randomized trial to investigate the impact of intraperitoneal drain use reported by Conlon et al. randomized 179 patients following pancreaticoduodenectomy and distal pancreatectomy to intraperitoneal drain placement or surgery without drains [43]. This study demonstrated that patients in the drainage group were more likely to have an intra-abdominal abscess, collection, or fistula compared to patients without drains. More recently, Bassi et al. randomized patients who were at low risk for leak based on drain amylase level <5000 U/L on postoperative day 1 to early drain removal (postoperative day 3) or late drain removal ($\geq$ postoperative day 5) [44]. The trial reported a significant reduction in pancreatic fistulas (using the ISGPF definition) in early drain removal group versus the late drain removal group 1.8–26.3%. While these studies show that drains may not be necessary, most surgeons routinely still use postoperative drains and have not changed their clinical practice. Recently, a randomized multicenter trial was conducted to further evaluate the necessity of drains after pancreaticoduodenectomy [45]. There were no differences between the drain and no-drain cohorts in demographics, comorbidities, pathology, pancreatic duct size, pancreas texture, or operative technique. Pancreaticoduodenectomy without intraperitoneal drainage was associated with an increase in the number of patients with complications, number of complications per patient, and the severity of complications. The no-drain cohort also had a higher incidence of gastroparesis, intra-abdominal fluid collection, intra-abdominal abscess, and severe diarrhea. Furthermore, patients in the no-drain group more often required postoperative percutaneous drains and had a prolonged hospital stay. The Data Safety Monitoring Board stopped the study early because of the increased mortality from 3 to 12% in the patients undergoing pancreaticoduodenectomy without intraperitoneal drainage. Thus, most surgeons feel that this level 1 evidence provides strong support for routine drainage following pancreaticoduodenectomy. This same study continues to determine the necessity of drains for patients after distal pancreatectomy.

Complications of Pancreatic Fistula

Multiple studies have demonstrated that patients with pancreatic leak have a significant increase in secondary complications compared to patients without leak [8, 46]. Commonly observed

complications are mainly caused by undrained infected pancreatic fluid collections. Pancreatic fluid is an enzymatically active and aggressive substance that may cause erosion of the surrounding tissue, organs, and blood vessels. This can lead into leakage from other adjacent anastomoses or bowel (particularly in patients with pancreatic necrosis) causing a biliary, gastric, or enteric leak.

Postoperative hemorrhage associated with a pancreatic leak is one for the most dreaded complications following major pancreatic resections. The pancreatic enzymes in combination with infection can cause erosion of the gastroduodenal artery or splenic artery stump or from an arterial pseudoaneurysm resulting in significant bleeding requiring immediate therapy. This complication usually occurs after the first week after the surgery and in most cases with what appears to be adequate drainage of the pancreatic leak. Management is guided by the patient's clinical status and hemodynamic stability. In general, most patients should be approached via angiographic embolization or arterial stenting to provide the best outcomes [47]. Patients who are hemodynamically unstable may require operative re-exploration and packing and then angiographic control. A high index of suspicion should be maintained because postoperative hemorrhage is associated with significant risk.

The occurrence of pancreatic fluid collections due to a pancreatic leak is also a potential cause of ongoing abdominal sepsis that can lead to generalized systematic organ failure. Percutaneous drainage of the fluid collections by interventional radiology and broad spectrum antibiotic therapy are as important as supportive ICU therapy in these patients.

An important aspect of the pancreatic fistula complications is the economic impact from the prolonged treatment. The longer duration of hospital stay is an important factor that increases treatment costs. The average hospital stay in uncomplicated resections is usually 6–8 days, but can increase to 25–40 days in cases of fistula development, especially with type B or C fistula [46]. The associated treatment costs in these patients are 4–5 times higher than in patients without fistulas, highlights the socio-economic dimension of the health care system [8].

Management of Pancreatic Fistula

Regardless of the cause or the location of the pancreatic fistula, the steps required for treatment of a clinically relevant pancreatic fistula are similar. First, stabilization of patients and medical optimization are the crucial steps. Drainage of collections and insuring operatively placed drains are adequately controlling the fistula output to control sepsis that is mandatory. In cases with sepsis or high output fistulas, the patient is made "nil per os" (NPO) and parenteral nutrition is considered necessary. Only then should the nature of pancreatic duct injury be investigated and definitive management of the fistula be addressed.

Initial Management

The type of initial management needed for patients depends on the type of classified fistula and severity of symptoms. A clinically uncomplicated postoperative Grade A fistula can usually be managed by drainage alone, via intraoperatively placed drains which are still in situ and kept as long as necessary. Usually within 2–4 weeks, one sees spontaneous closure of the fistula. Fistula output volume and inflammatory parameters including white blood cell (WBC) should be monitored to avoid unrecognized fluid collections causing infectious complications despite continuing drainage.

In patients without drains or if drains have already been removed, patients with a pancreatic leak will display symptoms of pain, fever, nausea/vomiting, and other signs of sepsis. Initial management of patients with symptomatic (Grade B or C) pancreatic fistula requires control of the pancreatic secretions. A control can be accomplished with percutaneous drains placed under computed tomography (CT) or ultrasound guidance (Fig. 28.2a, b**).** Broad spectrum antibiotics are administered to treat the likely infected fluid and to avoid ongoing abdominal sepsis. Using this method, fistulas often resolve within a 2–6 week period.

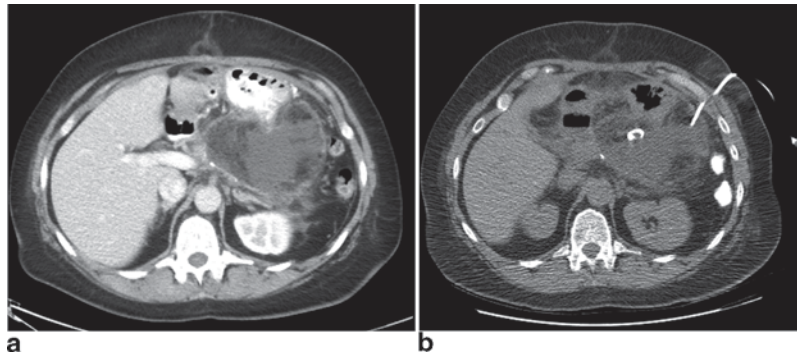

Fig. 28.2 **a** Large fluid collection present on postoperative day 7 after open distal pancreatectomy. **b** Same patient after the fluid collection has been drained percutaneously by interventional radiology (Grade B fistula)

Further management after control of the collection and antibiotics include getting the patient medically optimized. Patients with pancreatic fistula are at risk for having significant nutritional and electrolyte imbalances, especially significant loss of sodium and bicarbonate caused by pancreatic exocrine secretions. Patients with pancreatic fistulas often have significant nausea, anorexia, and the inability to tolerate oral intake. Furthermore, since most pancreatic fistulas occur in the postoperative period, some degree of malnutrition is usually present. Thus, depending on the severity of the pancreatic fistula, patients will require total parenteral nutrition (TPN) in an effort to overcome their catabolic state. The TPN provides the benefit of minimizing protein loss while decreasing pancreatic secretions from the lack of pancreatic stimulation; however, the risks include potential line sepsis, electrolyte and glucose abnormalities, and cholestatic injury to the liver. Enteral feeding should be initiated as early as possible because of simpler administration, cost-effectiveness, and the ability to maintain mucosal barrier function. Ideally, the tube feeds should be delivered in a postpyloric location via a nasojejunal feeding tube. However, studies show no benefit of postpyloric feeding over gastric feeding or even oral intake if tolerated by the patient [48, 49].

In contrast, grade C fistulas require more aggressive therapies. The most life-threatening of this uncontrolled fistula is erosional bleeding from enzymatic digestion of nearby vascular structures. Bleeding often begins with a "sentinel bleed" which is self-limited and not associated with hemodynamic changes. However, some patients may present with massive bleeding acutely without any warning event. The common algorithm is a contrast-enhanced CT scan to visualize the site of bleeding and associated collections, followed by arterial angiography of the visceral segment. This treatment is successful in stopping the bleeding in 80 % of patients [47]. An operative intervention should be considered when bleeding control cannot be achieved interventionally or when further complications seem to be likely. Most times, the evacuation of clot and packing may be all that can be accomplished, although an effort should be made to ligate the bleeding vessel if visualized. In such cases, after gaining stability, embolization may still be the optimal management of the arterial disruption. The need for completion pancreatectomy is a very rare event after a pancreaticoduodenectomy for bleeding complications [50].

Grade C fistula where there are multiple undrained fluid collections that cannot be accessed by interventional procedures and have extensive intra-abdominal sepsis, should also be considered for operative intervention. These patients should have extensive lavage of the abdominal cavity and wide drainage of the anastomoses to achieve best control for the critically ill patient. An emergency resection or completion pancreatectomy after a pancreaticoduodenectomy may be beneficial if there is minimal remnant and

extensive enzymatic digestion that cannot be widely drained. In most cases, completion pancreatectomy which is used as a salvage procedure is associated with higher perioperative mortality greater than 50 % and results in the severe morbidity of brittle diabetes [51]. Resection of the pancreatic head to control complicated fistula after distal pancreatectomy is not necessary, as these fistula can usually always be managed nonoperatively.

Delineation of Pancreatic Duct

After the initial steps to drain collections, control sepsis, and address nutrition, patience is appropriate as many fistulas will close spontaneously. If a fistula persists, the location and extent of pancreatic duct injury should be identified. Identification of the ductal disruption will help dictate the need for further intervention including surgical management. The first diagnostic study usually is a CT scan to assess for and drain any fluid collections and possible evaluation of a dilated obstructed pancreatic duct (Fig. 28.3). To further evaluate the pancreatic duct, a magnetic resonance cholangiopancreatography (MRCP) is a valuable noninvasive tool. MRCP can delineate the sites of ductal disruption and identify other findings, such as pancreatic stones or ductal strictures. The standard MRCP can be combined with a secretin stimulation MRCP, which is useful in the diagnosis of chronic pancreatitis by stimulating the pancreas to produce exocrine secretions while performing the imaging. Another noninvasive technique to define the pancreatic ductal pathology is injection of an existing drain which should visualize the pancreatic duct at the site of leakage (Fig. 28.4).

ERCP has the benefit of visualizing the pancreatic duct while at the same time providing potentially therapeutic interventions, including sphincterotomy, stenting, and nasobiliary drainage; however, ERCP does require conscious sedation and carries the risk of duodenal perforation and/or pancreatitis. Endoscopic studies after pancreaticoduodenectomy can be technically very difficult. Thus, the main indication for ERCP would be after distal pancreatectomy or in fistulas after pancreatitis.

In cases of fistulas after pancreatitis, the criteria for the diagnosis of disconnected duct syndrome include: ERCP evidence of main pancreatic duct cutoff or discontinuity with the inability of accessing or cannulating the upstream pancreatic duct; CT scan evidence of viable pancreatic tissue upstream from the pancreatic duct cutoff or discontinuity and a nonhealing pancreatic fistula, pseudocyst, or fluid collection despite a course of conservative medical management [52]. Other authors suggest criteria should include necrosis

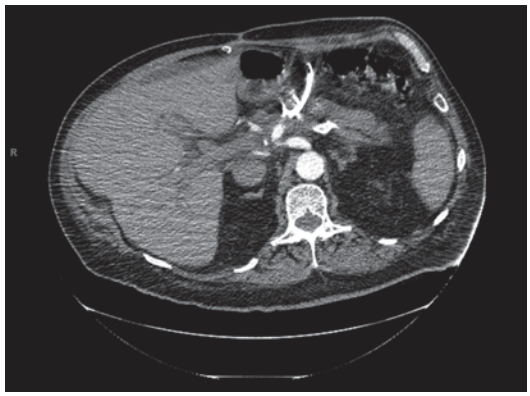

Fig. 28.3 Patient with persistent pancreatic fistula that shows upstream viable pancreas and a dilated pancreatic duct

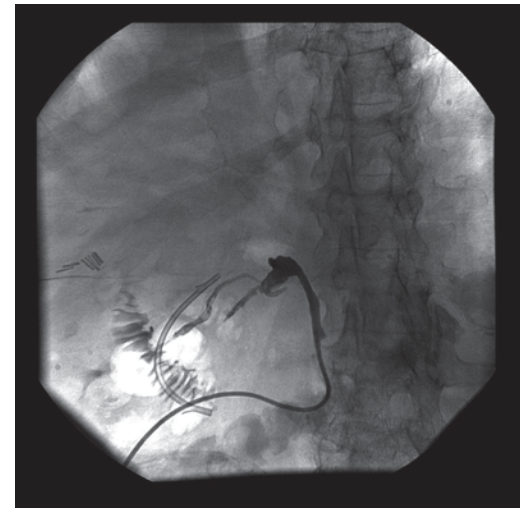

Fig. 28.4 Fistulogram through the drain showing connection to downstream pancreatic duct draining into duodenum

of at least 2 cm of pancreas, viable pancreatic tissue upstream from the site of the necrosis and extravasation of contrast material injected into the main pancreatic duct at pancreatography [53].

Definitive Treatment of Pancreatic Fistula

After the anatomy of the pancreatic duct and the location of the injury have been identified, definitive management of a long standing persistent pancreatic fistula can then be considered. Studies show that 70–82 % of pancreatic fistula will close spontaneously without the need for operative intervention [54]. Simply making patients NPO and reducing pancreatic stimulation will result in resolution of the pancreatic fistula. However, long-standing persistent pancreatic fistula that last longer than 6 weeks will require further intervention.

Patients that are medically stable who have a persistent pancreatic fistula with output less than 100 cc a day and no intra-abdominal collection can have slow drain removal. This process begins with removing suction from the drain bulb, followed by downsizing of the drainage catheter via interventional radiology. Slow incremental withdrawal of the drain should be performed while monitoring drain output.

Recently, fibrin glue has been used to obliterate the fistula tract. This technique involves injection of fibrin glue either under radiographic guidance or through a previously placed drainage tract. Studies of this technique are limited, but in small case series, it has been shown to be successful treatment option for patients with low-output pancreatic fistulas [55].

The use of ERCP in the evaluation and definitive treatment of a persistent pancreatic fistula after distal pancreatectomy should be considered. In patients with a persistent pancreatic fistula despite adequate drainage and medical optimization, an ERCP with sphincterotomy or stenting can be performed to promote fistula closure. Closure rates as high as 82 % have been reported [56]. In general, endoscopic transpapillary stenting is considered helpful in the management of external pancreatic fistulas and side fistulas. Similarly, endoscopic drainage can be useful in the management of internal pancreatic fistulas causing pancreatic ascites. In necrotizing pancreatitis patients who have a pancreatic duct disruption, an endoscopic stent to bridge the disruption has a success rate of more than 50 % [57]. However, a recent multicenter series for patients with necrotizing pancreatitis comparing endoscopic transpapillary stenting versus conservative treatment failed to show a significant improvement in the fistula closure rate (84 vs. 75 %) or in time to closure (71 vs120 days) [58]. Despite these results, an endoscopic stenting should be considered for long-term persistent pancreatic fistulas and attempted where favorable anatomy is present.

Recent studies have investigated the role of endoscopic therapies for management of the disconnected duct syndrome, but with limited results. However, other studies have found that patients may temporarily improve with endoscopic therapy, but will still often go on to require surgical intervention. In patients who may not be considered surgical candidates or who refuse surgery, a rendezvous technique using endoscopic ultrasound guided access to the distal duct and standard ERCP may be employed to bridge the gap.

Operative Management of Pancreatic Fistula

The operative management of pancreatic fistulas remains an important component of their treatment, but is generally reserved in patients where conservative or endoscopic procedures have failed. Surgery may prove necessary in patients who are unable to have endoscopic or interventional therapies secondary to postsurgical anatomy or who have an inability to cannulate the pancreatic duct, a significant ductal stricture, or a very large defect. The type of surgical intervention proposed for patients varies on the location

of ductal injuries, the severity of fistula, and the underlying pathology.

The most common indication for surgical intervention is in patients with complicated pancreatitis who have a persistent pancreatic fistula after percutaneous drainage of a pancreatic pseudocyst, operative debridement of acute pancreatic necrosis, a disconnected duct syndrome, or recurrent manifestations of chronic pancreatitis of the distal gland. Patients who present with a large pancreatic duct (7 mm or greater) are generally managed with duct decompression, usually via a lateral pancreaticojejunostomy. If pancreatic pseudocyst is present, this area should be incorporated into the anastomosis with a cyst gastrostomy or cyst jejunostomy. In some clinical situations, the pseudocyst can be successfully managed with endoscopic drainage into the stomach or duodenum [59]. Patients with a pancreatic duct injury isolated to the body or tail of the pancreas are often best served by a distal pancreatectomy, resecting only the area of the pancreas beyond the disruption.

Definitive surgical management is dependent on the location of the ductal injury. If the ductal disruption is near the neck of the pancreas, then these patients are best served by prolonged external drainage of the fistula until a fibrous fistula can develop. The waiting time between drainage placement and surgery encountered in the literature is usually 3–6 months [60, 61]. At this time, a fistula-enterostomy can be performed using a Roux-en-Y jejunal limb (Fig. 28.5). The success rate of surgical drainage has been reported to be as high as 82–100% in certain series, with minimal complications [62, 63]. However, long-term failure may occur because of obliteration of the fistula tract over time. The recurrence rate after fistulojejunostomy is reported to be around 35% and is usually manifested by a pseudocyst formation or the development of diabetes mellitus, as an indicator of a poorly drained pancreatic remnant [64]. However, fistulojejunostomy to the site of duct disruption is the operative treatment for persistent pancreatic ascites.

Another surgical option for a disconnected duct at the neck of the gland is distal pancreatectomy. However, this option sacrifices a significant amount of otherwise functional pancreatic parenchyma. A study by Murage et al. showed equal short- and long-term results when evaluating internal drainage versus distal pancreatectomy for the disconnected left pancreatic remnant. A pancreatic remnant >6 cm favored an internal drainage while the strongest indicator for distal pancreatectomy was a small pancreatic remnant and splenic vein thrombosis [62]. However, long-term outcomes of pancreatic function were not evaluated.

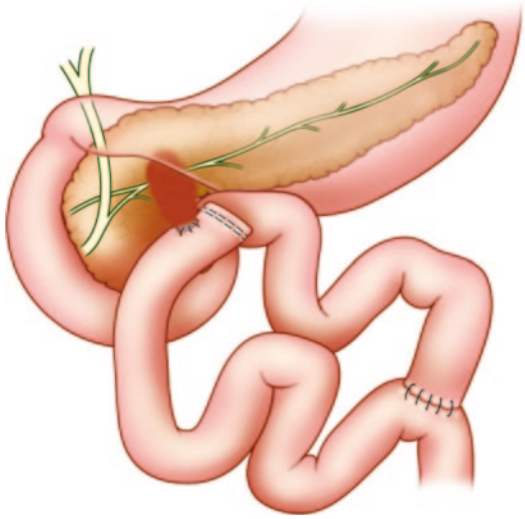

Fig. 28.5 Diagram of Roux-en-Y fistulojejunostomy

Conclusion

Pancreatic fistula is a significant complication that can occur after all types of pancreatic surgery. The incidence varies from 2 to 50% depending on the type of procedure. A definition of postoperative pancreatic fistula has been standardized according to the ISGPF with regard to clinical symptoms and associated complications. The management of pancreatic fistula can be difficult and necessitates a multidisciplinary approach. Basic principles of fistula control/patient stabilization, delineation of ductal anatomy, and definitive therapy remain of paramount importance.

Key Points to Avoid Complications

1. High risk conditions such as pancreatic texture, central pancreatic necrosis, and procedures such as tumor enucleation, central pancreatectomy and distal pancreatectomy must be identified and appropriate measures taken to prevent and minimize the complications of pancreatic fistula.
2. Although a number of operative and other measures have been subjected to randomized clinical trials to identify approaches to decrease the incidence of fistula after pancreatic resection of both the head and body/tail of the pancreas, an experienced surgeon with meticulous operative technique is likely the most important in prevention.
3. Carefully placed perioperative drains and appropriate postoperative drain management is the key in minimizing the incidence and complications of pancreatic fistula.
4. Internal rather than external drainage of pancreatic pseudocysts.

Key Points: Diagnosing and/or Managing Complications Either Intra- or Postoperatively

1. All pancreatic fistulas should be defined by the definitions provided by theISGPF.
2. Early CT scan to assess for and guide drainage of any fluid collections.
3. Control of pancreatic secretions, broad-spectrum antibiotics for signs of sepsis, and medical optimization of patient with parenteral nutrition.
4. Patience and close observation plus providing reassurance and counseling to patient that a majority of fistulas will close spontaneously. In Type A fistulas, do not intervene or delay hospital discharge.
5. Delineation of pancreatic duct first by noninvasive techniques like CT scan, MRCP, and/or drain fistulogram.
6. Depending on reconstructed anatomy, ERCP may be useful for diagnostic as well therapeutic interventions including sphincterotomy, stenting, and nasobiliary drainage.
7. Surgical intervention should only be considered when all conservative and endoscopic procedures have failed. A significant period of time should be allowed before operative drainage especially following drainage in patients with pancreatic necrosis.

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Management of Chyle Leaks Following Pancreatic Resection

29

Neda Rezaee and Christopher L. Wolfgang

Introduction

Significant morbidity following pancreatic resection is common with reported rates of overall complications ranging between 40 and 60%. The most common complications following pancreatectomy include postoperative pancreatic fistula and wound infection. In addition, delayed gastric emptying occurs in up to 25% of patients undergoing pancreaticoduodenectomy. These complications impede recovery, prolong hospitalization, and increase the risk of readmission [1]—but are seldom life-threatening. In contrast, some of the less frequent complications are associated with a greater risk of mortality. This is the case for certain forms of postoperative chyle leak in which the accompanying malnutrition and immunosuppression significantly reduce the rate of long-term survival [2]. This chapter focuses on the management of a chyle leak following pancreatic resection and includes a discussion of the general physiology and anatomy of the abdominal lymphatic system as it relates to pancreatic surgery, the composition of chyle, a review of the literature that specifically studies chyle leak following pancreatic resection, and an algorithm for the management of chyle leak following pancreatectomy.

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Background

Chyle leak is not unique to pancreatic resection and is also observed in other operations in which an extensive retroperitoneal dissection is performed. The operations in which chyle leak is commonly reported include abdominal aortic aneurysm repair, resection of large retroperitoneal tumors, extensive retroperitoneal lymph node dissection, and liver transplantation [3–6]. The rate of chyle leak following pancreatectomy varies greatly [2, 6–13]. For example, the largest series on this topic reported a rate of 1.3% in a cohort of 3532 patients undergoing pancreatic resection. At the other end of the reported range, Hilal et al. [7] published a 16.3% rate of chyle leak in 245 patients undergoing pancreatectomy. The variation in published rates may result from differences in surgical technique, such as the extent of retroperitoneal dissection, and with differences in management, such as early postoperative initiation of enteral feeding.

Several factors appear to be related to postoperative chyle leakage following pancreatectomy. These include factors resulting in a more extensive or difficult dissection such as peripancreatic fibrosis from pancreatitis [6] or neoadjuvant radiation, major vascular resection and reconstruction [2], and early enteral feeding [7, 8, 12]. Specifically, in the series from Johns Hopkins when matching for tumor size, tumor type, and resection type, the number of harvested lymph nodes and concomitant vascular resection were both significant predictors of increased risk of chyle leak [2]. Similarly, Hilal et al. [7] reported that both extensive lymphadenectomy and postoperative portal/

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mesenteric vein thrombosis were risk factors. It is interesting that this series reported the highest rate of postoperative chyle leaks in the literature and the general practice of this group is to initiate early enteral feeding using a semi-elemental tube feed on postoperative day 1. The possibility that early enteral feeding may promote chyle leak following pancreatectomy is supported by work from Kuboki et al. [8], who reported that the early initiation of enteral nutrition is an independent risk factor for chyle leak. In addition, this group also reported manipulation of the para-aortic area as a risk factor. It is difficult to know if early enteral feeding actually promotes chyle leaks or simply uncovers low-level chyle leaks that otherwise would have gone undetected had a diet been started later in the postoperative course.

The term "chyle leak" is a general term that includes two distinct entities each with a unique natural history. These include a *contained chyle leak* and *chylous ascites*. These two types of chyle leaks are very different in regard to management and outcome. A contained chyle leak is a walled-off collection that communicates with disrupted visceral lymphatics, whereas chylous ascites is a diffuse free-flowing chyle leak. The latter has a much higher impact on survival since it results in more significant immunosuppression, malnutrition, and fluid/electrolyte imbalances. Moreover, the risk for abdominal infection and fascial dehiscence is higher with chylous ascites. The increased mortality with chylous ascites following pancreatectomy has been reported [2]. In a large series of pancreatectomies, the overall survival for patients developing chylous ascites was 19% at 3 years compared to 53.4% for those with a contained chyle leak.

Anatomy and Physiology of Visceral Lymphatics

In order to better understand the etiology and the management of chyle leaks following pancreatectomy, it is important to understand the function and anatomy of the abdominal lymphatic system. The following section reviews information that is pertinent to this topic. The lymphatic system functions as a tissue drainage network and also plays a role in immune function. Essentially every tissue in the body has lymphatic drainage. Lymph fluid is produced at the level of the capillaries where the intravascular hydrostatic pressure is higher than that of the surrounding interstitial compartment resulting in the outflow of fluid into this space. The electrolyte composition of lymph fluid is similar to that of plasma [14] (Table 29.1). In addition, there is a colloid component of lymphatic fluid which consists of protein at a relatively low concentration and a cellular component consisting of immune cells. A breach of the interstitial space by trauma, infection, or malignancy can result in further interstitial fluid components within the lymph fluid such as cellular debris, cancer cells, and bacteria. This fluid is taken up by passive diffusion into the thin-walled porous lymphatic capillaries that lack a continuous basement membrane. Small lymphatic capillaries coalesce into larger vessels that contain one-way valves. The action of muscular contraction, respiratory pressure variation, and gravity result in the flow of lymphatic fluid into successively larger and more centrally located vessels. Anatomic regions of lymphatic drainage are channeled through lymph node basins that "filter" the lymphatic fluid by means of immune cell function. The importance of lymph drainage is more evident in conditions leading to lymph flow obstruction such as axillary or groin lymph node dissection or parasitic infestation that may result in lymphedema or even "elephantitis".

Table 29.1 Biochemical characteristics of chyle. (Adapted from [14])

Component	Concentration
Calories	200 kcal/L
Lipids	5–30 g/L
Protein	20–30 g/L
Lymphocytes	400–6800/mm
Sodium	104–108 mmol/L
Potassium	3.8–5.0 mmol/L
Chloride	85–130 mmol/L
Calcium	3.4–6.0 mmol
Phosphate	0.8–4.2 mmol/L

In addition to the general role of lymphatics for immune function and interstitial fluid balance, the abdominal lymphatic system is necessary for normal fat absorption. The process of fat absorption begins with the breakdown of triglycerides into monoglycerides and fatty acids within the gut. This is mainly through the action of pancreatic lipase and is facilitated by the formation of micelles consisting of bile salts, monoglycerides, and fatty acids. Micelles are absorbed within the intestinal villi where triglycerides are enzymatically reformed. Triglycerides consisting of long-chain fatty acids (>12 carbons) combine with cholesterol and specific proteins to form chylomicrons. The small intestine has a rich lymphatic network with specialized terminal branches known as lacteals that are necessary for the uptake of chylomicrons. Once within the lymphatic system, this fluid is known as chyle and ultimately enters the systemic circulation through the thoracic duct.

Lymph drainage from all structures below the diaphragm, as well as the left upper extremity and left chest enters the thoracic duct via the cysterna chyli and returns to the circulatory system at the level of the left subclavian vein. This includes the lymphatic system of the gut. Lymphatic drainage of the right chest and upper extremity drains into the right subclavian vein. Lymphatic drainage of the abdominal visceral connects to systemic lymphatic drainage at the level of the cysterna chyli. The cysterna chyli is a roughly 5-cm sack-like dilatation of the lymphatic system located deep within the retroperitoneum at the level of the first and second lumbar vertebrae. The structure is located to the right of the aorta, deep within the interval between the aorta and the inferior vena cava. The function of the cysterna chyli is unclear, but it has been suggested that it functions as a bellows that drives lymph flow via the abdominal pressure changes that occur with normal respiration. The cysterna chyli receives systemic lymphatic drainage from the lower body, lumbar drainage beds, and the visceral drainage beds including the liver. Lymphatic drainage from the intestine and portions of the head of the pancreas course along the superior mesenteric artery through the base of the mesentery and join the cysterna chyli near the junction of the superior mesenteric artery (SMA) with the aorta. The liver, portal, and remainder of the pancreatic lymphatic flow follow the course of the celiac axis distribution retrograde to its junction with the aorta. The exact location of the disruption of the lymphatic system resulting in chyle leak following pancreatic resection is unknown. However, based on this understanding of lymphatic anatomy and chyle flow, one can speculate on the potential areas of disruption of these vessels and the resulting chyle leak. These areas include dissection of the hepatoduodenal ligament, the base of the mesentery at the mid portion of the SMA, the soft tissue surrounding the celiac trunk, and retroperitoneal space in the interval between the inferior vena cava and the right side of the aorta.

The volume of chyle flow ranges from 2 to 4 L/day and varies depending on numerous factors including the composition of the diet [14]. The majority of lymph flow through the thoracic duct is from visceral sources. It is estimated that 25–50% of all flow from through the thoracic duct originates from the liver. The majority of the remainder comes from the other viscera (chyle) while the minority of lymph through the thoracic duct is from the lower extremities. Approximately 70% of chyle consists of dietary fat mainly in the form of triglycerides. The concentration of fat varies and ranges from 5 to 30 g/L and has an energy value of approximately 200 kcal/L (Table 29.1). The volume of lymphatic drainage from the abdominal viscera is evident in pathological conditions such as chylous ascites resulting from cirrhosis, pancreatitis, or malignancy in which liters of chyle can be produced each day.

Diagnosis of a Chyle Leak

The diagnosis of a chyle leak is often straightforward and can be determined at the bedside based on the appearance of the drain output in the correct clinical context. The typical presentation of a chyle leak is the transition of clear peritoneal drainage to a milky white color following the institution of a regular diet. Of course, this is

often the same time period when the much more common postoperative pancreatic fistula is also diagnosed. Usually, a simple visual inspection of the drain output is able to differentiate between the two types of leaks. Whereas a postoperative pancreatic fistula is often a cloudy tan fluid with fibrinoid debris, a pure chyle leak is most often homogenous and pure white. In order to confirm a chyle leak, the drain fluid should be analyzed for triglycerides and a level of 110 mg/dL is necessary to make the diagnosis. In addition, drain amylase should also be evaluated since, on occasion, a pancreatic fistula may coexist with a chyle leak.

Once the diagnosis of a chyle leak is made, the next determination should be to classify the leak as either a contained leak or as free-flowing ascites. If this is not apparent based on a physical exam demonstrating ascites, an imaging study may be required.

Management of a Chyle Leak

The majority of chyle leaks will resolve spontaneously with conservative treatment which includes management of fluid, electrolytes, nutrition, and chyle drainage. However, a small percentage of chyle leaks will be refractory to this type of treatment and will require a more direct intervention to correct the problem. The general goal in the management of a chyle leak is to control the output and optimize the fluid and nutrition until the leak closes. The best way to accomplish this goal is to tailor management based on further descriptive classification of the leak. First, a determination should be made as to whether or not the patient has a contained chyle leak or chylous ascites. As mentioned previously, this may be evident based on physical exam or may require an imaging study to demonstrate abdominal ascites. Second, the chyle leak should be classified as either high or low output based on the drain volume. Drain volume of less than 200 cc/day constitutes a low-output leak. The determination of these features will be helpful in guiding the route of nutrition, need for fluid and electrolyte repletion and the prognosis. The natural history of a contained chyle leak is very different than that of chylous ascites [2]. A contained chyle leak is easily controlled with drains, has a better chance of closure, and an improved overall outcome compared to chylous ascites. The determination of high-volume leak is also important since this will most often require more intensive nutritional support.

The Contained Chyle Leak

The initial management of a contained chyle leak differs based on whether it is a low- or high-volume leak. A patient with a leak of less than 200 cc/day should simply undergo a change in diet from regular to a "nonfat" or medium chain fatty acid diet. After 12–24 h of this diet, an assessment should be made of the drain output volume and character. Most patients with a low-volume contained leak will have a reduction in output and a change to clear fluid with this maneuver. If there is no change in the drain output over this time, the patient should be made nil per os (NPO) and given intravenous nutritional support. A patient with a chyle leak greater than 200 cc/day should be made NPO placed on total parenteral nutrition (TPN), and be administered octreotide since it is unlikely to seal expeditiously unless the volume is reduced. As with a low-volume leak, the success of the intervention is determined by a drop in the volume of the drain output and a change from milky to clear. In either case, once the drain output clears and the volume drops below 100 cc/day, steps should be taken toward drain removal.

Care must be taken in the process of drain removal so as not to convert a controlled leak into chylous ascites. The best way to avoid this problem is to always restart a regular diet prior to drain removal in order to "test" that the leak is truly sealed. In addition, the proper timing and method of drain removal are important. This is particularly true for drains that have been in place for longer than a week. In this situation, reimaging should be performed to assess the size of the collection and the location of the drain with respect to the fluid cavity. This is best accomplished by a contrast-enhanced computed tomography (CT) scan. A drain sinogram often provides additional useful information about the size of the fluid cavity, length of drain tract, and the relationship of the drain

to the collection. Leaks are more likely to close if the cavity is small and the tract is relatively long.

A judgment should be made as to when to give a trial of per os (PO) intake following the initial treatment and reimaging. There are no defined rules but, in general, a trial is warranted if the drain output remains low and non-milky for several days. Once these criteria are met, the patient should be placed on a regular diet. This should have little impact on the drain output if the leak is sealed and the drain can then be removed safely. If the patient fails the challenge, then a nonfat/medium-chain fatty acid diet or TPN should be restarted. If the output modestly increases or turns slightly milky with a regular diet, the drain can still be removed if the tract is long and the collection is small. In this case, the drain is removed by a process called "cracking" in which the drain is pulled out a few centimeters each day until the output abruptly drops or the drain is removed. If at any time the output drops below 10 cc, an imaging study is performed to assess for a clogged drain suggested by an increase in collection size. The drain is removed if no collection is present or flossed if the collection is still present or increased in size.

Those patients who have a high-volume chyle leak that does not decrease upon removing oral intake and instituting octreotide should be maintained on TPN without a trial of a diet. A careful assessment of volume of the drain output should be made and accounted for in the caloric, fluid, and electrolyte replacement in the parenteral replacement. It is important to supplement fat-soluble vitamins in the intravenous nutrition. Moreover, appropriate assessment of electrolytes, albumin and prealbumin should be made to guide the management of the TPN. The patient should be maintained on this therapy until the volume of drain output drops below 100 cc/day and the patient is managed as described above.

Chylous Ascites

Patients found to have chylous ascites pose a difficult problem. The volume of drainage is often extensive, measuring up to several liters a day. This results in significant loss of fluid, electrolytes, and calories. In the short term, drainage of the ascites maybe necessary to relieve the increased abdominal pressure associated with high volume of output characterized by this complication. Moreover, chylous ascites can interfere with wound healing and can cause a fascial dehiscence as chyle flows through the path of least resistance. The poor wound healing is exacerbating by malnutrition resulting from deranged fat metabolism. The treatment of chylous ascites begins by making the patient NPO, initiating TPN, and administering octreotide. These measures will often result in reducing the triglyceride content of the output turning it clear and limiting caloric losses. The reduction in volume is often more variable. The patient should be prepared for a protracted course and, although some cases of chylous ascites seal within a few weeks, more often it will take up to a few months. Therefore, once the patient is initially stabilized with regard to fluid, nutrition, and wound healing, they are often transitioned to home-care or a rehabilitation facility for the long-term management of the leak. Care should be taken to adjust the TPN based on frequent laboratory draws to compensate for the fluid and nutrient losses. Moreover, these patients are susceptible to pneumonia, urinary tract, and abdominal infections.

The effect of the ascites with regard to increased abdominal pressure, pain, and respiratory compromise can be managed through either the placement of one or more percutaneous drains or intermittent therapeutic paracentesis. The disadvantage of paracentesis is the need for frequent procedures and the abrupt shifts in third space fluid. On the other hand, percutaneous drains are associated with less repeat procedures but carry a higher risk of abdominal infections. In most cases of chyle leak following pancreatectomy, drains are already in place from the operation or percutaneous drains are replaced to divert flow from the healing wound.

Initially, the drain or paracentesis output from patients with chylous ascites can be liters per day. Once the volume of output falls to less than 200 cc/day, a CT scan should be performed to assess the extent of residual ascites. If there

is minimal residual fluid collections in the setting of low drain output, the patient is challenged with a regular diet. The best-case scenario is that the drain volume and character do not change. If the volume remains less than 50 cc/day and the triglyceride in the drain fluid is low on a regular diet, the drains are removed. If the drain output is greater than 50 cc but less than 200 cc/day, the drains are removed by "cracking" as described above.

Management of Refractory Chyle Leaks

The majority of contained chyle leaks will resolve within 4 weeks with proper diet and drain management. In patients who fail this treatment, several more aggressive options exist and have been employed with varying degrees of success. These include attempting sealing of the leaking vessel through the use of glue or coils and surgical closure. In addition, management of the ascites can be attempted through the placement of a peritoneovenous shunt.

There are several percutaneous methods that are used to gain access to the lymphatic system in order to perform diagnostic lymphoscintigraphy and embolization of leaking vessels [15]. The most commonly employed method is to gain access to the lymphatic system in the web spaces between the toes. This requires significant skill and is often painful for the patient. Recently a method has been described in which ultrasound is used to access the lymphatics through an intranodal route in the groin [16]. Regardless of the route, once the lymphatic system is cannulated an assessment is made using radio-opaque contrast in order to identify the site of leakage. If a definitive source of leakage is found an attempt at embolizing the vessel is made with n-butyl cyanoacrylate (NBCA) glue, microspheres, or microcoils. The success of the procedure is often known within a few days and is demonstrated by an abrupt change in drain volume and character. It should be noted that the procedure is often successful when the site of the leak is identified—but quite often this is not possible and the technique fails. Therefore, the rate of successes of this procedure is higher if the level of injury is at the level of the cysterna chyli or thoracic duct, which is common in thoracic surgery, aortic surgery, or radial nephrectomy. This site of injury is less common in pancreatectomy in which the chyle leak has the potential to develop from the divided tissue at the base of the mesentery or hepatoduodenal ligament. These vessels are now disconnected from the main lymphatic trunk and are not accessible by lymphoscintigraphy since they are leaking from the "distal" end of the disruption.

In patients who fail percutaneous embolization and continue to have a significant chyle leak that interferes with their recovery, surgical intervention should be considered as a last resort. There are two possible intents of operating for a chyle leak. The first is to identify the source of leakage and over sew the damaged vessel. If this is not possible, the second is to manage the leak by placing a peritoneovenous shunt. The decision to proceed to surgery should not be taken lightly. One must consider that there is a significant chance that the operation will not be successful. At operation it can be extremely difficult to identify a localized source of the chyle leak even if it was found on preoperative lymphoscintigraphy. Moreover, it is likely that the operative field will be difficult and marked by a thick inflammatory rind around collections and drains, dense postoperative adhesions, and poor healing due to inadequate nutrition. Prior to operation it is helpful to understand where the potential locations of chyle leakage may occur and this includes the dissected area of the retroperitoneum at the level of the cysterna chyli, the cut edge of the mesentery near the mid portion of the SMA and, less likely, the hepatoduodenal ligament. If preoperative imaging studies do not localize the area of the leak, feeding the patient a high-fat diet such as cream may assist in identifying the source of leakage at operation. This maneuver is classically described as having the patient drink cream 2–4 h prior to surgery, but in my experience this results in a patient with an abdomen filled with white chyle emanating from all surfaces. What I have found to be more helpful is to maintain the patient NPO until the abdomen is entered and the

potential sources of leakage are exposed. At that time cream is instilled through an nasogastric tube (NGT) placed postpyloric and the suspect regions are evaluated for leakage. One must be patient using this variation of the cream method since it may take up to 30 min to notice a change in the appearance of the chyle from clear to white. Moreover, one must be prepared that the site of leakage may not be identified. In these cases, the plan should change from closing the leak to managing the nutritional, fluid, and immune aspects of chylous ascites.

For this goal, placement of a peritoneovenous shunt can be performed at the same operation [10]. Prior to doing so, the following issues must be considered. First, in a patient who underwent a resection for malignancy the potential for dissemination of peritoneal disease exists. There is no direct evidence that can guide our decision regarding this point, but in a patient with severe immune and nutritional deficits, the risk-to-benefit ratio of a shunt seems reasonable. Second, a peritoneovenous shunt has a limited lifespan and is prone to obstruction due to debris and infection. A shunt should not be considered if the bowel was entered at exploration. Following the placement of a peritoneovenous shunt the patient should be monitored in the intensive care unit since the abrupt shift in fluid from the third space to the intravascular compartment may result in congestive heart failure even in fit individuals. This will resolve with diuretic and judicious fluid management. No data exist regarding the outcome of placing peritoneovenous for postoperative chyle leaks but anecdotally this has been successful in some cases in our practice.

Conclusion

A chyle leak is an uncommon but a potentially life-threating complication following pancreatic resection. A contained chyle leak will often close with conservative management and has little impact on long-term survival, while chylous ascites are less likely to close and is associated with a reduction in long-term survival. Risk factors for developing a chyle leak following pancreatectomy include extended lymph node or retroperitoneal dissection, vascular resection and reconstruction, and early enteral feeding.

Key Points in Managing a Chyle Leak

1. Differentiate between chylous ascites and contained chyle leak.
2. Classify as high- or low-output leak.
3. Remove long-chain fatty acids from the diet by either a nonfat diet or medium-chain fatty acid diet of TPN.
4. Octreotide should be used to reduce the volume of high-output leaks.
5. Drains must me managed carefully to avoid converting a contained chyle leak to chylous ascites.
6. Surgical intervention should be reserved as a last resort.

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Preventing Pancreatic Fistula Following Distal Pancreatectomy

30

Bharath D. Nath and Mark P. Callery

Overview

Postoperative pancreatic fistula (POPF) is a feared complication following distal pancreatectomy that contributes significantly to patient morbidity and mortality. While the majority of POPF can be managed conservatively, the presence of pancreatic fistula is a risk factor for the development of intra-abdominal sepsis and post-pancreatectomy hemorrhage, which individually can be life threatening. Estimates of the incidence of pancreatic fistula following distal pancreatectomy range widely. Some centers report rates under 10%, while others report POPF in close to 50% of patients undergoing distal pancreatectomy. To some extent, this variation may be secondary to the method used to diagnose POPF. Uncontrolled pancreatic fistula, while less common, is the most dangerous and can evolve into other complications, such as pancreatic pseudocyst and abscess. The incidence of pseudocyst as a complication of distal pancreatectomy is between 1 and 2%. In one series of patients who underwent distal pancreatectomy for trauma, 2 of 72, or about 2.7%, developed pancreatic pseudocyst postoperatively [1].

Numerous investigations, analyses, and clinical trials devoted to identifying risk factors for POPF have been reported and have guided strategies for its management and prevention. A short list of risk factors for the development of POPF includes pancreatic texture, pathology, duct size, age, intraoperative blood loss, and others [2]. A number of technical factors have also been investigated. Few of these, however, have been demonstrated to have an effect on the overall incidence of POPF, understandably to the frustration of surgeons and their patients [3]. This chapter considers proposed interventions for the reduction of POPF that have been evaluated in the preoperative, intraoperative, and postoperative settings.

Diagnosis

The consensus classification scheme devised by the International Study Group on Pancreatic Fistula (ISGPF) in 2005 divides pancreatic fistula into three grades. In general terms, POPF is defined as leakage of pancreatic secretions from the pancreatic parenchyma or a disrupted pancreatic duct stump or anastomosis. The leak may result in the formation of a pseudocyst, may be drained externally via a surgical drain, or may communicate with another epithelialized surface [4]. However, it is important to note that if there is high drain output, even a high-output pancreatic fistula may have no obvious abnormality on cross-sectional imaging. Clinically, the diagnosis of POPF may be heralded by a variety of symptoms and consequently should be considered in nearly all cases wherein a patient's clinical course deviates from what is expected. Drain character may

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become cloudy and grayish, which is characteristic of POPF. Amylase levels collected from the drain or collection on or after postoperative day #3 must be three times the upper limit of normal to define a leak according to the ISGPF classification. Patients with pancreatic fistula have a spectrum of presentation, from patients that appear well and are unlikely to have significant sequelae from the POPF (grade A), to patients that appear ill, with signs of sepsis and risk of death, and a high likelihood of reintervention and persistent drainage (grade C). Grade B falls between these extremes and, in general, are patients with signs of infection, with persistent drainage, who typically require admission and inpatient management, but who typically do not require interventional procedures and who do not appear septic [4]. Since its publication, the ISGPF classification scheme has been validated as a useful clinical tool, as well as a predictor of increased hospital costs, particularly in a cohort of patients undergoing pancreaticoduodenectomy [5].

Even this scheme, however, is not without limitations. Perhaps most importantly, one large series identified a latent presentation of pancreatic fistula occurring in 3.2% of patients undergoing distal pancreatectomy. In these patients, initial drain output was notable for normal or minimally elevated amylase levels that did not meet biochemical criteria for pancreatic fistula by ISGPF definitions. Subsequently, all these patients had the diagnosis of pancreatic fistula confirmed by clinical or radiographic investigation. Patients with latent fistula were more likely to have superimposed infection versus clinically evident fistula [6].

Although drain amylase measurement has been the standard since the ISGPF consensus statement, recent investigations have suggested that drain lipase may be equally effective at detecting fistulas and possibly superior in terms of sensitivity and specificity in detecting clinically relevant fistulas [7].

Another limitation arises from the broad classification of pancreatic fistula from all operations within the ISGPF system. Recent work has suggested that there was little difference in clinical impact between grade B and C pancreatic fistula among patients undergoing distal pancreatectomy, as well as only marginally increased hospital costs, versus robust increases in hospital costs between patients who had grade B and C fistula following pancreaticoduodenectomy [8].

Prevention

Identifying Risk Factors

For pancreaticoduodenectomy, a fistula risk score has been recently developed that has been shown to be highly predictive of POPF. This score assigns points based on gland texture, gland pathology, duct diameter, and intraoperative blood loss. In general, high blood loss, soft gland texture, and smaller duct diameter confer increased risk of POPF, whereas pancreatic adenocarcinoma and pancreatitis as the indication for pancreaticoduodenectomy confer protection for the development of pancreatic fistula versus other diagnoses. Also of note, higher fistula risk scores correlated with greater incidence of clinically relevant (ISGPF grade B or C) fistula [9]. The adaptation of this risk score to patients undergoing distal pancreatectomy is yet to be validated; however, at least one published study indicates that this scoring system may have limitations in the setting of distal pancreatectomy. In that study, risk factors for pancreatic fistula after stapled gland transection in patients undergoing distal pancreatectomy were examined, and in a multivariate analysis, only the presence of diabetes and the use of a 4.1-mm staple cartridge were associated with increased risk of pancreatic fistula formation [10].

Some retrospective data have supported the conclusions drawn with regard to risk for pancreatic fistula after pancreaticoduodenectomy in the setting of distal pancreatectomy. A retrospective case-matched analysis looked at histopathologic features of patients with fistula and matched patient controls and found that gland fat content, smaller main duct size, and the lack of stigmata of chronic pancreatitis or interlobular fibrosis were correlated with increased risk of POPF. This study included 9 patients who underwent

pancreaticoduodenectomy as well as 16 patients who underwent distal pancreatectomy. A score was created using these and other characteristics, which had 92% sensitivity and 84% specificity for the postoperative development of pancreatic fistula [11].

Role of Octreotide

The somatostatin analog octreotide has been the subject of numerous investigations in pancreatic surgery and specifically in the prevention of the formation of pancreatic fistula following pancreaticoduodenectomy or distal pancreatectomy. The biologic plausibility of the effectiveness of octreotide is significant; by decreasing pancreatic secretions, pressure gradients across the pancreatic ductal anastomosis or closure would be decreased, thereby resulting in decreased fistula rates. Alternatively, where a fistula has already formed, octreotide might have the potential to convert a high-output fistula into a low-output fistula, decreasing the likelihood of complications and increasing the chances of a spontaneous closure. However, most studies to date have failed to definitively identify a role for octreotide in pancreatic surgery. Furthermore, the biologic rationale, while emotionally appealing, may not stand up to scientific scrutiny; a 2013 single-institution trial measured the effect of octreotide in patients who underwent a pancreaticoduodenectomy by directly measuring exocrine output using intraductal pancreatic catheters and failed to demonstrate any significant difference between octreotide and placebo in the volume of pancreatic exocrine secretion [12].

Recently, a multicenter randomized controlled trial was undertaken to answer the question of whether octreotide administration was of benefit in pancreatic surgery. Enrolling 230 patients with slightly more than half-randomized to the octreotide group, the study failed to demonstrate any overall benefit in octreotide administration. While a subgroup analysis suggested some benefit for patients with small duct diameters, the study overall was significantly weakened by a significant increase in the incidence of intraductal fibrin sealant administration in the octreotide group [13].

Role of Pancreatic Stenting

Stenting of the main pancreatic duct at the ampulla has been investigated as a method to prevent postoperative fistula formation after distal pancreatectomy. This again has a clear anatomic rationale, as decompression of the pancreatic tree via drainage across the ampulla would have the effect of decreasing pressure against the pancreatic stump, thereby reducing the likelihood of leakage from the resection margin. Retrospective data from several centers initially demonstrated some success with the technique. One small series published in 2008 noted a 20% incidence of mild pancreatitis but no instances of pancreatic leak among ten patients who underwent distal pancreatectomy with prior endoscopic placement of transampullary stent [14]. A second retrospective series involved the intraoperative placement of transampullary stents. In this series, the surgeons identified the transected duct at the resection margin of the distal pancreatectomy and subsequently advanced a pediatric feeding tube into the duodenum. The transected end of the duct was then ligated. The authors were able to demonstrate an association of intraoperative stent placement with decreased pancreatic fistula rates as well as decreased overall length of stay [15].

However, in 2012, a randomized prospective trial was performed in which patients were assigned either to distal pancreatectomy alone or to distal pancreatectomy with prior transpapillary stent placement. That trial failed to show a benefit of preoperative stenting of the pancreatic duct and in fact demonstrated a trend toward a significantly increased rate of pancreatic fistula among patients with preoperative stent placement [16]. An example that highlights the significant difficulty in obtaining robust best practice standards in this area comes from a similar controversy in pancreaticoduodenectomy. Although the operations are significantly different, prior retrospective examination of patients undergoing pancreaticoduodenectomy with intraoperative stent

placement demonstrated no benefit for the prevention of POPF [17]. However, a randomized trial performed around the same time actually demonstrated a benefit to intraoperative pancreatic stenting [18].

Dissection and Management of the Pancreatic Stump

The management of the pancreatic stump created during a distal pancreatectomy has also been the subject of some controversy. Historically, techniques of transection of the pancreatic stump included sharp division and oversewing of the transected surface. With the advent of staplers, controversy has arisen with regard to their use in transection of the pancreatic body. Some authors initially suggested that hand-sewn closures had lower rates of fistula, whereas others demonstrated superior results with stapler use [19]. Recently, a multivariate analysis identified increased thickness of the pancreatic body as a risk factor for failure with stapled transections. Additionally, use of a double-row (as opposed to a triple-row) stapler load was associated with increased risk of fistula [20].

Anatomic techniques have also been widely investigated. A recently published randomized controlled trial compared stump reinforcement with fibrin glue and a falciform patch to no reinforcement among patients undergoing distal pancreatectomy with stapled or hand-sutured stump closure techniques, and found identical rates of pancreatic fistula among the two groups [21].

Another group of techniques described in the literature include the creation of anastomoses between the pancreatic stump and either the bowel or the stomach. One prospective case series described 21 patients undergoing distal pancreatectomy with the creation of pancreaticogastrostomy, and the authors were able to report a 0% rate of grade B or C pancreatic fistula [22]. Another group in a retrospective review demonstrated a statistically significant elimination in the number of pancreatic fistula when a roux-en-Y limb was brought up to provide distal drainage to the transected pancreatic stump after distal pancreatectomy [23]. Indeed, numerous studies have reported somewhat favorable results with creation of an anastomosis at the distal pancreatic stump [24]. A large series by Kleef et al. [25] examined 302 patients undergoing distal pancreatectomy with an overall fistula rate of 12%. Data were gathered prospectively, and four main techniques of pancreatic stump management were described: (1) pancreaticojejunostomy; (2) seromuscular patch; (3) suture of the duct with polydioxanone (PDS) stitch followed by parenchymal closure with PDS suture, with or without collagen patch; (4) closure with a stapler, primarily with a vascular load. In this series, a stapled anastomosis was associated with a higher rate of fistula formation. As this was a retrospective, single-center review, certain subgroup analyses such as a strict comparison of patient characteristics between the various closure techniques were not reported [25]. Additionally, the use of nonvascular stapler loads, which the authors suggest were occasionally used, may be quite significant. One single-center study suggested that the rate of pancreatic fistula was much lower when a vascular (2.5 mm) cartridge was utilized instead of a standard cartridge or a hand-sewn technique [26]. More recently, a large multicenter trial was conducted to answer the question of whether a stapled or hand-sewn technique prevented POPF. The DISPACT trial randomized patients into a stapled or hand-sewn closure of the pancreatic stump. The primary endpoints included combined mortality and/or the detection of pancreatic fistula prior to postoperative day #7. Secondary endpoints included detection of pancreatic fistula up until postoperative day #30. No difference in fistula rates was described between the two groups. Additionally, outcomes among a range of clinical factors were similar. A post hoc analysis was conducted within the trial to determine the factors associated with the development of pancreatic fistula and did not reveal any factor to be causative in a multivariate analysis [27].

Ligation of the main pancreatic duct, where technically feasible, has been reported to dramatically reduce the incidence of pancreatic duct leak in some studies, with conflicting reports in others. The main limitation of data addressing

this technical point is that it is limited to single-institution retrospective studies. Some authors have been able to demonstrate a reduction in the rate of pancreatic fistula from greater than 30% to less than 10% and that the performance of duct ligation was a significant negative predictor of pancreatic fistula by multivariate analysis [28]. Notably, in that study, which included an overall pancreatic leak rate of approximately 20%, other factors including pancreatic pathology, hand-sewn or stapled closure, octreotide use, blood transfusion, and operating time, among other factors, were all demonstrated to be unrelated to the postoperative development of pancreatic leak in a multivariate analysis. A recent retrospective review of 704 patients undergoing distal pancreatectomy at a single institution was not able to detect a significant effect of duct ligation on the prevention of pancreatic leak, and in fact detected a trend toward increased clinically significant leak rate when duct ligation was performed. Of note, however, duct ligation was employed selectively at this institution, and thus may have been reserved for those cases with large duct diameters or other intraoperative findings that raised concern for increased likelihood of duct leak [3].

There has been new interest in managing the transected pancreatic stump by reinforcing the stump with a mesh closure. Early retrospective data from single centers suggested that use of an absorbable mesh to reinforce the staple line of the transected pancreas reduced the rate of stump leak [29]. This method has been investigated with a randomized, single-blinded clinical trial with a total enrollment of 100 patients. Reinforcement of the distal pancreatectomy resection margin with mesh reduced the rate of clinically significant (ISGPF B and C) pancreatic fistula from 20% to less than 2% [30]. One potential disadvantage of this technique relates to expense, as the placement of a mesh significantly increases the cost of operation. However, a recent cost analysis suggested that patients who received mesh placement during distal pancreatectomy had overall lower hospital charges and decreased length of stay versus patients who underwent distal pancreatectomy without mesh placement [31].

Minimally Invasive Versus Open Techniques

Despite advances in laparoscopic and robotic approaches, the vast majority of distal pancreatectomies continue to be performed via an open approach. Recent retrospective data have demonstrated that minimally invasive distal pancreatectomy is associated with decreased blood loss and shorter hospital stays than open pancreatectomy [32]. A large recent study utilizing the Nationwide Inpatient Sample database suggested, first, that the minimally invasive approach is becoming more widely utilized, increasing from 2.4 to 7.3% over a study period from 1998 to 2009. Second, that study reported that the minimally invasive approach was associated with decreased length of stay as well as decreased incidence of infectious complications, bleeding complications, and blood transfusions [33]. This population-based study echoes conclusions drawn by a large multi-institutional study performed several years previously. Drawing on a combined patient sample of 667 patients, with 24% initially attempted laparoscopically, the authors were able to demonstrate lower overall complication rate, decreased blood loss, and shorter hospital stays among patients undergoing laparoscopic approach via a multivariate analysis. Notably, there was no significant difference in the pancreatic leak rate between the open and laparoscopic approaches, although there was a nonsignificant trend favoring the laparoscopic approach [34].

More recently, the robotic approach has generated significant interest as a technique for performing distal pancreatectomy. Retrospective analysis has suggested that the robotic approach is well suited for pancreatectomy. Fistula rates, however, remain a concern. A retrospective review of patients undergoing robotic pancreatic operations included 83 patients who underwent distal pancreatectomy. About 27% were identified as having a ISPGF type A pancreatic leak; 12 and 4.8% were identified as having a grade B or C leak, respectively [35]. At our own institution, we have increasingly come to utilize the robotic approach as the operation of choice for elective distal pancreatectomy. Early data based

on retrospective analyses have demonstrated no difference between the robotic approach and the laparoscopic approach with regard to the development of pancreatic fistula. The robotic approach, however, was associated with lower rates of conversion to open in comparison with the laparoscopic approach as well as shorter operative times. Additionally, oncologic outcome including nodal harvest and R0 resection were improved with the robotic approach. No significant difference in outcome with regard to pancreatic fistula has been demonstrated between the robotic and the laparoscopic approach [36].

Drain Placement and Management

Drain placement after pancreatectomy has been a subject of controversy for several years. At least one randomized trial demonstrated no benefit to drain placement after pancreatic resection; that trial, however, included both pancreaticoduodenectomy and distal pancreatectomy [37]. More recently, retrospective data in patients undergoing distal pancreatectomy demonstrated that 50% of patients who developed pancreatic fistula were given that diagnosis after the drain had been removed. Put another way, that data suggested that the presence of a drain was only useful for the detection of pancreatic fistula in 50% of patients [38]. Other retrospective analyses have failed to demonstrate a benefit to peritoneal drainage after distal pancreatectomy [39]. However, our specific practice has remained to leave a drain in place anterior to the stapled transection margin. In our experience, placement of a drain has the potential to control intra-abdominal fluid collections that form as a result of pancreatic stump leak, and we choose to drain nearly all cases of distal pancreatectomy. Our approach to management of operative intraperitoneal drains is to monitor daily output and remove drains when drain output is less than 50cc per day, the character of the effluent is serous, and the patient appears clinically well and is tolerating enteral feeding [6]. Though admittedly a practice preference, we have seen very few complications related to the actual drain itself.

Management of Complications of Pancreatic Leak

Mostly, any deviation from the expected clinical course in a patient who has undergone distal pancreatectomy should prompt consideration of a pancreatic leak. Pancreatic leaks may present in a latent fashion, or be clinically evident early after resection. If a drain has been left in place, retrospective data suggest that features of the drain prior to its removal should not be reassuring with regard to the subsequent consideration of pancreatic fistula when a patient presents postoperatively with fever and abdominal pain. The preceding data in this chapter underscore the wide variety of strategies that have been employed to prevent pancreatic exocrine complications after distal pancreatectomy and the very limited success that any single strategy has enjoyed. Indeed, a recent survey of hepatopancreatobiliary surgeons worldwide demonstrated that there is little consensus on the management of patients with POPF [40].

One area where there is significant consensus is the use of enteral nutrition. A recent single-institution randomized controlled trial demonstrated that the use of enteral, rather than parenteral, nutrition in patients with POPF was associated with a significantly higher rate of fistula closure and success of conservative management. A significant caveat to the interpretation of these data is that it includes all patients with postsurgical pancreatic fistula, and only a minority of patients in this study had undergone distal pancreatectomy [41]. Nonetheless, our approach in general has been to feed enterally wherever possible.

In comparison with pancreaticoduodenectomy, collections that form after distal pancreatectomy are less likely to present with superinfection, but more likely to require prolonged drainage. Additionally, patients with postoperative collections after distal pancreatectomy were more likely to present in a latent fashion after discharge [42].

Ductal disruption after distal pancreatectomy can lead to a variety of complications, each of which has different specific management strategies. In general, we manage patients using the

ISPGF criteria. Patients with grade A or B leaks are managed conservatively, with grade B patients often requiring inpatient management with observation, hydration, and antibiotics.

Rarely, we have come across patients that have developed complications such as pancreatic pseudocyst following distal pancreatectomy. Our essential approach to managing these patients involves four steps. The first principle is resuscitation toward goal-directed endpoints and adequate infection control pending further management. The second is adequate anatomic information, particularly with regard to main pancreatic duct disruption and ongoing fistulous formation, with endoscopic intervention where necessary. The third is optimization of the patient to undergo prolonged conservative management, including careful attention to nutritional status, ongoing antibiotics if indicated, judicious management of electrolyte abnormalities, and overall attention to physical and psychological well-being. Fourth, when intervention is necessary, a strategy of deliberate reintervention is preferred.

Goal-Directed Resuscitation and Infection Control

The patient presenting with latent pancreatic leak or pseudocyst frequently will present with complaints of abdominal pain, fever, nausea, or vomiting. In more dramatic cases, full-blown signs of sepsis or even shock may be present. Initially, we manage these patients as we would any other postoperative intra-abdominal complication. Resuscitation with crystalloid proceeds expeditiously with a goal of maintaining adequate tissue perfusion. Hence, urine output is followed closely, with placement of a Foley catheter if there is any uncertainty as to whether adequate urine output can be recorded. Full laboratory studies, urinalysis, and blood cultures are obtained, and initial imaging studies including a contrast abdominal computed tomography scan are obtained. After blood cultures are drawn, antibiotic therapy is administered empirically. Individual patient-specific data on history of resistant organisms and institution-specific resistance patterns are considered. Often the combination of vancomycin and a carbapenem is selected for adequate penetration into a potential pseudocyst cavity. Signs of severe infection, such as necrotizing features or evidence of gas-forming bacteria within the fluid collection, typically require prompt drainage, either surgically or through radiographic means. Prompt initiation of vasopressor support and observation in a monitored bed are pursued as clinically indicated.

Further Definition of Anatomy and Source Control

The next key decision point involves defining the anatomic basis of the patient's complication and offering targeted interventions where appropriate. Where CT imaging has not provided sufficient data, Magnetic resonance cholangiopancreatography (MRCP) may be pursued at this point, which has the significant advantage of imaging of pancreatic ductal disruption. In most cases, we prefer obtaining an MRCP prior to considering endoscopic intervention. However, where evidence of ongoing ductal leak is evident, endoscopic retrograde cholangiopancreatography with sphincterotomy and stent placement is pursued in order to decompress the pancreatic ductal system. Lastly, if the clinical status warrants percutaneous intervention, IR-guided drain placement may be considered. Our primary consideration in this regard is the clinical status of the patient and the appearance of concerning features, such as gas within the pseudocyst collection.

Optimizing Patient Clinical Status for Ongoing Conservative Management

Postoperative complications such as pancreatic fistula or pseudocyst are significant, physically and emotionally challenging complications for patients to endure. Scrupulous attention to the maintenance of the patients' well-being as they suffer the ordeal of prolonged hospitalization or external drainage is mandatory. Careful attention to ongoing fluid losses and electrolyte abnor-

malities can minimize physiologic stress. Additionally, it is not likely that patients can maintain adequate caloric intake in the face of the psychological stress as well as the physical discomfort attendant on such a complication. Consequently, we initiate supplemental enteral nutrition quickly, with the recognition that supplemental feeding via a Dobhoff tube can place its own burden on the patient. Parenteral nutrition is avoided wherever possible. Antibiotics are typically continued for several weeks in the absence of definitive source control. Careful coordination of resources is necessary if patients are to continue these treatments on an outpatient basis, whether at a rehabilitation hospital or at home. Intraperitoneal drains, whether present from the initial operation or placed under radiologic guidance, are maintained until output has ceased or until further surgical intervention is pursued.

Deliberate Reintervention When Clinically Indicated

Our final approach involves reintervention when clinically indicated, preferably with minimally invasive approaches whenever necessary. The majority of patients with this complication will resolve with conservative management. However, when a persistent pseudocyst has formed and is causing ongoing abdominal symptoms, surgical and occasionally endoscopic procedures such as cyst gastrostomy or cyst jejunostomy are considered (when a nonresolving mature pseudocyst exists). Another useful operation is internal drainage of a mature fistula tract to the jejunum, avoiding the temptation to dissect to the actual origin location of the leak. Typically operative planning requires repeat MRCP in order to define whether ongoing ductal disruption is present. Repeat ERCP with stent exchange is considered on a case-by-case basis.

Summary

Left pancreatectomy is an attractive operation for patients with distal pancreatic disease. Nonetheless, despite significant investigation in this area, high rates of POPF are reported across multiple centers. Few technical modalities have been conclusively shown to prevent this complication. Recent studies indicating a role for mesh reinforcement of the staple line are encouraging, but will require further external validation. We anticipate continued growth in minimally invasive and robotic approaches. The adaptation of technical modalities to the minimally invasive approach may yield further improvements in preventing the complication of pancreatic stump leak. The management of the complication of pancreatic leak with or without formation of pseudocyst requires careful multidisciplinary strategies. The role of the surgeon in caring for the patient with a postoperative pancreatic leak is critical to a successful outcome and a healthy patient.

Key Points on Avoiding Complications

1. Consider gland texture, duct diameter, and gland thickness when transecting pancreatic body. Use triple-row stapler when technically feasible.
2. Consider mesh placement to reinforce staple line.
3. Octreotide administered perioperatively has never been demonstrated to provide benefit, but is utilized by a number of centers given its low cost and relative ease of administration.
4. Minimally invasive distal pancreatectomy has not been demonstrated to be superior to open pancreatectomy in terms of overall fistula rates, but is associated with decreased blood loss and shorter overall hospital stay.
5. When performed, enteric anastomoses to the distal pancreatic transection margin are associated with low rates of fistula formation, but are infrequently utilized.

Key Points on Diagnosis/ Management of Complications

1. Consider pancreatic leak in the differential diagnosis of any patient who undergoes distal pancreatectomy and experiences a significant deviation from the postoperative course.
2. No more than 50% of pancreatic leaks are likely to be detected on the basis of intraperitoneal drains, and axial imaging may reveal no anatomic abnormality in the setting of high drain output.
3. Enteral nutrition is preferred wherever possible and is associated with increased rates of spontaneous fistula closure.
4. Endoscopic and surgical techniques may be considered for patients who develop persistent fistula or complications such as pseudocyst.
5. When a pseudocyst develops, consider all multidisciplinary approaches, as surgical reintervention can often be avoided.

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Part IV
Colorectal Surgery

Pearls for the Small Bowel and Colon That Will Not Reach

31

Daniel I. Chu and Eric J. Dozois

Introduction

Colorectal operations involve two phases: resection of target pathology and then reestablishment of gastrointestinal continuity. When intra-abdominal continuity cannot be fully established, stomas are constructed. In either scenario, surgeons may face a stressful situation in which the small bowel or colon "just does not reach," either to the distal end for an anastomosis, or to the skin, to construct a stoma. This chapter will describe the techniques and operative pearls on making difficult reconstructions possible.

We can classify most colorectal operations by their levels of resection and matching reconstruction (Table 31.1). Most reconstruction problems occur after very distal rectal resections. For example, a low anterior resection almost always requires, at the very least, mobilization of the descending colon from the retroperitoneum and splenic flexure for a tension-free colorectal anastomosis. A right colectomy, on the other hand, does not require extensive mobilization of the ileum or transverse colon to create the ileo-transverse anastomosis because the mesentery at both ends is not retroperitoneal.

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Perhaps the most critical point when dealing with the bowel that "does not reach" lies with preemptive planning. For any colorectal operation that will require reestablishment of gastrointestinal continuity, the surgeon should have a preoperative plan of what needs to be done for reconstruction after the specimen is resected. Patients should therefore be positioned to enable splenic flexure mobilization, for example, along with having the necessary equipment for mobilization maneuvers no matter the approach (open, hand-assisted laparoscopy, or purely laparoscopic). These strategies should be conveyed to both the patient and the surgical team so that any unexpected surprises can be mitigated.

Anatomic Constraints

The primary concern in difficult bowel reconstruction is a tenuous and unsafe anastomosis. Multiple studies have demonstrated both "local" and "systemic" factors that contribute to poor anastomotic healing [1–4]. During an operation, the surgeon has immediate control of the local factors and a tension-free anastomosis with adequate blood supply is the most critical technical point that needs to be achieved to decrease the risk of anastomotic leak. Successful mobilization of the small bowel and colon to create tension-free anastomoses or stomas requires a clear understanding of their anatomic attachments. These attachments include (1) embryonic fusion planes, (2) peri-organ "ligaments," and (3) vascular pedicles that can be ligated to maximize

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Table 31.1 Classic colorectal operations and reconstruction techniques

	Reconstruction
Segmental resection	
PROXIMAL	
Small bowel resection	Enteroenterostomy
Ileocecectomy	Ileo-ascending colostomy
Right colectomy	Ileo-transverse colostomy
MIDDLE	
Right extended colectomy	Ileo-transverse colostomy
Transverse colectomy	Colocolostomy
Left extended colectomy	Colocolostomy
DISTAL	
Left colectomy	Colocolostomy
Sigmoidectomy	Colorectostomy
Low anterior resection	Colorectostomy
Proctectomy	Coloanal anastomosis
Nonsegmental resection	
Subtotal colectomy	Ileo-sigmoid colostomy
Total abdominal colectomy	Ileorectostomy
Total proctocolectomy	Ileo-anal anastomosis

mobility while preserving necessary blood supply (Fig. 31.1).

The small bowel is tethered to the posterior abdomen in an obliquely arranged mesentery that runs diagonally from the ligament of Treitz in the left upper quadrant to the right lower quadrant. The small bowel mesentery is usually very mobile with retroperitoneal fixation only at the ligament of Treitz and near the terminal ileum as it joins the retroperitoneal cecum and right colon. The right colon mesentery posteriorly abuts the right kidney, right ureter, and duodenum. After turning at the hepatic flexure, the transverse colon emerges from the retroperitoneum and its mesocolon is usually mobile before fixation into the splenic flexure. At this juncture, the left colon becomes retroperitoneal and its mesentery posteriorly abuts the left kidney. The splenic flexure is additionally fixated by the greater omentum and several peri-organ "ligaments" (splenocolic, renocolic, pancreatocolic, and phrenocolic ligaments). The sigmoid colon is nonperitonealized and usually held by a few lateral attachments as its mesentery courses over the left ureter and gonadal vessels. As the tenia disappears, the rectum begins intraperitoneally at the sacral promontory before traveling under the peritoneal reflection with its mesorectum to the pelvic floor and anorectal junction.

While mobilizing the small bowel and colon from the retroperitoneum and peri-organ attach-

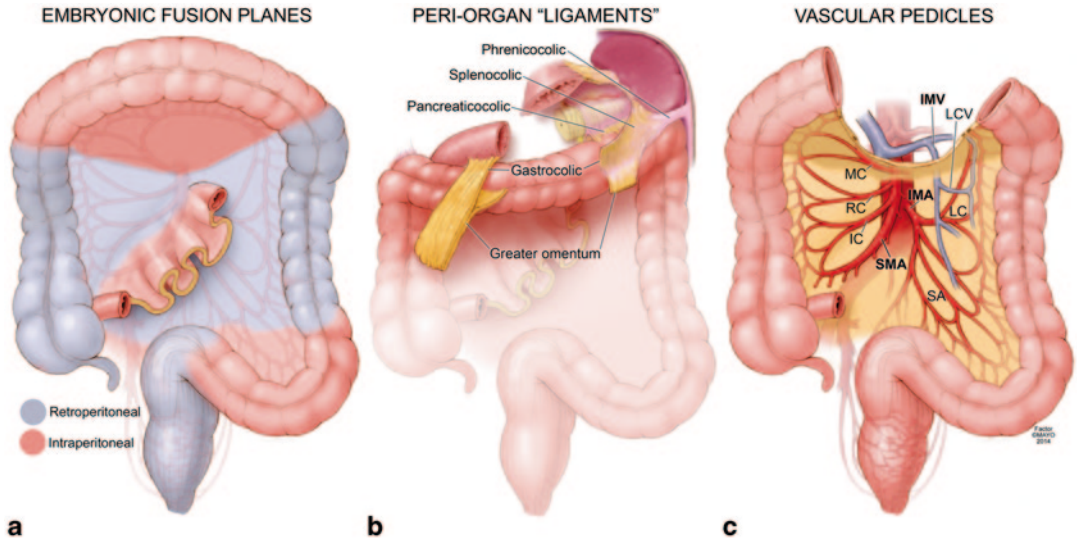

Fig. 31.1 Anatomic constraints within the abdomen. *Highlighted* are the embryonic fusion planes (**a**), peri-organ ligaments (**b**), and vascular pedicles that are the targets of primary and secondary mobilization techniques (**c**). *SMA* superior mesenteric artery, *IMA* inferior mesenteric artery, *IMV* inferior mesenteric vein, *IC* ileocolic artery, *RC* right colic artery, *MC* middle colic artery, *LC* left colic artery, *SA* sigmoid arteries, *LCV* left colic vein. © Mayo Clinic

Table 31.2 Mobilization techniques for difficult reconstructions

Maneuvers	Goals of maneuver	Examples
Primary	Separation of embryonic fusion planes	Cattell and Mattox maneuvers
	Division of peri-organ "ligaments"	Splenic flexure mobilization
Secondary	Ligation of vascular pedicles	Ligating the ileocolic artery during IPAA
	Preservation of collateral blood supply	Preserving the middle colic artery to supply ileal pouch
Tertiary	Extended resection to mobile proximal bowel	Completion colectomy
	Stoma construction	End ileostomy or colostomy

ments such as the spleen and omentum is often sufficient to provide needed reach, these "first-line" maneuvers simply free, but preserve embryonic planes. Secondary and more advanced maneuvers exploit the vascular tethers within the mesentery. These vessels include the superior mesenteric artery (SMA) and its branches (the ileocolic, right colic, and middle colic artery), the inferior mesenteric artery (IMA) and its branches (the left colic, sigmoid, and superior rectal artery), and the inferior mesenteric vein (IMV). Thoughtful and directed transection of these vessels while relying on collateral blood flow can provide significantly more reach while maintaining a tension-free anastomosis with adequate blood supply.

Diagnosing the Problem

Surgical trainees are taught that a successful anastomosis is one that is tension-free and well-vascularized. But is there a way to quantify how much tension is allowable for an anastomosis to be safe? Is there a way to quantify if adequate blood supply is reaching an anastomosis? These are critical questions that are always asked during mortality and morbidity conferences when presenting an anastomotic leak case, but unfortunately our ability to answer these questions with objective data is limited. On the contrary, we often rely on past experience and make clinical judgments when making these decisions.

Probably the simplest way to ask if an anastomosis is under tension is to lay the proximal and distal bowel ends in the field without any pulling or pushing. If the ends overlap each other by at least 5 cm, one can presume that there will be minimal to no tension on the anastomosis. When we need to pull inferiorly on the proximal end, or superiorly on the distal end, there will be problems and further mobilization needs to be performed. Similarly, during ileal-pouch anal anastomoses (IPAA), we use the inferior edge of the pubis symphysis as a rough estimate of adequate length if the apex of the pouch can reach it without tension.

Blood supply can be initially assessed with the gross appearance of the proximal and distal ends of the bowel. Completely ischemic tissue will have an obvious black-blue, discolored appearance, but this assessment is easiest at the extreme end of ischemia. In reality, bowel ends could be bruised, or "dusky," and a clinical judgment needs to be made on its viability. In these cases, we observe whether there was bleeding at the anastomotic line during transection or use the Doppler to assess for blood flow. While somewhat rudimentary, we find these methods useful in those moments of doubt. Future diagnostic tests may include using intraoperative indocyanine green (ICG) angiography, which shows promise in distinguishing anastomotic ends with poor perfusion [5].

Specific Techniques: Making It Reach

When presented with the bowel that cannot reach, mobilization should begin in a sequential and logical fashion that uses defined technical principles to remove anatomic constraints (Table 31.2). **Primary** maneuvers include (1) mobilizing embryonic planes and (2) dividing peri-organ "ligaments" or attachments. **Secondary** maneuvers include directed ligation of vascular pedicles that restrict the mobility of the corresponding proxi-

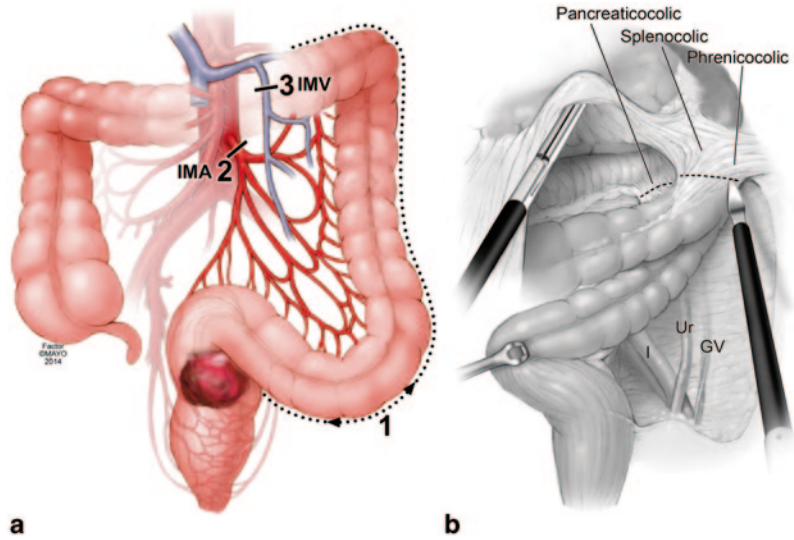

Fig. 31.2 Overview of primary and secondary maneuvers for colorectal and coloanal anastomoses. **a** Lateral-to-medial dissection proceeds with (*1*) mobilizing the line of Toldt and splenic flexure, (*2*) high ligation of the inferior mesenteric artery (*IMA*), and (*3*) high ligation of the inferior mesenteric vein (*IMV*) to provide maximum bowel length for a colorectal or coloanal anastomosis. A medial-to-lateral dissection proceeds in another order with (*2*) high ligation of the IMA, (*3*) high ligation of the IMV, and finally (*1*) mobilization of the retroperitoneal embryonic plane. **b** Critical retroperitoneal structures that can be identified during mobilization of the left colon are illustrated including the left iliac artery (*I*), left ureter (*Ur*), and left gonadal vessels (*GV*). Splenic flexure mobilization involves ligating the splenocolic, phrenicocolic, and pancreaticolic ligaments. © Mayo Clinic

mal bowel. Often, these vascular ligations are already part of the oncologic resection. **Tertiary** maneuvers include more extended bowel resections to reach a mobile proximal portion of bowel versus the construction of a stoma if no tension-free option is possible. To illustrate these principles, we describe several challenging operative situations in which multiple strategies may be necessary to achieve intestinal continuity.

Colorectal and Coloanal Anastomosis

Primary reconstruction of the distal gastrointestinal tract after resection of the left colon, sigmoid, and/or rectum requires a colorectal or coloanal anastomosis. The construction of a tension-free anastomosis requires significant mobilization for the proximal bowel to reach into the pelvis and can be performed using open or minimally invasive techniques.

Primary maneuvers separate the left colon from its retroperitoneal and peri-organ attachments. This maneuver can be done using a lateral-to-medial or medial-to-lateral approach (Fig. 31.2). Either approach is effective and depends on the surgeon's experience, training, and comfort level. The medial-to-lateral approach immediately identifies and ligates vascular pedicles such as the IMA and IMV before dissecting "underneath" the retromesenteric plane to the lateral line of Toldt and splenic flexure. The lateral-to-medial approach is more classically taught and equally effective, and both techniques have been thoroughly described before [6–8]. As such, we will go over general principles and add our specific commentary and operative pearls.

Lateral-to-Medial Approach

For a lateral-to-medial approach, we first open the line of Toldt at the pelvic brim to enter the retromesenteric space (Fig. 31.2). With firm counter-traction on the colon medially, the white, wispy, and avascular fibers marking the embry-

onic, retromesenteric fusion plane can be visualized and dissected bluntly, sharply, or with electrocautery. The retroperitoneum, gonadal vessels, and left ureter remain undisturbed posteriorly and the dissection is continued superiorly toward the splenic flexure. One of the teaching points during this maneuver is to keep closer to the colon edge and to avoid laterality once the line of Toldt is incised. If the latter is done, then the dissection will actually come around the retroperitoneum rather than the colon mesentery, and the left kidney will be elevated. The colon mesentery will often maintain a sheer glistening layer of parietal peritoneum that can be used to distinguish from the underlying fat of the retroperitoneum.

As the surgeon works superiorly, the left kidney will be encountered posteriorly with its overlying Gerota's fascia. The kidney should remain undisturbed, and any bleeding suggests that the wrong plane has been entered. With firm medial and inferior traction on the colon, the splenic flexure can be approached laterally while staying close to the colon to avoid "wandering off" into the more lateral retroperitoneum and sometimes thick omental attachments. Tension lines should be demonstrated and sharply cut, cauterized, or divided with energy devices. The goal is to enter the lesser sac which would signify the surgeon coming "around the bend" of the splenic flexure. Often there is abundant omentum that will need to be dissected free from the distal transverse colon and its epiploica. If there is difficulty freeing the splenic flexure with a lateral, counterclockwise approach, then the surgeon should switch to a medial, clockwise approach by flipping the omentum superiorly and detaching the inferior omental leaflet from the mid-transverse colon to enter the lesser sac. Once the lesser sac is entered, then the surgeon can approach the splenic flexure medially to join the lateral dissection.

Mobilizing the splenic flexure is an important first step in distal reconstructions such as colorectal or coloanal anastomoses. Cadaveric studies have shown that an additional 10–28 cm of colonic length can be gained with mobilization of the splenic flexure and distal transverse colon [9, 10]. Some surgeons advocate splenic flexure mobilization at the very beginning of the operation to avoid any future debate at the end of a long resection, while others advocate selective use of the technique on an as-needed basis depending on colon redundancy [9]. It is our routine practice to mobilize the splenic flexure preceding an anticipated mid-rectal to coloanal anastomoses.

If the proximal colon cannot reach the distal rectum or anus for a tension-free anastomosis after splenic flexure mobilization, then secondary mobilization techniques are employed (Fig. 31.3). These maneuvers involve ligating the vascular pedicles on the left colon/rectal mesentery including the IMA and the IMV. During oncologic resections, these vessels are usually taken anyways as part of the specimen, but in benign indications such as diverticular disease, these vessels may have been preserved.

Ligation of the IMA and IMV provides significant additional length to the left colon for distal anastomoses (Fig. 31.3). Cadaveric studies have shown that after primary mobilization of the left colon and splenic flexure, "high ligation" of the IMA 1 cm from the aorta and "high ligation" of the IMV superior to its junction with the left colic vein (usually at the inferior border of the pancreas) provide up to 19.1 ± 3.8 cm of additional colon length [11]. In contrast, "low ligation" of the both the IMA and IMV at the level of the left colic artery releases only 8.8 ± 2.9 cm of colon length. Ligation of the remaining left colic artery then provides an additional 8.2 ± 2.7 cm of length for a 17 ± 3.1 cm total mean gain in colon length. Ligation of the vascular pedicles at these locations can thus provide significant mobility for low pelvic anastomoses with the caveat that blood supply to the remaining colon relies on collateral supply from the middle colic and marginal arteries.

Medial-to-Lateral Approach

The medial-to-lateral approach, often used during laparoscopic approaches, begins with identification of the IMA as the sigmoid colon is held under ventral and lateral tension (Fig. 31.2). The IMA appears as a bow string in the fold of the sigmoid mesocolon. The peritoneum at the base of the mesentery is scored above and parallel to

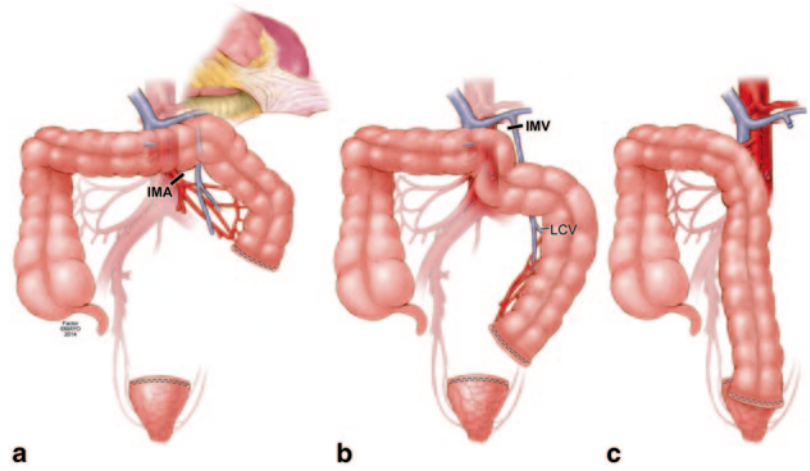

Fig. 31.3 Increasing colon length with primary and secondary maneuvers**. a** Primary maneuvers such as splenic flexure mobilization provide additional reach for the proximal colon, but maximal reach is restricted by the inferior mesentery artery (*IMA*). **b** After high ligation of the IMA, the colon is further restricted by the inferior mesenteric vein (*IMV*). Transection of the IMV must be performed proximal to the confluence of the left colic vein (*LCV*). **c** Ligation of the IMV proximal to the LCV provides maximum colon reach to the pelvis for tension-free colorectal or coloanal anastomoses. © Mayo Clinic

the aorta beginning at the sacral promontory. An avascular plane should be found that stays above the aorta/hypogastric nerves and under the IMA/superior rectal artery as it courses into the pelvis. This plane is carried superiorly to the base of the "bow string" as the IMA takes off from the aorta. Both sides of the base of the IMA are developed, and the IMA can be then be divided using suture, clips, staplers, or with energy devices.

While the left colon mesentery is held under tension, the retromesenteric plane is bluntly developed from the medial side. The left ureter and gonadal vessels are left posteriorly in the retroperitoneum. As this plane is dissected, the IMV should become identifiable as it courses superiorly before slipping under the pancreas. If the retromesenteric plan is correctly developed, the IMV will be elevated off the retroperitoneum. Both sides of the IMV can then be opened and the vessel ligated at the inferior border of the pancreas and superior to its junction with the left colic vein. At this point, the surgeon continues dissecting laterally underneath the left colon mesentery until the lateral border is reached. This approach continues up to the splenic flexure and at any time, the surgeon may also choose to work from a lateral approach by incising the lateral attachments to connect with the medial approach after the IMA and IMV have been ligated.

The end result of a medial-to-lateral approach is the same as a lateral-to-medial one, and the same primary and secondary mobilization techniques are utilized to maximize the bowel length necessary for a colorectal or coloanal anastomosis. The anastomotic technique will not be discussed in detail in this chapter, but can be performed with hand-sewn or stapled techniques. It should be noted that stapled techniques require additional bowel length as the proximal and distal ends need to be "purse-stringed" or closed over the stapling device head/spike and anvil. Hand-sewn techniques utilize the edge of the bowel ends and thus can preserve some bowel length in those difficult reconstructions.

Ileal-Pouch Anal Anastomosis (IPAA)

Surgeons who perform IPAA know that a tension-free pouch anal anastomosis is a challenge due to the anatomic constraints of the ileal mesentery,

which is anchored by the SMA. To determine if a tension-free anastomosis will be possible, a somewhat crude estimate for adequate length is to see if the base of the pouch reaches the *inferior* portion of the symphysis pubis without tension. It is important to emphasize that there can be a 2–4-cm difference between the superior and inferior border of the pubis. Cadaveric studies by Smith et al. estimate that the total length from the SMA origin to the dentate line is 34.5 cm (range, 28–36 cm) but only 31.2 cm (range, 28–33 cm) to the inferior border of the pubis [12]. Thus, there is a gap of 3.3 cm that needs to be accounted for when constructing an IPAA. Interestingly, Smith et al. observed that if the base of the pouch can reach 6 cm below the pubis, then the pouch will reach to the dentate line 100 % of the time without tension. If the pouch reaches to 2 or 4 cm below the symphysis, then the pouch will reach without tension 33 and 55 % of the time, respectively. In our experience, pouches often do not reach easily and additional mobilization techniques are always required.

As described previously, primary maneuvers mobilize the embryonic fusion planes. The first step in creating more reach, therefore, is to mobilize the small bowel mesentery off the retroperitoneum to its mesenteric root as the SMA emerges from the inferior border of the pancreas and duodenum (Fig. 31.4). Further mobilization of the SMA over the head of the pancreas can yield 2–3 cm of additional length. Horizontal stepwise scoring of the peritoneum and avascular portions of the small bowel mesentery can provide upward of 2–3 cm of additional mesenteric length for an ileal pouch [13–15]. Typically, at least three to six relaxing incisions are made. This simple maneuver is particularly useful for mesenteries foreshortened by peritoneal fibrosis and/or adhesions from prior operations (Fig. 31.4c**)**.

Secondary maneuvers, which can provide significant additional length, involve ligation of the ileocolic artery [16], distal SMA [17] or, less commonly, individual ileal mesenteric vessels [18]. There is still debate on which vessel should be ligated to provide the greatest gain in length, but the average additional gain ranges from 4 to 7 cm in any of the three techniques with no observed differences in morbidity [15]. The first pedicle we prefer to ligate is the proximal ileocolic artery (Fig. 31.4d). In thin patients, this blood vessel can be directly visualized by splaying out the mesentery under the bright, overhead lights. In the obese patient with mesenteric fat, these vessels are much harder, if not impossible, to visualize and palpation or Doppler devices may be needed to verify collateral circulation.

In one cadaver study, ligation of the ileocolic artery provided an additional 3 cm of pouch reach as compared to 6.5 cm in additional reach with ligation of the distal SMA (inferior to the takeoff of the ileocolic artery) [16, 17]. In rare cases, the distal SMA, not the ileocolic artery, creates the most amount of tension when the mesentery is pulled caudally to the pelvis. In this circumstance, if appropriate collateral circulation exists from the ileocolic artery, the distal SMA can be ligated. If there is concern about collateral blood supply, trans-illumination of the mesentery should be done and a bulldog vascular clamp can be used to temporarily occlude the distal SMA. If adequate collaterals exist, no signs of ischemia will be seen in the distal ileum.

Proponents of "first-line" ligation of the SMA, with preservation of the ileocolic artery, suggest employing this technique when a significant discrepancy in pouch reach is assessed at the beginning of the case [15]. In general, and as confirmed by cadaveric studies [19], significantly increased mesenteric length can be achieved with ligation of the distal SMA. The benefit of length, however, is tempered by the risk of ligating the major inflow to the distal small bowel. No study has demonstrated increased morbidity with distal SMA ligation, but these studies are all small, retrospective, and limited by selection bias [17, 20], and we would caution surgeons when using this particular vascular technique.

When a severely shortened ileal mesentery is noted at the time of initial exploration, another advanced secondary technique can be considered. If this approach is to be used, it must be considered while the colectomy is being done because it requires preservation of the middle colic, right colic, ileocolic, and intervening marginal artery (Fig. 31.5). Upon completion of the colectomy,

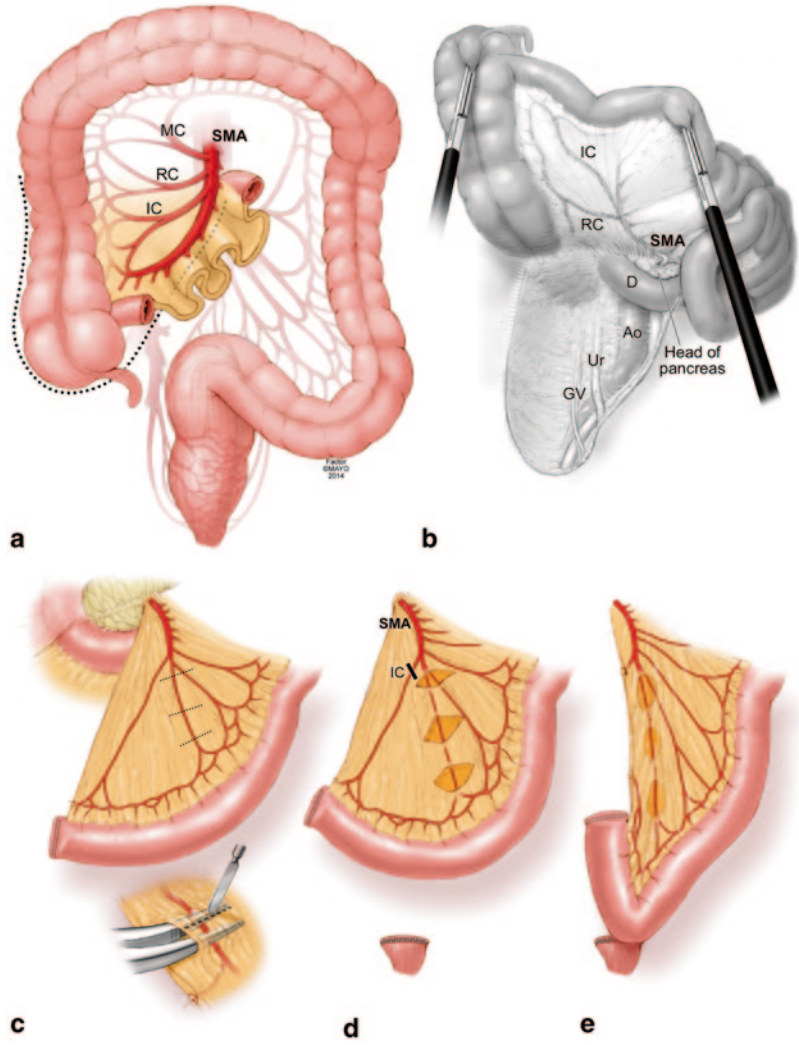

Fig. 31.4 Ileal-pouch anal anastomosis (*IPAA*) reconstruction. **a** Primary maneuvers mobilize the small bowel mesentery off the retroperitoneum to its mesenteric root as the superior mesenteric artery (*SMA*) emerges from the inferior border of the pancreas and duodenum. *IC* ileocolic artery, *RC* right colic artery, *MC* middle colic artery. **b** Critical retroperitoneal structures that can be identified during mobilization of the small bowel mesentery include the aorta (*Ao*), right ureter (*Ur*), right gonadal vessels (*GV*), and duodenum (*D*). **c** After resection of the colon, the terminal ileum is prepared by exposing the root of the SMA and then scoring the peritoneum stepwise over the path of the SMA under tension, which provides additional length for the ileal pouch. **d** and **e** Ligation of the IC, with preservation of the distal SMA, is a secondary maneuver that provides significantly more reach for the ileal pouch. © Mayo Clinic

the distal ileum, at approximately 8 cm from the transected ileum, is pulled caudally toward the pubis putting tension on the ileal mesentery. A series of sequential vessel ligations are then performed until adequate length is reached. The first vessel to be ligated is the right colic artery followed by the ileocolic artery if more length is needed. If tension is still a concern, the distal SMA can be ligated to generate maximum length. These series of ligations can be safely performed because of the preserved retrograde collateral circulation from the middle colic and right colon

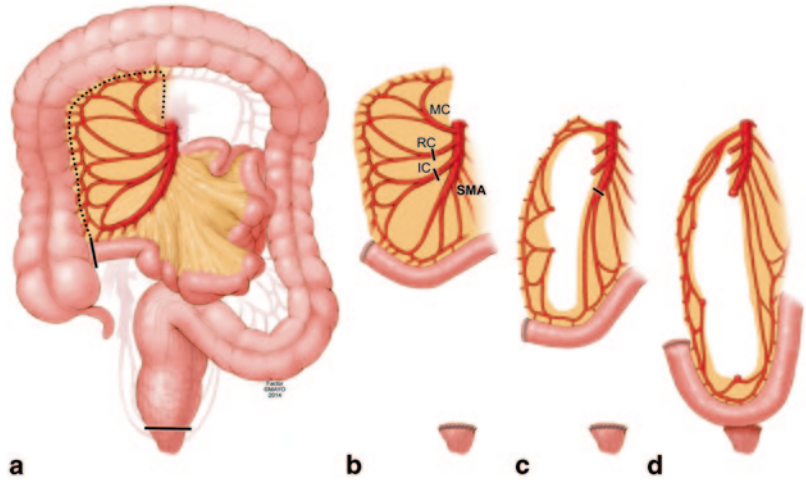

Fig. 31.5 Advanced ileal-pouch anal anastomosis (*IPAA*) reconstruction**. a** Overview strategy showing the correct line of transection during the colectomy to preserve the critical mesenteric vessels including the superior mesenteric artery (*SMA*), ileocolic artery (*IC*), right colic artery (*RC*), and middle colic artery (*MC*). **b** Ligation of the RC and IC preserves blood flow from the preserved MC via the right marginal arteries and provides additional length in pouch reach. **c** and **d** Ligation of the distal SMA provides the final and most significant gain in length for the construction of a tension-free IPAA with critical blood supply from the MC. © Mayo Clinic

marginal artery to the ileal pouch (Fig. 31.5). An additional reach of 11.2 cm has been estimated in cadaveric studies with this technique [21]. The authors have experience using this technique in three cases, all of which did well and achieved a successful tension-free anastomosis.

Whether or not an IPAA is hand-sewn or stapled significantly impacts how much length of ileal mesentery will be needed to perform a tension-free anastomosis. Because a stapled anastomosis joins the pouch to a rectal cuff at the level of the pelvic floor, there is approximately 2–4 cm less reach required as compared to a hand-sewn anastomosis to the dentate line. In addition, we routinely orient the J-pouch so that its mesentery lies posteriorly within the hollow of the pelvis, which has been reported to provide an additional 0.5–1 cm of reach [15]. Finally, in our practice, we always construct a J-pouch. Cadaveric studies have shown that a pouch configured in an "S-shape" reaches 2 cm or further than a J-pouch [16]. However, due to poor functional results observed in some S-pouches, we only consider this approach if the J-pouch cannot reach despite employing all the above mobilization maneuvers.

Stomas that Do Not Reach

The same principles for mobilizing small bowel and colon for distal anastomoses apply to mobilizing sufficient mesentery for construction of tension-free, well-vascularized stomas. The construction of an end colostomy during a Hartmann procedure, for example, may require both primary and secondary mobilization techniques. This strategy is especially relevant in obese patients that have a stoma sited in the left upper quadrant of the abdomen. In these situations, we begin with primary maneuvers by incising the line of Toldt along the left colon and freeing its mesentery from the retroperitoneum. The splenic flexure is then mobilized. If the proximal colon still does not reach the stoma site, secondary mobilization techniques are employed including ligation of the IMA and IMV. The collateral circulation to the stoma is the marginal artery supplied by the middle colic artery.

For the difficult end ileostomy that does not reach the skin, we begin with primary maneuvers by mobilizing the small bowel mesentery from the retroperitoneum to the ligament of Treitz,

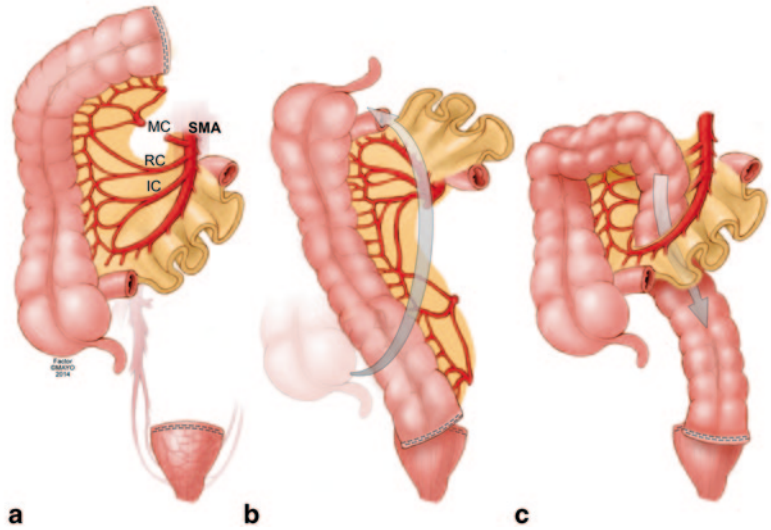

Fig. 31.6 Tertiary or Bailout Maneuvers. **a** Resection of colon to the proximal transverse colon and ligation of the middle colic artery prepares for two maneuvers that allow for a tension-free, low anastomosis. *SMA* superior mesenteric artery, *IC* ileocolic artery, *RC* right colic artery, *MC* middle colic artery. **b** Deloyers procedure. Counterclockwise rotation of the remaining right colon around the axis of the SMA may allow for a tension-free low pelvic anastomosis. **c** Retroileal reconstruction. Tunneling the remaining right colon through the ileal mesentery may allow for a tension-free low pelvic anastomosis. © Mayo Clinic

similar to IPAA reconstruction. Careful stepwise scoring of the peritoneum on the mesentery can provide additional length when the end ileostomy is held under tension. There may also be circumstances when the fixed, cut edge of the mesentery creates more tension than the mesentery of the bowel 4–6 cm proximal to the cut edge, and construction of an end-loop ileostomy, rather than an end ileostomy, makes the better tension-free stoma. In the unusual circumstance that primary maneuvers or the end-loop conversion fail to provide enough mesenteric length, then secondary maneuvers, including ligation of vascular pedicles such as the ileocolic artery, can be performed after ensuring adequate collateral circulation to the distal bowel edge.

Bailout Maneuvers—It Just Does Not Reach

There will be very rare situations when the small bowel or colon will not reach the distal bowel for an anastomosis despite all the above primary and secondary maneuvers. At this juncture, there are a few remaining tertiary, or bailout, maneuvers within the surgeon's armamentarium.

In the rare situation when primary and secondary maneuvers fail to deliver enough colon length for a low colorectal or coloanal reconstruction, a technique called the Deloyers procedure involves additional resection to the proximal transverse colon and then counterclockwise rotation of the remaining right colon, around the axis of the SMA, to construct a tension-free anastomosis (Fig. 31.6a, b) [22]. Besides requiring complete mobilization of the right colon, this maneuver also requires ligation of the middle colic artery, but good clinical outcomes have been reported [23]. Blood to the remaining colon flows from the SMA through the right colic, ileocolic artery, and marginal artery arcades. Alternatively, there have also been case reports of orienting the remaining right colon behind the ileal mesentery to construct a retroileal colorectal anastomosis after left colectomy (Fig. 31.6c) [24, 25].

If the above maneuvers are not possible, a completion colectomy to the terminal ileum

might be justified depending on the indication for the operation. The terminal ileum can then be used for a distal anastomosis (ileorectostomy or IPAA). In every situation, if a safe anastomosis is in serious doubt, the surgeon should consider construction of a stoma to establish a dependable gastrointestinal outlet.

Conclusions

Reestablishment of gastrointestinal continuity is a technically challenging but rewarding part of abdominal surgery. Undoubtedly, surgeons will encounter situations when the bowel does not easily reach for an anastomosis, but if these situations are approached in a deliberate fashion, the techniques illustrated in this chapter can be used to allow construction of a safe anastomosis or stoma in almost all circumstances.

Key Points on How to Avoid the Complication

1. A detailed understanding of embryologic planes and gastrointestinal vascular anatomy is essential to be technically proficient in employing advanced anastomotic techniques.
2. If a patient has had prior bowel surgery, operative notes should be obtained to clearly define the patient's current anatomy and remaining blood supply as it may impact intraoperative decisions in advanced reconstruction options.
3. If the patient has had a previous bowel resection in which key vessels were ligated that may be necessary for a second resection and reconstruction, alternative strategies will have to be considered. An angiogram in some circumstances may be necessary to clarify a patient's gastrointestinal vascular anatomy.
4. During colorectal or coloanal anastomoses, the proximal bowel end should easily reach the distal end without any pulling or tension. If a tension-free configuration is not achieved, there is high risk for anastomotic complications and further mobilization needs to be performed.
5. During IPAA, use the inferior edge of the pubis symphysis as a rough estimate of adequate length if the apex of the pouch can reach it without tension.

Key Points on Diagnosing/ Managing the Complication

1. Intraoperative techniques to assess blood supply, such as mesenteric trans- illumination and handheld Doppler probes, can facilitate decision making regarding safe vascular ligation and adequate perfusion to an anastomosis.
2. Primary maneuvers to provide additional bowel length should be employed first and include mobilizing embryonic planes and dividing peri-organ "ligaments" or attachments.
3. Secondary maneuvers include directed ligation of vascular pedicles that restrict the mobility of the corresponding proximal bowel. Often, these vascular ligations are already part of the oncologic resection.
4. Tertiary mobilization techniques should only be considered in those rare circumstances when primary and secondary maneuvers fail.
5. Externalizing the bowel as a stoma is better than leaving a high-risk anastomosis that could lead to significant intra-abdominal sepsis and death.

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Anastomotic Leak/Pelvic Abscess

32

Seok Byung Lim and Jose G. Guillem

Introduction

Anastomotic leakage is a major postoperative complication that can occur following a low anterior resection in 2–12% of cases [1, 2]. The reported incidence varies according to the clinician's definition of leakage. Although there is no single acknowledged definition for anastomotic leakage, several terms such as anastomotic failure, defect, or dehiscence have been used to describe the complication that is characterized by peritonitis, fecal drainage from wound or drain, and systemic symptoms associated with infection. The International Study Group of Rectal Cancer has proposed three clinical scenarios to characterize anastomotic leakage: (1) a communication between the intra- and extraluminal compartments owing to a defect at the anastomosis between the colon and rectum or the colon and anus, (2) a leakage originating from the suture or staple line of a neorectal reservoir (e.g., J-pouch or transverse coloplasty), and (3) a pelvic abscess in the proximity of the anastomosis [3].

The severity of the anastomotic leak dictates the management approach and the degree of urgency as well as the risk to the patient. Clearly, in severe cases, mortality may reach up to 12% [4], and it can account for nearly one-third of postoperative deaths following colorectal surgery [5]. In addition, due to associated stricturing at the anastomosis, as well as lack of compliance of bowel in the vicinity of the anastomosis, function is often impaired following an anastomotic leak [6]. Finally, the associated chronic inflammation that may persist at the site of a localized anastomotic leak/fistula track may be associated with worse oncologic outcomes [7].

Prevention

The prevention of an anastomotic leak following a low anterior resection consists of several strategies. Most importantly, it is imperative to adhere to basic principles of optimal surgical technique. The anastomosis needs to have a good blood supply, be tension free with full sacralization in the pelvis, and be properly oriented. In order to assure adequate bowel length for a tension-free anastomosis using diverticula-free, supple colon, a splenic flexure mobilization may be required. The intraoperative air insufflation test via a sigmoidoscope is used to detect an air leak after anastomosis; if an air leak is detected, then that would be an indication for performing a diverting proximal protecting loop ileostomy, which would help diminish the severity of an anastomotic leak should one occur. Although some recommend a side-to-end or colonic pouch anastomosis to minimize the risk of anastomotic leakage [8], anastomosis type has not been associated with risk of anastomotic leakage nor necessity to create a stoma [9]. Recent meta-analysis of four randomized controlled trials demonstrated that there

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was a significantly lower number of clinically symptomatic leaks and fewer reoperations in the group of patients with a defunctioning stoma and recommended the usage of a proximal protecting stoma following surgery for a low rectal cancer [10]. However, there are a number of potential problems associated with creation of a stoma including reduced patient satisfaction and self-image, quality of life, stoma-related morbidity, bowel obstruction, need for a second hospitalization and reoperation for stoma closure, as well as the possibility of ending up with a permanent stoma. Therefore, a protective stoma should be used selectively.

Many factors are associated with the risk of leakage, including patient factors such as male gender, obesity, hypoalbuminemia, malnutrition, anemia, weight loss, use of alcohol, and a history of heavy smoking (more than 40 pack-years); tumor factors include distal location requiring a low anastomosis, while treatment factors include usage of preoperative radiotherapy, adverse intraoperative events, and long operative time [11–15].

The widespread introduction of preoperative chemoradiation therapy in the multimodality management of locally advanced rectal cancer and the introduction of minimal access surgical techniques have raised concerns over the impact that these would each have on anastomotic leak rates. Although a national cohort study in Norway reported that patients receiving preoperative radiotherapy showed a higher rate of anastomotic leakage [16], recent randomized trials have failed to confirm this observation [17, 18]. In terms of laparoscopy, the reported leakage rates of the laparoscopic approach appear similar to those of an open approach as demonstrated by the CLASICC trial (open 7% versus laparoscopic 8%) [19].

Currently, most surgeons use a mechanical bowel preparation before rectal surgery. Although recent meta-analysis demonstrates no statistically significant decrease in the rate of leakage when using a mechanical bowel preparation [20, 21], a recent randomized trial suggested a benefit [22]. In our practice, we continue to use a full (mechanical as well as oral and IV antibiotics) bowel preparation for all rectal cancer resections.

In general, with some exceptions, we tend to perform a diverting loop ileostomy in patients with a low-lying anastomosis (within 5 cm of the anal verge or within 1 cm above the upper part of the anorectal ring), elderly patients, patients receiving preoperative chemoradiation, malnourished patients, patients on steroids, diabetic patients, and postmenopausal females with an anastomosis juxtaposed to a thin rectovaginal septum. An absolute indication for proximal diversion is a patient in whom air bubbles are noted to emanate from the staple line under a fluid-filled pelvis following air insufflation via a sigmoidoscope.

Diagnosis and Management

Diagnosis

Anastomotic leakage following a low anterior resection usually becomes clinically evident by the fifth to seventh postoperative day. Patients may present in a variety of ways. Some develop the classical signs of peritonitis such as abdominal pain, tachycardia, high fever, hypotension, low urine output along with foul odor, fecal-like discharge from drain or incision, and a rigid abdomen. In these cases, clinical findings alone are sufficient to diagnose leakage, and radiologic studies are more confirmatory and are likely to show obvious leakage of contrast material. However, the majority of patients with an anastomotic leak present in a more insidious fashion with nonspecific signs such as a mild fever, ileus, and failure to thrive. These nonspecific signs may be overlooked and may delay establishing a diagnosis of an anastomotic leak. In fact, it has been shown that approximately 12–30% of all anastomotic leaks are diagnosed more than 30 days after surgery [23, 24]. This underscores the importance of maintaining a high index of clinical suspicion during the immediate postoperative period as well as postdischarge period in order to detect an anastomotic leak and treat it in a timely fashion.

The clinical signs or symptoms depend greatly on a number of factors including the severity of leakage, the degree of contamination (peritoneal versus walled-off, localized), the timing of the

leakage (early versus late), and whether a proximal diverting stoma had been created at the time of the initial operation. There are several imaging modalities that help to secure a diagnosis of anastomotic leakage. The most commonly used are a Gastrografin enema and/or a CT of the abdomen and pelvis with and without oral and IV contrast and rectal contrast, when possible.

The usage of rectal contrast during a CT scan facilitates the detection of a small leak while IV and oral contrast are useful in detecting a walled-off abscess/pocket adjacent that perhaps no longer communicates with the anastomotic defect. For the patients with an insidious presentation, CT can be quite effective at detecting intra-abdominal and pelvic abscesses with sensitivity and accuracy over 90%. Gastrografin enema, while helpful for detecting and delineating the trajectory and possibly the extent of anastomotic leakage, is limited in detecting a walled-off, noncommunicating yet, drainable abscess. Digital rectal examination and sigmoidoscopic evaluation may be useful while under anesthesia but should not be relied upon to rule out an anastomotic separation in the awake patient since edematous mucosa and patient discomfort limit a thorough examination.

Management

The management of a patient with an anastomotic leak following a low anterior resection for rectal cancer can be challenging and requires careful consideration of numerous factors, thoughtful judgment, and deliberate interventions in a timely manner. The first determination to make is whether the patient needs to go to the operating room immediately or can wait. Once that is established and broad-spectrum IV antibiotics and hydration are begun, the next question is what type of intervention is required and is the patient stable to go to the operating room or needs aggressive resuscitation first. If the patient is stable enough to be evaluated, imaging as described above should ensue. If time and patient stability allow, an enterostomal nurse should mark the patient in all four quadrants for possible stoma placement based upon intraoperative findings.

Anastomotic leaks can be categorized into three types (Fig. 32.1) Type I is one associated with generalized peritonitis or sepsis. Type II is one associated with a CT image of a localized pelvic abscess around anastomosis. Type III is one associated with drainage of foul odor fluid or fecal contents from skin, urine, or vagina via fistula. In a stable patient with a well-drained fistula, conservative management may be considered. A fistulogram may be helpful in evaluating the location and severity of fistula and determine the necessity of exploration.

Type I: Generalized Peritonitis

Approximately 40–45% of all anastomotic leaks present in this fashion. Patients complain of severe abdominal pain and have a high fever, tachycardia, marked leukocytosis, and signs of generalized peritonitis such as rebound abdominal tenderness and/or rigidity. In these cases, imaging is not required to make a diagnosis of an anastomotic leak. Initial efforts should focus on broad-spectrum antibiotics and aggressive fluid resuscitation.

With the patient in a modified Lloyd-Davies position, an examination under anesthesia will allow for an assessment of the anastomosis, as well as access to the rectum in the event that rectal washout is indicated after abdominal–pelvic exploration. The operative exploration aims to identify the site and extent of leakage, contain further leakage, and aggressively lavage the entire abdominal/pelvic cavity. In cases where the anastomotic disruption and contamination are minimal, pelvic drainage and a proximal diverting stoma may be all that is required. Depending on the long-term plans, a temporary loop ileostomy is a quick option, but the possibility of high output and associated dehydration needs to be taken into consideration in the context of the patient's age and overall comorbidities. In cases where dehydration is of concern and/or a permanent proximal diversion is envisioned, a left upper quadrant, end-loop (Prasad–Abcarian) colostomy is an option that prevents further contamination, yet affords passage of mucus from the efferent limb should a distal obstruction from a stricture at the anastomosis develop. If the colon is full of feces and therefore a source of further

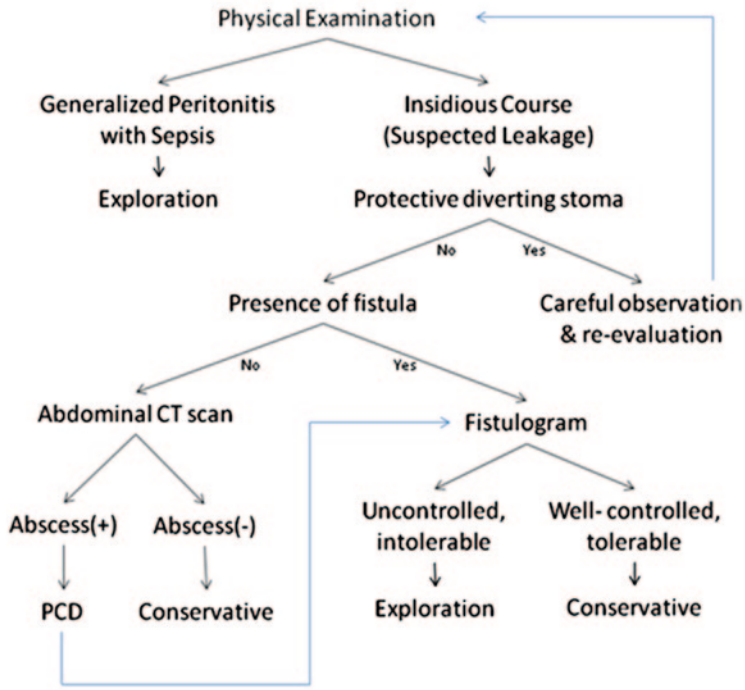

Fig. 32.1 Postoperative diagnostic and therapeutic algorithm. *PCD* percutaneous drainage

ongoing contamination, a proximal end or end-loop colostomy with distal limb rectal washout is indicated. When creating an end-loop colostomy, great care must be exercised to avoid damage to the marginal artery, which perfuses the afferent limb of the anastomosis, and may be the only source of perfusion in cases where the left colic artery is sacrificed during the initial resection. In cases where a large anastomotic disruption and contamination have occurred, a redo low anterior resection is not a viable option, and these cases are best managed by bringing the afferent limb out as an end colostomy and attempting to suture/staple shut the efferent limb; one should then create a Hartmann's pouch and assure adequate drainage of the pelvis with drains.

Type II: Localized Pelvic Abscess

About 30–40% of patients with an anastomotic leak present with vague abdominal pain, prolonged ileus, mild fever, leukocytosis, and abdominal distension associated with ileus and localized peritoneal signs. Such patients warrant an abdominal pelvic CT scan with oral, IV, and rectal contrast, when possible. When no extravasation of contrast is noted, it is sometimes difficult to distinguish between an anastomotic leak and a postoperative abscess. If the abscess is of reasonable size and walled off, it should be drained percutaneously under radiologic guidance. Success rates for CT-guided placement of a percutaneous drainage catheter are about 80% [25]. Following successful drainage, some patients go on to develop a chronic enterocutaneous fistula or sinus, which can be managed conservatively. Although most of these patients do not usually require a reexploration, some fail this conservative approach and develop symptoms late after discharge from the hospital. Long-term close follow-up is therefore warranted.

Type III: Fistula

A fistula may be a long-term sequelae in upward of 25–30% of anastomotic leaks following a low anterior resection. A thorough evaluation includes a careful physical examination as well as optimal contrast imaging with a CT scan and

fistulogram in order to delineate a fistula track and rule out distal obstruction. Endoscopy may be helpful in evaluating the orifices of a fistula. If the fistula is well drained and the overall nutritional condition of the patients is adequate, a conservative approach including optimal skin care with a stoma appliance, low suction device, with or without antibiotics, and somatostatin are often sufficient to control the fistula. In cases with a persistent, poorly drained, or intolerable fistula, a surgical approach should be considered. Local therapy with fibrin glue or plugs is rarely effective in this setting. Surgical options include creation of proximal diverting stoma versus primary closure of a rectovaginal fistula via a transanal approach with an advancement flap and temporary stoma or redo low anterior resection.

Long-Term Outcome

In addition to the immediate impact on postoperative morbidity and mortality, anastomotic leakage also impacts long-term functional outcome and possibly even long-term prognosis of the rectal cancer patient.

Need for a Permanent Stoma

Following an anastomotic leak, some patients may be left with a permanent stoma because the leakage and associated contamination may result in such profound fibrosis and scarring of the pelvis and residual rectum so as to prohibit a re-resection and creation of a supple and functional primary colorectal or coloanal anastomosis. In addition, because of fear of further complications, the surgeon and patient alike may choose to not pursue further major surgery. In these cases, the patient is left with either the initially created protecting proximal stoma or the stoma created during the reoperation following the anastomotic leak. In these situations, a reoperation may nevertheless be required in order to convert an ileostomy into a colostomy resulting in fewer evacuations and less volume loss. The reported rates for the need of a permanent stoma in these circumstances are 2.9 ~ 19 % [26–29].

Stenosis or Stricture

The rate of clinically significant stenosis or stricturing of a colorectal anastomosis ranges from 3 to 30 %, depending on the criteria employed. The most common cause of anastomotic stenosis/stricture is anastomotic leakage [30, 31]. Management, which depends on the severity of the stenosis, includes simple dilatation (digital or Hagar), balloon dilatation (radiologic or endoscopic), proximal diverting stoma, Hartmann procedure with/or without resection of stricture site, and redo low anterior resection. Because local recurrence is the second most common cause of anastomotic stricture after sphincter-preserving surgery for rectal cancer, a biopsy of the stricture should be obtained whenever feasible in order to exclude cancer.

Anorectal Dysfunction and Quality of Life

Following a sphincter-preserving low anterior resection, anorectal dysfunction in the form of fecal incontinence, evacuation problems, and clustering of bowel movements is frequently noted [32]. Anastomotic leakage has been identified as a predictive factor of anorectal dysfunction. Although there are few reports addressing bowel function and quality of life after an anastomotic leak of a low anterior resection (Table 32.1) [6, 33, 34], it is generally agreed upon that long-term function is impaired in patients with anastomotic leakage.

Local Recurrence

Great controversy exists on whether anastomotic leakage following a rectal cancer resection is a prognostic factor for local recurrence and/or survival (Table 32.2) [16, 35–42]. Conflicting results may be due to varied definitions of anastomotic leaks, patient selection, heterogeneity of cases (colon and rectal cancer versus rectal

Table 32.1 Impact of anastomotic leakage after low anterior resection for rectal cancer on bowel function and quality of life

Authors	Year	Study	No of pts	F/U period	Leakage rate (%)	Tools		Results and conclusion
						Bowel function	QoL	
Hallböök et al. [8]	1996	Case-matched	38	30 months	–	Manometry	–	There was no difference in sphincter function
								Neorectal volume, compliance, urgency, and MTV were significantly reduced in patients with leakage
								Long-term functional outcome may be impaired
Nesbakken et al. [6]	2001	Case-matched	22	2 years	–	Manometry questionnaire		Reduced neorectal capacity, more evacuation problem, and a trend toward more fecal urgency and incontinence
	–							Long-term anorectal function had been impaired
Ashburn et al. [34]	2012	Retrospective	864	3.2 years	6.0	FISI	Cleveland Global QoL	One year: worse physical and mental component scores, more frequent daytime and nighttime bowel movements, and worse control of solid stool
							Short-Form 36	Recent: worse mental component scores and increased use of perineal pads
								Early adverse consequences on bowel function and QoL

FISI fecal incontinence severity index, *MTV* maximal tolerable volume

Table 32.2 Impact of anastomotic leakage after low anterior resection for rectal cancer on oncologic outcomes

Authors	Year	Study	# pts	F/U period	Leak rate	Local recurrence			Cancer-specific survival			Overall survival		
						AL (+)	AL (−)	*p* value	AL (+)	AL (−)	*p* value	AL (+)	AL (−)	*p* value
Merkel et al. [35]	2001	Single center	814	90 months	10.9	22.0	12.5	0.018	69.6	77.8	0.0035	–	–	–
Bell et al. [36]	2003	Single center	403	–	12.7	25.5	10.0	0.001	–	–	–	–	–	–
Eriksen et al. [16]	2005	National cohort	1958	7.6 years	11.6	11.6	10.5	0.608	–	–	–	59.0	67.4	0.02
Ptok et al. [37]	2007	Multicenter	2044	40 month	14.8	17.5	10.1	0.006	70.9	75.4	0.020	–	–	–
Jung et al. [38]	2008	Single center	1391	40.1 month	2.5	9.6	2.2	0.14	63	78.3	0.05	55.1	74.1	<0.05
den Dulk et al. [28]	2009	Multicenter	2726	5.9 year	9.7	12.0	8.8	0.103	60.6	66.9	0.033	71.5	75.5	0.030
Bertelsen et al. [40]	2010	National database	1494	3.77 year	10.9	13.4	9.9	0.17	–	–	–	–	–	–
Jörgren et al. [41]	2011	Case-control National Registry	250	–	–	8	9	0.97	79	77	0.50	63	66	0.38
Smith et al. [42]	2012	Single center	1127	5.6 year	3.5	Ile (+) 9 Ile (-) 5	46	0.092	Ile (+) 88 Ile (−) 93	91 89	0.83	Ile (+) 89 Ile (−) 83	87 87	0.94

AL anastomotic leak, *ile* ileostomy, *F/U* follow-up

cancer, alone), and variability in the management of the anastomotic leak.

Key Points on How to Avoid the Complication

1. Following basic principles of good anastomosis is the most important to reduce leakage.
2. Bowel preparation prior to surgery and pelvic drainage are advisable to reduce symptomatic leakage.
3. The height of anastomosis from anal verge is significantly associated with the anastomotic leakage.
4. Selective use of diverting stoma in patients with high risk is highly advisable to reduce symptomatic leakage.
5. Surgeon should consider the possibility of permanent stoma while doing sphincter-preserving surgery.

Key Points on Diagnosing and Managing

1. Prompt diagnosis and appropriate management could lower mortality following leakage.
2. CT scanning for diagnosis is highly accurate, and CT-guided drainage of abscess has high treatment success rates.
3. The patients with anastomotic leakage could be categorized according to their presentation and severity of leakage.
4. Anastomotic leakage is the most common cause for anorectal dysfunction and anastomotic stricture.
5. Anastomotic leakage leads to anorectal dysfunction and might be associated with increasing local recurrence.

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Management of Anastomotic Stricture

33

Lindsey E. Richards, Sarah Y. Boostrom and James W. Fleshman

Introduction

While the incidence of colon cancer is declining in the USA, approximately 40 % of colon cancers identified are discovered at the regional stage, when colonic resection is the first-line therapy [1]. This, coupled with the increase of inflammatory bowel disease (IBD) globally [2], gives rise to a large number of colon and rectal operations in the USA each year. However, despite improvement in operative techniques, the achievement of event-free healing following intestinal anastomoses remains a challenge. Anastomotic stricture complications compromise approximately 3–30 % of all colocolonic, colorectal, and coloanal anastomoses, with the wide range dependent on the definition of anastomotic stricture utilized. An anastomotic stricture may be defined as any chronic narrowing or obstruction to the flow of intestinal contents, resulting in clinical signs or symptoms of either complete or partial obstruction, following surgical resection. Given the subjective definition, in an attempt to objectively define a stricture, Fasth et al. defined a colorectal anastomotic (CRA) stricture as the inability to pass a 12-mm sigmoidoscope through a rectal anastomosis [3]. If not treated appropriately, these strictures may lead to poor function with urgency, frequent bowel movements, incontinence, and ultimately a permanent stoma [3]. We review the risk factors, prevention, and diagnosis of CRA strictures, as well as discuss the individual treatments for colocolonic anastomotic (CCA), colorectal anastomotic (CRA), and coloanal anastomotic (CAA) strictures.

Etiology of Anastomotic Stricture

Many causal agents have been linked to the development of anastomotic strictures; however, three frequent causes of CRA strictures include anastomotic leaks/inflammation, ischemia, and anastomoses created under tension (Table 33.1) [4].

Anastomotic leaks instigate inflammation and pelvic sepsis, which leads to fibrosis, with a stricture being the end result [5]. An increased risk for stricture formation exists for anastomoses created after resection for an inflammatory process, such as diverticulitis and IBD, because inflammation itself is a risk factor for stenosis [6]. Other independent risk factors associated with anastomotic leaks include anastomoses <10 cm from the anal verge, ligation of the inferior mesenteric artery distal to the left colic artery ("low" ligation), male sex, intraoperative complications, and general patient comorbidities. In fact, both diabetes and atherosclerosis have been identified in small studies as significant risk factors for impaired local blood flow and thus anastomotic leaks [7].

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Table 33.1 Factors influencing anastomotic integrity

Surgeon factors	Patient factors	Disease factors
Intestinal blood supply	Body mass index (BMI)	Inflammatory bowel disease (IBD)
Tension at anastomotic site	Anesthesia severity assessment (ASA)	Metastatic carcinoma
Perioperative hypoxia	Age	Radiation therapy
Perioperative resuscitation	Smoking status	Damage control surgery
Intraoperative blood loss	Nutritional status	Emergent surgery/peritonitis
Operative times	Alcohol use	Steroids

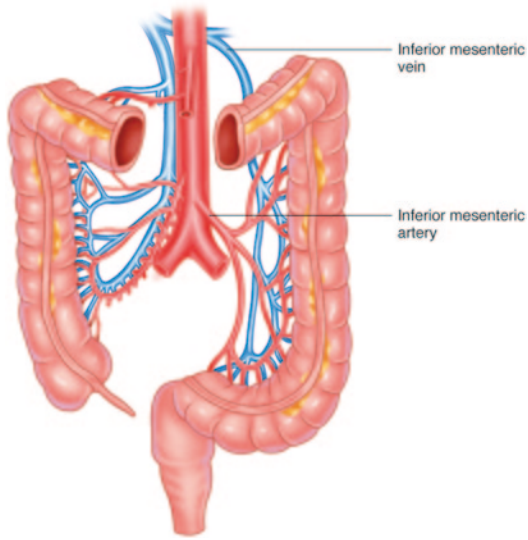

Fig. 33.1 In order to provide complete splenic flexure mobilization to allow maximum reach for CRA and CAAs, and a tension-free anastomosis, the inferior mesenteric vein should be ligated proximally at the inferior border of the pancreas

A correlation has been found between CRA strictures and failure to mobilize the splenic flexure and "low" ligation of the inferior mesenteric artery and vein [8]. In order to provide complete splenic flexure mobilization to allow maximum reach for CRA and CAAs, and a tension-free anastomosis, the inferior mesenteric vein should be ligated proximally at the inferior border of the pancreas (Fig. 33.1) [9]. Hiranyakas et al. found that 90% of patients with CRA strictures had a nonmobilized splenic flexure and intact inferior mesenteric vessels; these data support the necessity to fully mobilize the left colon and splenic flexure [8].

Adequate blood flow at the anastomotic site is also imperative to prevent anastomotic strictures [5]. If the terminal end of the bowel has questionable blood flow, it should be resected until acceptable flow is present. Clinical indicators implying adequate blood flow may be assessed with evaluation of the color of the mucosa, bleeding at cut bowel edges, and palpable pulses within the vasculature. Doppler and fluorescence imaging are other modalities that can aid in the assessment of blood flow at the anastomosis. It has been demonstrated that the transverse and descending colon have increased measured oxygen tension, whereas oxygen tension is diminished in the circumstances when the sigmoid is utilized for the anastomosis. Thus, the sigmoid is a suboptimal choice for routine anastomosis [10].

The best method of creating the anastomosis (stapled versus hand-sewn) continues to be a debated topic. While stapling allows for a reduction in operative time, ease of use, and decreased blood loss, some small studies illustrate higher rates of complications with stapled anastomoses [6]. Higher levels of collagen deposition and inflammation in the stapled anastomosis correlate with a higher stricture rate [6]. Reports of increased stricture rates in low stapled anastomoses with fecal diversion suggest that stapled anastomoses may "require" the dilation effect from the passage of stool [4]. Some clinicians also believe that they have more control of the shape and caliber of the anastomosis when the anastomosis is performed hand-sewn, thereby decreasing the risk of anastomotic stricture. Of note, a 2012 Cochrane meta-analysis review noted that stapled and hand-sewn anastomosis were equivalent in all categories except stricture formation [11]. The frequency of stricture was significantly

Table 33.2 Cochrane review: stapled versus hand-sewn methods for colorectal anastomosis surgery

		Stapler		Hand-sewn	
Study/year	Strictured	Total	Strictured	Total	*p* value
Infraperitoneal anastomosis					
Fingergut [26]	8	50	2	52	
Subtotal	*8*	*50*	*2*	*52*	*0.04*
Supraperitoneal anastomosis					
Fingergut [26]	4	82	2	72	
Sarker [27]	0	30	0	30	
Subtotal	*4*	*112*	*2*	*102*	*0.5*
Colorectal anastomosis					
Elhadad [28]	10	122	1	133	
Gonzalez 1987	8	55	3	55	
Kracht [29]	10	137	1	131	
Thiede [30]	0	24	1	23	
Subtotal	*28*	*338*	*6*	*342*	*0.000089*
Total	*40*	*500*	*10*	*496*	*0.000012*

higher with stapling than hand-sewn technique ($p < 0.05$) (Table 33.2).

Factors predictive of anastomotic stricture include patient age, obesity, smoking status, and relevant comorbidities including diabetes [12]. Obese patients undergoing ileo-anal pouch anastomosis were found to have an increased rate of overall complications (80 versus 64%) compared to nonobese patients, with stricture being a specific increased complication (27 versus 6%) [13].

Presentation and Diagnosis

Anastomotic strictures typically present 2–12 months after surgery [4] with symptoms such as constipation or watery diarrhea, pain, cramps, fractionated evacuation, abdominal distention, leakage, or feelings of incomplete evacuation [6]. In cases where the indication for the initial resection was malignancy, it is essential that local recurrence of the cancer be ruled out. Initial studies performed should include carcinoembryonic antigen (CEA level), hypaque enema, contrast CT for colon primary or MRI for rectal primary, and a positron emission tomography (PET) scan in the setting of patient with an elevated CEA. Ultimately, a colonoscopy with biopsy is mandated [4]. A stricture that is not responsive to repeated dilation requires repeat biopsy and a high level of clinical suspicion [14].

Strictures are more common when the anastomosis is distal, with rectal strictures being the most frequent [3, 8]. It is crucial to eliminate technical risk factors (rotation, ischemia) as well as tension (especially operations that require an anastomosis within 15 cm of the anal verge). Patients with a diverting stoma created at the initial resection may develop a soft stricture or even heal the lumen closed. A digital exam 4–6 weeks postoperatively or prior to closure of the diverting stoma relieve those strictures, which are often much softer and easier to dilate early in the postoperative course [4]. Similarly, patients with a low rectal anastomosis require a digital examination in addition to a hypaque enema prior to diverting ileostomy closure (Fig. 33.2). If a tight, firm stricture is present, intraoperative dilation with Hegar dilators may be performed in conjunction with loop ileostomy closure. It is occasionally necessary to place a flexible scope through the distal limb of the loop stoma to guide placement of a guide wire, using Seldinger technique, through the center of the strictured anastomosis. This guide wire can then be used to guide a dilator through the stricture. The light of the scope from proximal to the anastomosis targets the center of the anastomosis when viewed from the distal aspect of the anastomosis.

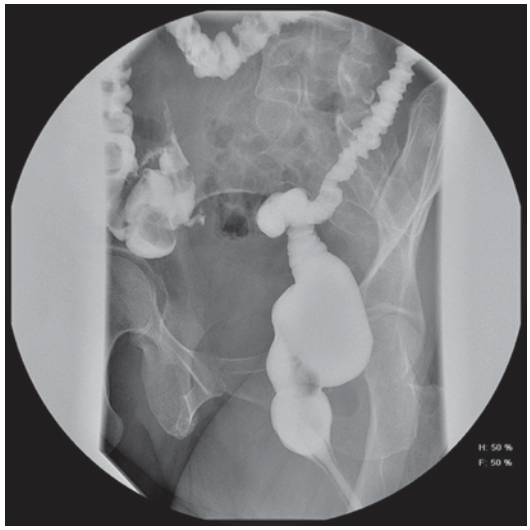

Fig. 33.2 Patients with a low rectal anastomosis require a digital examination in addition to a hypaque enema prior to diverting ileostomy closure

Nonoperative Treatment

Balloon Dilation and Endoscopic Options

It is often possible to treat the early stricture in the office with a long cotton-tipped sigmoidoscopy swab passed through the rigid proctoscope. Up to three swabs can be passed through the central gap in the stricture. The swabs are then pulled through the stricture as a group, with gentle traction, while the ends are held to the same level at the outer end of the proctoscope. This stretch effect then allows the 23-mm diameter scope to be passed through the stricture to fully fracture the scar.

In most circumstances, endoscopic balloon dilation remains the first-line therapeutic modality for the treatment of benign colorectal strictures. The success of endoscopic dilation lies in its simplicity and immediate efficacy in up to 80% of cases [15]. However, patients often require sequential dilations with larger balloons over two to three endoscopic sessions to achieve long-term success [15]. Recurrence after balloon dilatation can range from 30 to 88% [16]. Recurrence of the stricture is often the result of tighter strictures being inadequately or inappropriately dilated [17]. Of note, most data on the efficacy of balloon dilation report only on subjective symptom relief [16]. While symptom relief is important, quantifiable data such as stricture size can provide more objective data as to the success of balloon dilation. Kim et al. reported a defined protocol for balloon dilation consisting of single and double balloon dilation, with improvement in 74% of patients after 1 month and complete improvement in 86% of patients after 5 years. Only 5% required repeat dilation with an average increase in the stricture diameter of 50% [16]. With this technique, fluoroscopic guidance is used and the patient is awake and not anesthetized. A 20-mm balloon catheter is passed over a guide wire and filled by hand pressure until the waist on the balloon disappears. The pressure is maintained for 1 min. If no blood or pain is present, a second 10-mm balloon catheter is inserted adjacent to the existing balloon and both are inflated simultaneously. This protocol reportedly reduced recurrence rates to 7% at 1 year, and 10% at 5, 7, and 10 years. As mentioned prior, dilation can also be performed digitally, with flexible bougies or metal dilators (Hegar, Eder-Peustow); however, it is important to keep in mind that balloon dilation has the advantage of producing controlled incremental radial pressure.

Indications for endoscopic balloon dilation include a narrow lumen (<10 mm) and a short segment stricture (<4 cm) [18]. Balloon dilation is not appropriate when numerous strictures or complete obstruction exist, when there is an associated fistula within the stricture, inflammation around the stricture, recent surgery, or a tight angulation [18]. Stenoses that are long or appear late and are caused by ischemia will develop surrounding nonexpandable fibrotic tissue and a rigid colon and are unlikely to respond to balloon dilation [19].

When dilation fails or is contraindicated, other treatments should be considered. With CRA and CAA strictures, alternative treatment options include laser strictureplasty, urethroscope resection, endoscopic retrograde cholangiopancreatography (ERCP) papillotomy knife, and

resection and re-stapling with a circular stapling instrument.

Stents

Self-expandable metal stents (SEMS) have also been used to treat strictures that are more proximal, such as CCA and CRAs. In small studies, SEMS have proven to have a 70–90% success rate [12, 20]. However, migration after placement remains a concerning complication with SEMS. A possible solution to migration could be the use of biodegradable stents, similar to those utilized for esophageal strictures. However, with only a few published case reports on biodegradable stent placements, more research is needed in this area [21]. The idea of radial strictureplasty with any of the above modalities, followed by placement of an expanding fully covered stent, has merit. The stent returns the luminal diameter to an acceptable size and the covered internal conduit prevents leak.

Operative Treatment

Reoperative Surgery

In those patients in whom endoscopic treatment of the anastomotic stricture has failed, reoperative surgery should be considered. Approximately 30% of symptomatic anastomotic strictures are severe enough to require surgical correction [5].

Anastomotic strictures have been reported to be the most frequent indication for reoperative colorectal surgery and represent 40–50% of reoperations. This exceeds the rate of reoperation for anastomotic leak, fistula, chronic pelvic sepsis, and cancer recurrence [3, 19].

Anastomotic revision is a surgical challenge with long operative times, intraoperative technical difficulties, and increased morbidity. Anastomotic revision remains, however, the most valuable option to provide a symptom-free quality of life and avoidance of a permanent stoma for some patients. Indications for surgical intervention include strictures that meet contraindications for dilation (long, fresh, ischemic), strictures refractory to multiple dilation or endoscopic techniques, and patients who continue to require a stoma for other reasons [3]. Strict adherence to selection criteria should be practiced with preference to patients having acceptable comorbidities, given the increased morbidity associated with this reoperative surgery if the anastomosis is within the pelvis [3, 5]. The Association Française de Chirurgie (AFC) score identifies four factors to predict accurately postoperative mortality and morbidity for patients treated for cancer or diverticulitis: age >70, poor nutrition, neurologic comorbidities, and emergency surgery [22]. In two of the three landmark papers reviewing reoperative surgery success, only patients with 0–1 risk factors (mortality risk <1%) were considered, with a resulting 70–88% of patients possessing a functional anastomosis after 28–37 months follow-up period [19]. For reoperations, specifically for anastomotic strictures, the success rate was even higher at 100% [5]. Successful results within these three studies were measured as less than four bowel movements a day, normal continence, and reduction in urgency, fragmentation, and constipation. Lefevre et al. identified three risk factors for increased likelihood of complications postoperatively: male gender, first procedure consisting of coloanal anastomosis, and reoperation requiring a coloanal anastomosis [3].

The time necessary for a trial of first-line treatments such as endoscopic techniques and balloon dilation is often quite long [2]. In fact, most series report an average time between the initial surgery and reoperation of 14–41 months [3, 5, 19]. Once surgery is undertaken, long intraoperative times can be expected due to the usual history of previous laparotomies coupled with hostile pelvic conditions (chronic inflammation and fibrosis) [3, 19]. Adhesiolysis and small bowel resection are usually required and add to the intraoperative time. In addition, other organs are at risk and bladder injury is one of the more common complications reported, with an overall operative morbidity ranging from 26 to 55% [3, 19]. Postoperatively, wound infection and herniation are common causes of morbidity.

Anastomotic Revision and Diverting Stomas

Colorectal and coloanal anastomoses are considered "high risk" when compared to higher intraperitoneal anastomoses [5]. These low anastomoses have a significant risk in the early postoperative period for both leak and pelvic abscess [3]. Many patients with rectal cancer may have received preoperative chemotherapy and radiation prior to the initial operation. In the majority of patients who receive a low pelvic anastomoses, a temporary diverting stoma is constructed at the initial procedure [23]. An anastomosis free of tension remains crucial to minimize leakage complications and is accomplished by adhering to standard procedure: splenic flexure mobilization, high ligation of the IMA, and sigmoid resection. Reconstruction after revising a strictured colorectal or coloanal anastomosis is technically difficult [5]. Although some favor a colonic pouch for function, Genser et al. and Schlegel et al. both favored straight anastomoses in hostile pelvic conditions. The shortened length of the remaining colon, the narrowing of the pelvis secondary to sepsis and fibrosis, and the fear of leakage from the extra staple line of the pouch all support the straight anastomosis [19]. A well-vascularized anastomosis is also imperative to the success of the procedure, and when in doubt, additional colonic resection should be performed to provide a healthy colon with adequate blood supply [19].

New Technology

Reaction against the presence of a foreign body, such as metal staples or sutures, will instigate an inflammatory response, resulting in fibrosis and stenosis. A nickel–titanium alloy compression ring has been recently described for the use of constructing an anastomosis without the use of staples or sutures. The memory shaped alloy is a reversible, temperature-dependent device that transitions from rigid to malleable when cooled to 0 °C and back to rigid when it is applied to the bowel. When warmed, it slowly returns to its hard closed shape compressing the intestinal edges and applying uniform pressure to cause controlled ischemia and necrosis. At approximately 1–2 weeks, the device is expelled from the body. In a small preliminary study of 20 patients, 90 % were found to be stricture-free at 3- and 6-month follow-up [24]. In addition, the 2-week postoperative histopathology revealed minimal inflammation with uniform healing process [24]. While promising, the data are only from a very small study with very short follow-up time and has not been reproduced; thus further studies are warranted. Animal studies using a porcine model showed a more organized, near-normal intestinal wall structure with less inflammation at the anastomosis after a compression ring anastomosis. The compression may provide a more physiologic result with fewer strictures [25].

Conclusion

Anastomotic strictures continue to be a complication in colorectal surgery. There are many known perioperative risk factors that can be optimized, as well as operative techniques that can be utilized for the prevention of anastomotic stricture formation. Understanding patient comorbidities and risk factors prior to surgery may allow for the correction of some parameters including smoking cessation and improving nutritional status. The resulting minimization of risk factors yields improved healing rates. Recognizing the risk of low anastomoses and practicing excellent technique, to construct a well-vascularized, tension-free anastomosis, will minimize the risk of stricture formation.

Preoperative anastomotic dilation at the time of closure of the diverting loop ileostomy is valuable for treating a soft stricture associated with a non-used primary anastomosis. Treatment of an established anastomotic stricture includes balloon dilation, self-expanding metal stents, radial strictureplasty by laser, electrocautery, urethroscope, and combination techniques (Fig. 33.3). Finally, reoperative surgery may be required, in which a tension-free and well-vascularized anastomosis is constructed with adherence to "best" practice to reduce strictures. Future technology and innovations including the memory shaped alloy ring may eventually provide relief to the

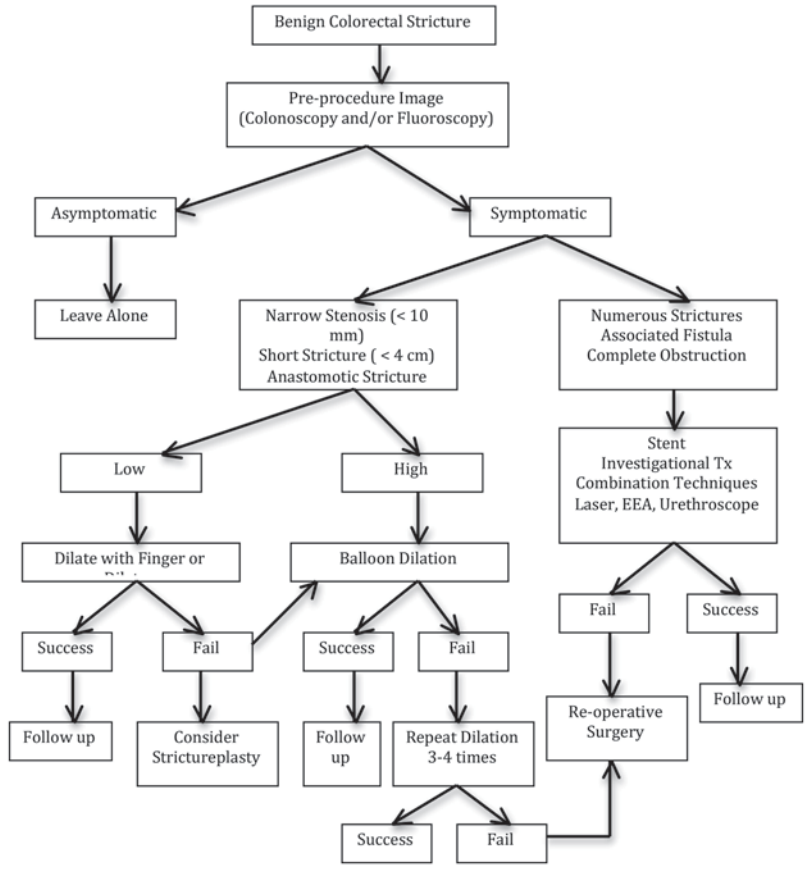

Fig. 33.3 Treatment of an established anastomotic stricture includes balloon dilation, self-expanding metal stents, radial strictureplasty by laser, electrocautery, urethroscope, and combination techniques

anastomotic stricture complication; however, further study is warranted in this regard.

To Avoid Anastomotic Strictures in Colorectal Resections

1. Recognize anastomoses constructed at < 15 cm above the anal verge have the highest risk.
2. Primary anastomosis should be tension free and well vascularized.
3. Early postoperative dilation prior to stoma closure may alleviate future strictures.
4. Controllable patient risk factors such as smoking, alcohol intake, nutritional status, and BMI should be managed prior to surgery when possible.
5. New technology such as the memory shaped alloy requires more study and remains on the forefront of newest available resources.

Five Points on Diagnosing and Managing Anastomotic Strictures

1. Symptoms:
   a. Constipation or watery diarrhea
   b. Pain and/or cramps
   c. Fractionated evacuation and/or feelings of incomplete evacuation
   d. Abdominal distention
   e. Leakage
2. Diagnosis:
   a. Colonoscopy and/or fluoroscopy

3. Evaluate:
   a. Do not treat unless symptomatic
   b. Exclude malignancy
   c. Define length and configuration of stricture
   d. Evaluate primary anastomosis prior to closure of diverting stoma
4. Manage:
   a. Dilate
   b. Repeat up to 3–4 times if unsuccessful
   c. Stent, laser, EEA, urethroscope are all options prior to reoperative surgery
   d. Reoperative surgery
5. Keys to a successful reoperative surgery
   a. Select patients with few to no comorbidities
   b. Create a tension-free anastomosis
   c. Anastomosis must be well vascularized

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Intraoperative Ureteral Injury

34

W. Shannon Orr, Louis L. Pisters
and Miguel A. Rodriguez-Bigas

Introduction

In locally advanced colorectal cancer, tumor extension into adjacent structures has been reported to occur in 5–10% [1]. The primary neoplasm most commonly arises from either the sigmoid colon or the rectum. Extended resections are often required to achieve resection margins clear of tumor [2]. The surgical approach to these advanced tumors is often determined by the extent of the urinary tract involvement [1, 2].

Iatrogenic injury to the urinary tract during pelvic and retroperitoneum operations occurs most commonly to the ureters followed by injuries to the bladder and urethra. The incidence of ureteric injury during colorectal surgery has ranged from 0.2 to 4.5% [3–6]. In colorectal surgery, abdominoperineal resection and low anterior resections are most commonly associated with iatrogenic ureteric injury [4]. The majority of these injuries, 70–85%, are unrecognized at the initial operation [7, 8].

Ureteral injuries are classified based on the mechanism of injury, namely laceration, ligation, devascularization, and thermal energy [4, 5, 9]. Devascularization and thermal injuries may not be apparent at the time of initial operation. Devascularization injuries may present as ureteral stricture months after the initial operation. These injuries occur more common after radiation therapy or previous vascular surgery. Thermal injuries typically present early in the postoperative period as a fistula. Knowledge of the anatomy and early identification of the ureter are critical steps in avoiding these injuries. The consequences of ureteral injury can be serious and early recognition is essential to minimize morbidity.

Role of Preoperative Stenting

Prophylactic ureter stenting can help identify the ureters and aid in the identification of ureteral injuries, but does not prevent the injuries. Some surgeons advocate for the routine use of ureteral stents, while many surgeons use a selective approach for patients at increased risk of ureteral injury [4, 5]. Surgeon's selective use of ureteral stents reflects the factors that are thought to increase the risk of iatrogenic injury [4, 5, 7–9] (Table 34.1).

In a study of 120 ureteral catheterizations in patients undergoing colorectal procedures for either primary or recurrent cancer, Kyzer et al. reported prophylactic ureteral catheterizations in 65% of the patients [8]. Based on their experience, these authors concluded that prophylactic ureteral stents were beneficial in identifying the ureter in patients with large rectal or rectosigmoid cancers and in patients where the ureter may be

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Table 34.1 Factors associated with iatrogenic ureteral injury

Bulky tumors
Recurrent disease
Previous radiation therapy
Previous pelvic surgery
Previous urologic surgery
Reoperative surgery
Obesity

involved by the tumor on preoperative imaging. Bothwell et al. reviewed 561 consecutive patients who underwent sigmoidectomy or rectosigmoidectomy [9]. Ninety-two patients underwent prophylactic ureteral stent placement, which was bilateral in 80 patients. There were two ureteral injuries each, in patients who underwent stent placement and in those who did not. In the former group, there was a surgical injury and an injury related to stent insertion. In the latter group, there were two surgical injuries. The authors concluded that the complications related to ureteral catheter insertion are not insignificant, but prophylactic ureteral stents may assist in recognizing transmural injuries.

Incidence of Ureteric Injury and Early Identification of Injury

Delayed recognition of ureter injuries is associated with significant morbidity [3, 6]. The timing of the diagnosis of ureteral injuries correlates with morbidity and long-term results. Following 111 abdominoperineal resections, Andersson and Bergdahi reported five ureter injuries [3]. In two patients, the injuries were recognized and repaired intraoperatively with good long-term results. In the other three patients, the injuries were recognized postoperatively. One patient underwent delayed repair and died from peritonitis. The other two patients suffered acute renal failure, with one patient subsequently undergoing nephrectomy and the other patient having a nonfunctioning kidney based on intravenous urogram. In a 20-year experience of ureteral injuries in surgical patients, Selzman and Spirnak reported that injuries detected postoperatively were more complicated and required more complex repairs compared to injuries detected intraoperatively [6]. In their study, an average of 1.6 procedures were required to repair ureteral injuries detected postoperatively compared to 1.2 procedures for injuries detected intraoperatively, ($p < 0.0006$). Five nephrectomies had to be performed, four of which were for injuries discovered postoperatively. Immediate repair of a ureteral injury leads to less morbidity than delayed repair.

Placement of Ureteral Stents

Ureteral stents are placed by the urologist after induction of anesthesia and before the abdominal procedure begins. There are multiple designs of ureteral stent, which are aimed at improving patient comfort, reducing urinary tract infection, and stent handling. Prophylactic ureteral stents are primarily composed of silicone allowing the stent to be flexible, elastic, and inert, which allows them to be very well tolerated by patients. The length of the stent depends upon the patient's height. In an average adult, the typical stent is 24–26-cm long. Stent diameters range from 4 to 7 French (Fr). In cases in which the ureteral stents are used for intraoperative identification of the ureter with planned removal at the end of the case, 5 Fr open-ended ureteral stents are commonly used and can be internalized into the lumen of the urethral catheter draining the bladder. If prolonged ureteral drainage for a period of weeks to months is needed, then double-J type ureteral stents either 6 or 7 Fr are placed. Since the double-J stents are entirely internal (and therefore invisible to the patients), it is important that patients are not lost to follow-up and that the stents are removed or exchanged at the desired time interval. Patients who are lost to follow-up can develop a stone-encrusted ureteral stent, which may damage renal function and be difficult to retrieve.

Several studies have reported on the time associated with the placement of prophylactic ureteral stents. Operative times are increased by a mean of 10–23 additional minutes with a range of 5–55 min [8, 10–13]. Pokala et al. randomized

24 patients undergoing reoperative complicated colorectal surgery into sequential (before starting the procedure) or simultaneous (intraoperative) ureteral stent placement [12]. The authors demonstrated that simultaneous insertion of ureteral stents reduced the duration time to incision and to peritoneal entry ($p=0.0001$) without an increase in morbidity. They concluded that simultaneous approach may allow for a more selective use of ureteral stents based on intraoperative findings.

Due to the lack of tactile feedback in laparoscopy, lighted stents were developed to aid in ureteral identification through light visualization. With the increasing number of colorectal procedures being done laparoscopically or robotically, the use of prophylactic lighted ureteral stent placement has increased. Senagore and Lutchtefeld reported a series of 49 consecutive laparoscopic-assisted colectomies comparing patients who had lighted stents [14] and those without stents [13, 15]. Ureters were identified in the retroperitoneum without any dissection by light visualization in 20 of 24 (83%) patients who underwent lighted stent placement. The remaining patients in this group and all the patients in the group without stents had ureters visualized by standard retroperitoneal dissection. In the patients with lighted stents in which the ureter was not identified, two catheters had migrated into the bladder and two patients had thick retroperitoneal fibrosis impairing light transmission. The authors concluded that lighted catheters made identification of the ureter easier in potentially difficult cases. In a similar series, Chahin et al. retrospectively reviewed 66 patients that had lighted prophylactic ureteral stents placed for laparoscopic colectomy [10]. In this series, one (1.5%) patient suffered a ureteric injury, which was identified on postoperative day 2 and was managed conservatively with replacement of the ureteral stent. In this study, the most common complication was self-limiting hematuria, which occurred in 98.4% of patients. The average duration of hematuria was 2.5 days for unilateral stenting and 3.3 days for bilateral stenting.

The overall cost associated with the placement of prophylactic ureteral stents ranges from $ 1500 to $ 3500 [9, 10]. The cost of placement of ureteral stents may be offset by the potential benefit for avoiding a ureteral injury and its morbidity in high-risk patients.

Detection of Ureter Injury

Prevention of iatrogenic ureteral injury is based on knowing the anatomy of the ureter. The patient's preoperative CT scan should be carefully assessed to determine the anatomic relationship of the colon or rectal cancer with the adjacent urinary tract, especially the course of the ureter if the tumor is bulky. Approximately 1–2% of the population will have ureteral duplication, which can be partial or complete, and can be detected on the CT scan. Although there are several anatomic patterns of ureteral duplication, it is common for the ureters to be totally separate in the upper and mid-ureteral levels and then run side by side in a common sheath at the level of the lower ureter. Horseshoe or pelvic kidneys will also have an altered orientation of the renal pelvis and ureter [16].

During mobilization of the descending colon, the ureter will adhere to the peritoneum rather than maintaining its normal position along the psoas muscle. The most likely points where ureteral injuries occur are at the time of ligation of the inferior mesenteric vessels, at the level of the sacral promontory where they cross over the iliac artery, and during transection of the lateral rectal attachments [4, 5, 17]. Before transection of the colonic mesentery, visualization of the ureter is critical. Visualization of the ureter can be aided by observing its peristaltic activity, which can be demonstrated best by squeezing the ureter briefly with Debakey-type forceps. A key anatomic landmark for ureteral identification in the pelvis is the obliterated umbilical artery, which is the first large anterior branch of the internal iliac artery. The ureter is always medial to the obliterated umbilical artery.

There should be a high index of suspicion and a low threshold for imaging or direct ureteric exploration when there is concern for an intraoperative ureteric injury. The first step in the evaluation of a suspected injury is visual inspection of

the ureter to assess its integrity and the nature and severity of the injury. In some cases, extravasation of urine can be seen from a defect in the ureter after a laceration or transection has occurred. If there is no obvious defect in the ureter, the diagnosis of a suspected ureter injury can be confirmed with the use of intravenous dye injection (methylene blue or indigo carmine). Five milliliters of methylene blue or indigo carmine is given intravenously over 5 min. After 5–10 min, the dye will begin to be excreted by the kidneys. Extravasation of blue dye is a reliable sign of ureteral injury and will allow for identification of the site of injury. Cystoscopy can be used to assess urine efflux from the ureteral orifices. Ureteral catheterization can be employed at the time of cystoscopy, but may not detect partial transection or thermal injury.

In the postoperative period, one must have a high index of suspicion for an injury to the urinary tract since early signs and symptoms may be subtle. Urinary tract injuries that are not identified intraoperatively are most likely present within the first 2 weeks after surgery [4]. During this time after surgery, signs and symptoms such as leakage of urine from abdominal incision or rectum, high drain output, unilateral or bilateral flank pain, hematuria, oliguria, anuria, ileus, and fever should raise suspicion for ureter injury [3, 18, 19]. Physical examination and laboratory studies are valuable in identifying other complications associated with ureteral injury and help determining which diagnostic studies are needed. Physical examination should assess hemodynamic stability, urine output, signs of peritonitis, ascites, and the integrity of incisions. Laboratory evaluation should consist of serum electrolytes, blood urea nitrogen (BUN), and creatinine (Cr) [5, 20]. Bilateral ureteral obstruction will result in acute renal failure, while unilateral obstruction will result in a transient increase in Cr while the other kidney compensates. If physical examination demonstrates evidence of ascites or if there is high drain output, then biochemical analysis of the peritoneal fluid by paracentesis or sending fluid from intraperitoneal drains can be performed. The BUN and Cr of the peritoneal fluid are compared to the patient's serum levels. If the values of serum and ascites are similar, there is no urinary ascites. If the BUN and Cr are normal in the serum but elevated in the ascites fluid, this confirms a urinary tract injury that needs further evaluation. The creatinine level of the peritoneal fluid will help determine the magnitude of the urine leak. A high-volume urine leak is often associated with a drain creatinine above 30 mg/dl. A small-volume urine leak will have a drain creatinine level that is lower and closer to the serum level.

Once a ureteral injury is suspected, an ultrasound can be performed to assess for hydronephrosis or to exclude retroperitoneal fluid collections. Following the ultrasound, a computed tomography with IV contrast or cystoscopy with retrograde intravenous pyelography should be performed. Retrograde pyelogram can give the precise location of the injury, and a stent could be deployed in cases of ureteral injury without obstruction.

Management of Ureter Injury

Intraoperative recognition of ureteral injuries occurs only in 15–30% of patients undergoing open operation [7, 8]. If the ureteral injury is recognized intraoperatively, it should be repaired during the same operation. Prior to initiating the repair, if it has not been previously done, one should assess the baseline renal function and preoperative imaging of the urinary tract to ensure there are two functioning kidneys. The patient's prior cancer treatment including the previous radiation exposure, extent of radiation field, prior chemotherapy, and history of targeted therapy should be reviewed. A thorough surgical history should include any history of ureteral, bladder, prostate, or kidney surgery, which might prevent ureter mobilization or an elongation procedure. The surgeon should review the patient's medical history with special attention to a history of chronic kidney failure, renal stones, or hypertension.

Once the extent and location of the injury is delineated, several general principles apply for repair. At the site of injury, the ureter should be

Table 34.2 Suggested management options for ureteral injuries at different locations

Upper ureter injury
Direct ureteroureterostomy
Transureteroureterostomy
Ileal ureter
Autotransplantation
Middle ureter injury
Direct ureteroureterostomy
Transureteroureterostomy
Boari flap
Lower ureter injury
Reimplantation
Psoas hitch

debrided to healthy tissue with a good blood supply to ensure healing. There should be minimal grasping of the ureter with forceps. Stay sutures can be placed on the ureter to help provide exposure and move the ureter. A watertight tension-free spatulated anastomosis should be performed with fine absorbable sutures, which will decrease the risk of stricture and stone formation. The specific repair is based on the location and the extent of the injury [21, 22] (Table 34.2). Renal and bladder mobilization is extremely useful in reducing the gap of ureteral loss. The perinephric tissues (Gerota's fascia) and the bladder itself can be on moderate tension with fixation, but any ureteral anastomosis must be tension free or it will stricture.

Minor contusions and thermal injuries of the ureter can be managed with stent placement and drainage. The ureter should be inspected to ensure adequate blood supply as minor injuries may stricture or break down. If the ureter is inadvertently ligated, the suture should be removed and the ureter examined for viability. If the ureter is viable, then the injury can be managed with stent placement and drainage. If there is a question of ureter viability, the injured portion should be debrided and an ureteroureterostomy should be performed.

Partial transection of the ureter can be repaired by primary repair if the ureter is viable. In order not to stricture the ureter, the injury is closed by converting a longitudinal transection into a transverse transection (Heineke–Mikulicz). The ureter is stented and the repair is drained.

Proximal Third Injuries

The proximal one-third of the ureter extends from the ureteropelvic junction to the upper border of the sacroiliac joints. Injuries in the proximal third of the ureters account for 2% of all ureteral injuries [6]. The length and location of the damaged segment of ureter determines how the injury will be repaired. The optimal repair is a direct ureteroureterostomy for an injury in this location, provided that the length of ureteral loss is less than 5 cm (ideally only 2–3 cm). If sufficient length cannot be obtained by mobilization of the ureter, additional ureteral length can be obtained by mobilization of the kidney. Full mobilization of the left kidney can achieve an additional 3–4 cm with fixation to the psoas tendon or retroperitoneum (nephropexy). Full mobilization of the right kidney will only achieve an additional length of 1–2 cm due to the shorter right renal vein. An interrupted spatulated anastomosis with 5-0 absorbable suture is performed over a stent when sufficient length of ureter has been obtained. If the anastomosis is on tension, it will stricture. If after mobilization of the kidney sufficient ureteral length cannot be obtained to perform a direct ureteroureterostomy, then one might consider a transureteroureterostomy (TUU) with full mobilization of both the donor (index) kidney and the donor ureter and mobilization of the recipient kidney and ureter. It is important in a complex TUU to bring the lower poles of both kidneys together (but suturing Gerota's fascia from the lower pole of each kidney together to create an iatrogenic "horseshoe kidney"). One must be sure not to devascularize the recipient ureter during mobilization. An omental pedicle flap can be placed around the repair to separate it from the aorta as the TUU anastomosis in these cases is close to the aorta. If a complex TUU is not possible, then one must consider other options such as intestinal interposition graft, autotransplantation, or a nephrectomy [22, 23]. The ileum is typically used for an intestinal interposition graft. The ureteral segments are mobilized and the ureteral–ileal anastomosis is performed in an end-to-side fashion using absorbable suture, much in the same way that an ileal conduit is constructed

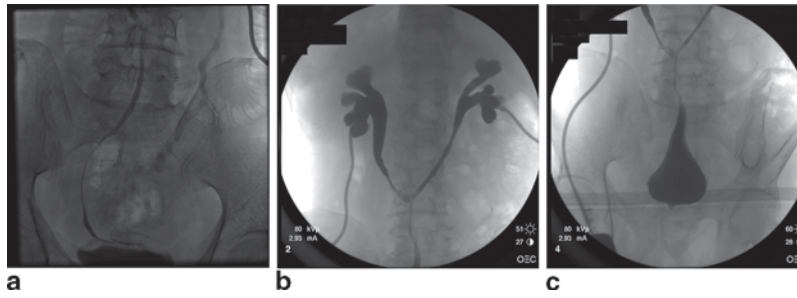

Fig. 34.1 Sixty-eight-year-old man with large volume anastomotic recurrence of sigmoid cancer treated with neoadjuvant chemoradiation followed by en bloc resection of sigmoid colon, upper rectum, and mid-left ureter, reconstructed with a left to right TUU and rectal anastomosis with temporary ileostomy. In the postoperative period, he develops a distal right ureteral stricture (**a**). The stricture is repaired by a reimplantation with bladder hitch to the sacral promontory at the time of ileostomy takedown (**b** and **c**). Note how the recipient right ureter is mobilized medially

after cystectomy. The ileal segment should be minimized as much as possible to reduce the risk of electrolyte reabsorption. The psoas hitch or nephropexy can be performed as an adjunct to ileal ureter. Contraindications to ileal interposition repair include Crohn's disease, radiation enteritis, and serum creatinine greater than 2.0 mg/dl [6, 22].

Autotransplantation and ultimately nephrectomy are alternatives to be considered after multiple attempts at repair of the ureteral injury have failed. Autotransplantation, which involves moving the injured ureter and ipsilateral kidney to an ectopic site, in the pelvis, is considered when the contralateral kidney is absent or poorly functioning. When performing the nephrectomy portion of the autotransplantation, maximal length of renal artery and vein should be harvested for anastomoses to the iliac artery and vein. The ureter is then anastomosed directly to the bladder. A nephrectomy is the last option after multiple attempts at repair have failed. It can be considered as an option when there is extensive upper ureteral injury and a normal contralateral kidney is present.

Middle Third Ureteral Injuries

Approximately 7% of all ureteral injuries occur in the middle third of the ureter. For short-segment injuries, the preferred method of repair is ureteroureterostomy [6]. If the injured segment is too extensive to perform, a tension-free anastomosis, a TUU or a ureteroneocystostomy with either a psoas hitch or a Boari flap can be performed. A TUU should be considered when the patient has severe bladder scarring or congenital small bladder, or if they have undergone a prostatectomy or partial cystectomy, which would prevent a bladder elongation procedure. A TUU involves mobilizing the donor ureter and tunneling it cephalad to the inferior mesenteric artery to the recipient ureter. The recipient ureter is mobilized medially toward the donor ureter being careful to maintain blood flow and avoid devascularization of the recipient ureter. Stay sutures are placed on both recipient ureter and donor ureter, and a 1.5-cm incision is made on the anteromedial side of the recipient ureter. The anastomosis is performed tension free, and the medial sutures (donor side) should all be placed before tying them. Having a stent in the recipient ureter greatly facilitates making the incision in the recipient ureter (Fig. 34.1). TUU is relatively contraindicated in patients with a diseased contralateral kidney or ureter, nephrolithiasis, history of radiation, chronic infections, or retroperitoneal fibrosis. An absolute contraindication to a TUU is a urothelial cancer. TUU is simple, fast, and highly effective and has no impact on bladder function [24]. One theoretical drawback

to TUU is that in many cases, the recipient kidney and ureter are normal and are placed at slight risk. However, Pisters et al. have shown that the risk of recipient kidney loss in TUU is extremely small and that TUU should be considered due to its simplicity [24]. Postoperatively, a single stent up the donor or recipient ureter will provide adequate drainage. It is not necessary to stent both sides of the TUU.

A Boari flap is an effective method for complex injuries to the mid-ureter. Full mobilization of the bladder allows for a tension-free anastomosis [5, 6, 22]. The bladder should be distended with saline, and a spiral rectangular flap is created on the anterior surface of the bladder and affixed to the psoas tendon. It is critical to preserve the blood supply to the flap, which is from the superior vesical artery. The base of the flap must be at least 4-cm wide to maintain viability. The ureter is tunneled through the proximal portion of the flap, and a neo-orifice is created in the flap. The ureter is widely spatulated, and a mucosa-to-mucosa anastomosis is created over a ureteral stent. The bladder flap is tubularized and closed in a one- or two-layer fashion. A Boari flap is contraindicated in patients with small bladder capacity. Functional bladder capacity can be significantly reduced by a Boari flap, which can result in bothersome and occasionally disabling postoperative voiding dysfunction. Another drawback to the Boari flap is that it can be difficult to assess whether the bladder flap will reach the ureter if the injury is high. It may be simpler to consider aggressive bladder mobilization with psoas hitch, and if the bladder does not reach the ureter with a psoas hitch, then perform a TUU.

Lower Third Ureteral Injuries

Approximately 90 % of ureteral injuries occur at the distal one-third of the ureter [6]. Injuries in this area can be repaired by ureteral reimplantation with or without psoas hitch [5, 6, 22]. Distal injuries are often difficult to repair primarily and a ureteral reimplantation (ureteroneocystostomy) is preferred. If the ureter is to be reimplanted, it is reattached in a medial and superior position to its original insertion. A 2–3-cm submucosal tunnel is fashioned. This potentially creates a flap valve preventing reflux. The ureter is then anastomosed to the bladder mucosa. When a tension-free ureteral reimplantation cannot be performed, a psoas hitch is used to eliminate tension. The bladder is mobilized on both the ipsilateral and contralateral sides to the injury. The contralateral superior vesical pedicle can be ligated to provide and ensure a tension-free anastomosis. A transverse cystotomy is made on the anterior surface of the bladder to help facilitate placement. The bladder is then secured to the psoas tendon using nonabsorbable sutures (Fig. 34.2). Care must be taken to avoid entrapment of the genitofemoral nerve. The ureter is then tunneled through the wall of the detrusor and a spatulated mucosa-to-mucosa anastomosis is performed. The posterior sutures are placed first and tied and then a ureteral stent is placed, followed by placement of all the anterior sutures prior to tying them. The anterior cystotomy is closed in a vertical fashion in two layers. In some cases, the bladder may be secured to other fixed structures, such as the sacrum, to facilitate a tension-free anastomosis.

A primary ureteroureterostomy should not be considered for repair of a lower ureteral injury, as the success rate of reimplantation of the ureter into the bladder is superior to the success rate of ureteroureterostomy. This may be due to the risk of devascularization of the lower ureter resulting in a higher rate of structure with ureteroureterostomy. Also, the lower ureter is very difficult to mobilize for tension-free anastomosis without devascularization (blood supply comes off of the internal iliac artery).

Delayed Ureteral Transection or Ligation

The timing of the repair of a delayed-recognized ureter transection and a ureteral ligation is controversial [6, 14, 17, 18, 21, 22, 25]. Some authors advocate that these injuries should be repaired as soon as they are recognized, while other authors recommend an immediate attempt at placement of a double-J ureteral stent with delayed repair.

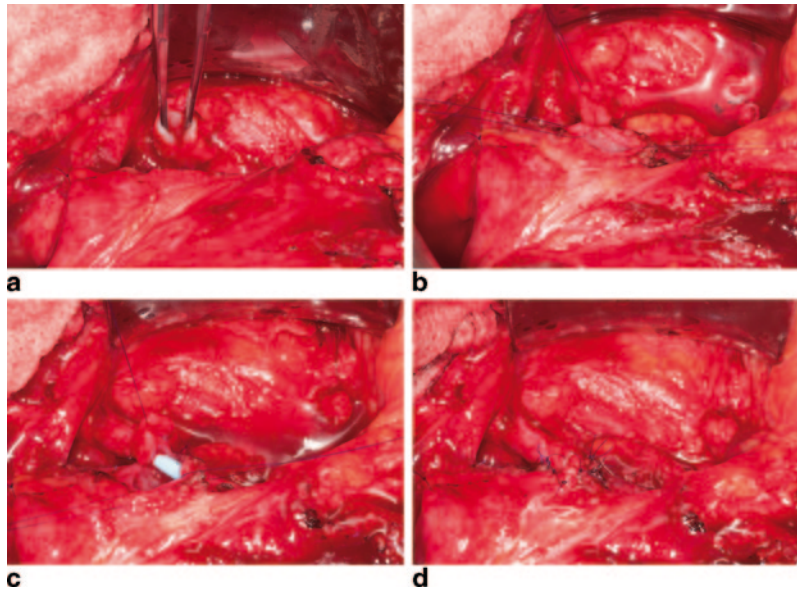

Fig. 34.2 Ureteral reimplantation to the bladder with psoas hitch. In **a**, the ureter is spatulated and the bladder hitch stitch is seen on the *left*. **b** demonstrates the stay sutures are placed on the ureter and bladder. The posterior aspect of the anastomosis has been completed with interrupted 5-0 absorbable suture. **c** demonstrates the ureteral stent has been placed and secured to the urethral Foley catheter. In **d**, the anterior aspect of the anastomosis is completed with interrupted 5-0 absorbable suture

Authors that recommend immediate repair have shown that these injuries can be repaired with complication rates as low as those where the injuries were recognized immediately. However, other studies have shown an increase in the complication rate of the ureteral repair from 10 to 40 % due to the delay in diagnosis.

Authors that advocate an immediate attempt at placement of a double-J stent have reported a success rate of 73 % without the need for open surgical repair. However, stents are only successfully deployed in 20–50 % of patients. Failure of stent placement is typically due to complete obstruction or too long of a gap between the proximal and distal end of the ureter. Once a stent has been placed, an image-guided drain should be placed near the site of injury. The time required for stenting also varies between authors. Selzman and Spirnak recommended stent placement for at least 6 weeks [6]. Cormio et al. were successful at treating late ureteral complications with a ureteral stent for 3 months [15].

If a retrograde stent cannot be placed, a nephrostomy tube is placed and an attempt of stent placement is done via an antegrade approach. If a stent is not able to be placed through the anterograde approach, the nephrostomy tube is left and another attempt is made in 7 days. If the ureter cannot be stented, then an attempt via an open repair is performed in 6 weeks. An open repair is required after stent placement if patients have persistent leak or stricture.

Management Post Repair

A Foley catheter, internal double-J stent, and closed suction drains are placed at the time of the repair operation. The closed-suction drains are monitored for an anastomotic urine leak. Biochemical analysis can be sent from the drain output to determine whether there is a urine leak. A CT cystogram is obtained on postoperative days 5–7. If no leak is observed on the cystogram, the Foley catheter and closed-suction drains are removed. The cystogram is repeated in 4–6 weeks post repair to confirm there is no anastomotic stricture. The internal stents are removed if no

anastomotic leak is demonstrated. A urinary leak occurs in approximately 10–24% of ureteroureterostomy repairs. Most early postoperative leaks can be managed with continued closed-suction drainage.

Outcomes

Recognition and treatment of ureteric injuries at the time of surgery are associated with less morbidity compared to those in whom the diagnosis was delayed. In patients with prompt diagnosis of ureteric injury, Al-Awadi et al. demonstrated a 94% successful resolution of ureteric injuries [18]. The success rate for a ureteroureterostomy is 90%. Between 10 and 24% of early repairs develop a urine leak, which is managed with the drain placed intraoperatively [18]. A ureteral stricture develops in approximately 10% of ureteroureterostomy repairs. Ureteral strictures are late complications and can be managed endoscopically with balloon dilation. If endoscopic management is unsuccessful, then open repair is required. Ileal replacement of the ureter has a reported success rate of 83–100% [26]. Armatys et al. reported a 3% anastomotic stricture and 6% fistula rate after ileal replacement [26]. Ileal replacement of the ureter can result in hyperchloremic metabolic acidosis, which can be treated by sodium bicarbonate. Pisters et al. demonstrated that the overall success rate of a TUU, measured in terms of patent anastomosis and bilateral functioning kidneys, is greater than 95% [24].

Psoas hitch and Boari flap have also been shown to be highly successful. Long-term success rates have been reported from 95 to 100% [5, 6, 18, 22]. Ureteral reflux typically does not lead to long-term complications. Obstruction at the reimplantation site has been reported in approximately 5−10%, which is typically managed with endoscopic dilation [5, 6, 18, 22].

Key Points to Avoiding Injury

1. Knowledge of the ureter anatomy is essential to avoid injury.
2. Preoperative imaging should be reviewed to determine the anatomy of the ureter and the possibility of the ureter being involved by tumor.
3. Prophylatic ureteral stents should be placed in high-risk patients.
4. The ureter should be identified with meticulous dissection early in the procedure.
5. Visualization of the ureter must be performed before transection of colonic mesentery.

Key Points to Diagnosis and Manage the Complication

1. Lower ureteral injuries are the most common injuries and should be managed with ureteral reimplantation to the bladder. Avoid primary ureteroureterostomy for lower ureteral injures.
2. If an injury is suspected intraoperatively, indigo carmine can be given intravenously and the ureter observed for extravasation of dye.
3. If an injury is detected intraoperatively, the ureter should be debrided to healthy tissue and a spatulated tension-free anastomosis should be performed if possible. The type of repair depends on the site and type of injury.
4. If an injury is suspected postoperatively, the BUN and Cr of an intra-abdominal fluid collection or drain fluid can be compared to the patient's serum level.
5. A retrograde pyelogram can give the precise location of injury, and a stent could be deployed over the injury.

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Prostatic Urethral Injury

35

Negar M. Salehomoum and Steven D. Wexner

Introduction

Colorectal surgery frequently involves pelvic dissection for both benign and malignant conditions. While the ureter is more commonly injured during pelvic surgery, the urethra is not immune [1]. The most common urethral injury in colorectal surgery is secondary to traumatic Foley catheter placement. We herein discuss prostatic urethral injuries, specifically offering tips on prevention, methods of detection, and management of injuries.

Anatomy

An important factor to help reduce the risk of prostatic urethral injuries is a thorough understanding of its anatomy. The urethra can be anatomically divided into an anterior and posterior portion, separated by the genitourinary perineal membrane.

The anterior urethra, also known as the spongy or cavernous urethra, consists of the bulbous portion and pendulous, or penile, portion. The bulbous portion starts at the genitourinary perineal membrane and extends to the penoscrotal junction where the pendulous portion begins and extends to the external meatus. Figure 35.1 illustrates this anatomy.

The posterior urethra is composed of the prostatic urethra and the membranous, or intermediate, portion of the urethra. The prostatic urethra is the first portion of the urethra leading to the intermediate portion which is enclosed by the sphincter urethrae muscle. While the membranous portion of the posterior urethra is most commonly injured secondary to pelvic fractures, the prostatic segment of the posterior urethra is susceptible to iatrogenic injury [2]. The majority of prostatic urethral injuries are secondary to prostatic resections such as transurethral prostatic resections (TURP) or radical prostatectomies. Figure 35.2 demonstrates the close relation between the prostatic urethra and rectum, which makes it susceptible to iatrogenic injury during pelvic surgery. The discussion within this chapter is limited to injuries of the prostatic urethra which can occur during colorectal surgeries.

Incidence

Colorectal operations at risk for injuring the urethra include proctectomies and abdominoperineal resections. Such injuries may occur during dissection for either benign or malignant conditions. This fact is not surprising considering that the anterior portion of the lower rectum is intimately associated with the posterior border of the prostate.

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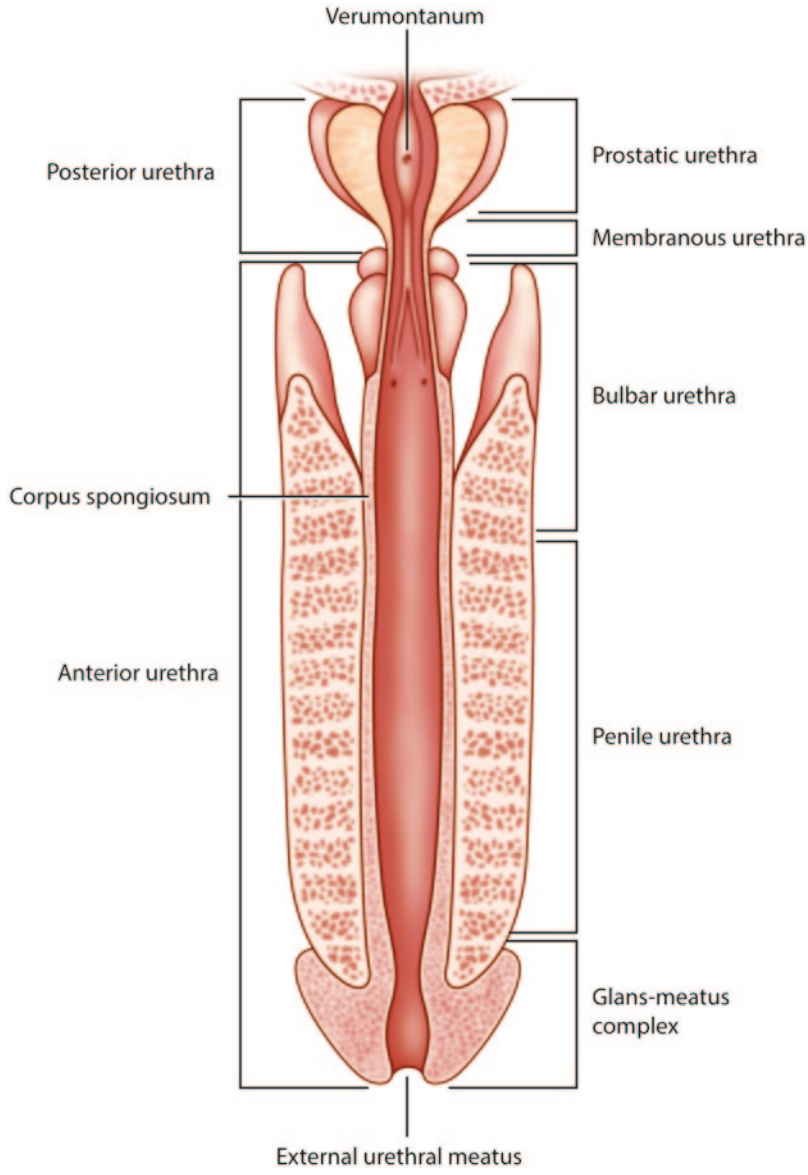

Fig. 35.1 The *anterior* and *posterior* portions of the urethra are depicted

Types of Prostatic Urethral Injury

During pelvic surgery and dissection of the rectum, the prostatic urethra is prone to two different types of injury. Transection of the urethra during sharp dissection may lead to immediate urine leakage although transection with an energy device may temporarily occlude the lumen resulting in a delayed leak. Pelvic dissection with electrocautery may lead to ischemia of the urethra followed either by a stricture or a delayed leak.

Prevention

The key to preventing a prostatic urethral injury, or any urinary injury for that matter, is to be vigilant about the risk. This risk is increased in patients

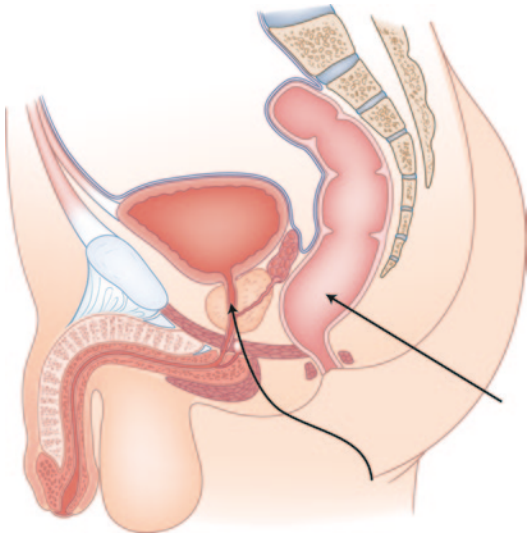

Fig. 35.2 Demonstration of the anatomy of the urethra in relation to the rectum. The *straight arrow* points to the rectum. The *wavy arrow* points to the prostatic urethra

with bulky anterior rectal tumors, a history of radiation, and/or history of a prostatectomy, all of which may obliterate the rectoprostatic space. The inflammation and scar tissue in the former setting make it difficult to visualize and dissect in the plane immediately anterior to the rectoprostatic, or Denonvillier's fascia. The large inflamed rectum in patients with proctitis and following an anastomotic leak also increases the risk of injury.

One technique to facilitate awareness of the location of the urethra is the placement of a large diameter Foley catheter. Alternatively, urethral sounds may be more easily palpated intraoperatively secondary to their rigidity. The wider diameter catheter can help the surgeon palpate the prostatic urethra especially when nearing it. However, it is important to not have an overwhelming sense of security with this technique as it may still be difficult to identify the location of the urethra in cases of previous radiation and/or prostatectomy. When reoperating on patients following a pelvic anastomotic leak or for a recurrent rectal carcinoma, special vigilance is needed.

Detection

Should the surgeon encounter the unfortunate situation of having injured the prostatic urethra, the ideal time for detecting the injury is during surgery. Early recognition may allow for synchronous repair and may potentially allow for a better repair without having to subsequently reenter the pelvis.

Some surgeons advocate the routine use of indigo carmine or methylene blue during colorectal surgeries in which the urinary system is at risk. Therefore, if the surgeon is concerned about the prostatic urethra, such as in cases where bulky tumors or radiation have eliminated the normal planes, the anesthesiologist can administer 10 mL of indigo carmine or methylene blue intravenously with or without furosemide to expedite diuresis. Another intraoperative method for detecting injuries is to inject 10–20 ml of methylene blue via an angiocatheter placed in the urethra adjacent to the Foley catheter [1]. Again, any visualized extravasation of methylene blue would indicate injury to the urinary tract.

The surgeon may also encounter delayed recognition of urethral injury. Postoperative signs of urinary injury may include a rise in blood urea nitrogen (BUN) and creatinine levels secondary to urinary absorption from the peritoneal cavity and an increase in drain output, particularly if serous in quality. If an injury is suspected, the drain output can be sent to the laboratory for a creatinine level. A drain creatinine level in excess of the serum creatinine level indicates a urinary leak. A renal ultrasound may indicate dilatation of the more proximal urinary system or a distended bladder if the urethra is strictured. A computed tomography scan of the abdomen and pelvis with intravenous contrast may also be used to detect urinary injuries; however, the contrast must have reached the site of injury for extravasation to occur and will not indicate the specific site of injury.

A retrograde urethrogram can also be used to visualize urethral injuries, either intraoperatively or postoperatively. Rosenstein and Alsikafi have

provided a detailed description the technical aspects of performing a retrograde urethrogram [3]. The patient is first positioned supine on the table, and then the left pelvis is elevated 30–45° from the table. The right thigh is bent at a right angle to the hip while the left leg is kept straight. A 14 French Foley catheter is then inserted into the tip of the penis and the Foley balloon distended with 2 ml of water; 30 ml of water-soluble contrast is then injected and a radiograph exposure taken at least near the end of the injection if not throughout the injection. This technique will allow appropriate visualization of the entire urethra and any leaks or strictures.

Management

A prostatic urethral injury detected at any time should lead to a urology consultation if available and primary repair at the initial operation. It is important to keep in mind that most data regarding the management and outcome of prostatic urethral injuries are based on traumatic urethral disruptions.

Intraoperative detection of a prostatic urethral injury will potentially allow for a primary repair if able to be performed in a tension-free manner [1]. The two ends of the urethra should be spatulated in such a repair to try to obviate subsequent anastomotic stricture. In patients who have undergone pelvic radiation, it may be prudent to reinforce the repair with omentum, a local tissue flap, and/or a biologic mesh [1]. In cases of significant loss of urethra, urethral reconstruction has been described using a pedicled gracilis flap [4]. During intraoperative repair of the urethra, if there is difficulty in identifying the more proximal urethra after a complete transection, a urethral sound may be placed through either a suprapubic location or by creating an anterior cystotomy.

Prostatic urethral injuries that are detected postoperatively are more difficult to manage. Unless a patient is within the first few postoperative days, there will likely be significant adhesions in the pelvis making any immediate surgical approach more difficult. Experience with traumatic posterior urethral injuries indicates that primary urethral realignment results in lower rates of fibrotic defects compared to primary bladder drainage with plans for delayed urethroplasty; however, the erectile dysfunction and urinary incontinence rates were higher [5–7]. Other authors have reported lower rates of erectile dysfunction and urinary incontinence following surgical realignment [8–10]. Primary urethral realignment can be performed either surgically, transabdominal or transperineal, or endoscopically. A urethral stricture, either from cautery injury or following initial management of the injury with primary urethral realignment, may be amenable to bulboprostatic anastomotic urethroplasty via either an abdominoperineal or transperineal approach [11–13]. It is important to keep in mind that some degree of the complications described with the various techniques may be related to the traumatic mechanism of injury.

The key to managing any urinary injury is to allow adequate drainage of the urinary system. A bladder catheter should be kept in place across the urethral injury postoperatively to keep the bladder decompressed. Some authors also advocate placing a suprapubic catheter in addition to the bladder catheter to ensure appropriate drainage should one mechanism fail. If, however, the urethral injury is postoperatively detected, a suprapubic catheter should be placed for drainage.

Additionally, drains placed adjacent to any of the above-discussed repairs will enable detection of urinary extravasation and, more importantly, help ensure adequate drainage should a urine leak or a fistula develop.

Delayed Rectourethral Fistula

A delayed urethral injury may also present as a rectourethral fistula. These patients may present with pneumaturia, fecaluria, urine draining through the rectum, or recurrent urinary tract infections. Different modes of treatment exist in the treatment of delayed iatrogenic rectourethral fistulas including transperineal, transanal, transsphincteric, and transabdominal approaches [14].

Transperineal repairs usually involve closure of the rectum and/or closure of the urethral opening. These outcomes are improved by interposing muscle between the rectal and urethral repairs, especially if the pelvis was previously irradiated. The gracilis muscle and dartos muscle interposition flaps are well described in the treatment of rectourethral fistulas [15–18]. The preference of the authors is to perform gracilis interposition flaps for pelvic fistula disease specifically using the transperineal approach because it provides great access to the fistula, brings a large piece of viable muscle to help buttress the fistula repair, and minimally affects the donor extremity with mild numbness being the main side effect [16, 19–21]. The gracilis muscle is a large muscle dependent on one main neurovascular bundle at its origin, which makes it versatile. All patients should undergo fecal diversion either prior to or occasionally at the time of graciloplasty. The creation of an ileostomy or colostomy should facilitate healing by reducing fecal contamination. Maintenance of an indwelling Foley catheter and occasionally also a suprapubic catheter throughout the duration of treatment is mandatory. The objective is to prevent both urine and stool from entering the area of the repair.

The technical aspects of performing a graciloplasty have been well described [19]. The gracilis muscle is harvested from the patient in the Lloyd-Davies position. A 3–4-cm incision is first made in the distal medial thigh, staying posterior to the saphenous vein. Dissection is carried down onto the gracilis muscle after which its tendon is encircled with either a red rubber catheter or a penrose drain. A second small incision is then made on the proximal thigh about four fingerbreadths distal to the pubic tubercle where the gracilis muscle is again identified and encircled. The surgeon then bluntly dissects through the space superficial to the gracilis muscle to create a tunnel connecting both incisions. The gracilis tendon is then divided from behind the medial condyle after which a laparoscopic energy device is used to circumferentially mobilize the muscle up to its neurovascular bundle 10 cm from the pubic tubercle. Throughout this procedure, it is important for the anesthesia team to avoid any paralytics so that the location of the neurovascular pedicle can be confirmed by stimulating the nerve. A tunnel is then created from the upper thigh incision to the site of the planned perineal incision. The thigh incisions are closed over a drain. The patient is then routinely repositioned into the prone jackknife position to optimize exposure. A 5-cm circumanal perineal incision is then made through the perineal body and carried proximally at least 2 cm above the fistula in healthy tissue. The edges of the fistula tract are then resected. While the rectal defect is always closed with an advancement flap, the urethral defect is almost always left open depending on the fistula size and on the condition of the surrounding tissues; very small urethral defects surrounded by healthy pliable tissue may occasionally be primarily repaired. A series of bilateral 2.0 prolene sutures are placed from the apex to the distal aspect of the dissected space, after which the sutures are passed through the gracilis muscle, interposing it between the rectum and urethra (Figs. 35.3, 35.4 and 35.5). A closed suction drain is also left under the perineal incision. Later, the patient is placed in an adduction splint prior to reversal of general anesthesia.

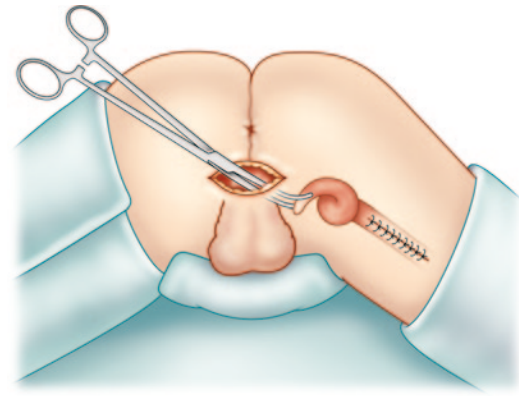

Fig. 35.3 The patient is in the prone jackknife position. The gracilis muscle is grasped and about to be pulled into the perineal incision

Postoperatively, the patient is on bed rest with an adductor splint for 3 days, intravenous antibiotics for 3 days after which oral antibiotics are started, and a bladder catheter for 6–8 weeks. Successful fistula closure is verified 6 weeks following surgery with a water-soluble contrast enema, a retrograde urethrogram, cystoscopy,

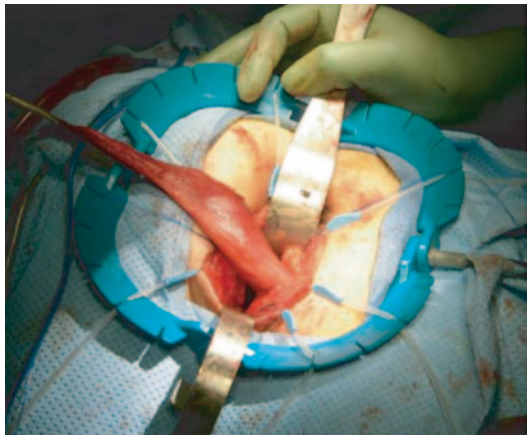

Fig. 35.4 The gracilis muscle after being pulled through the perineal incision. (With permission from Zmora et al. [15] © by Lippincott Williams & Wilkins)

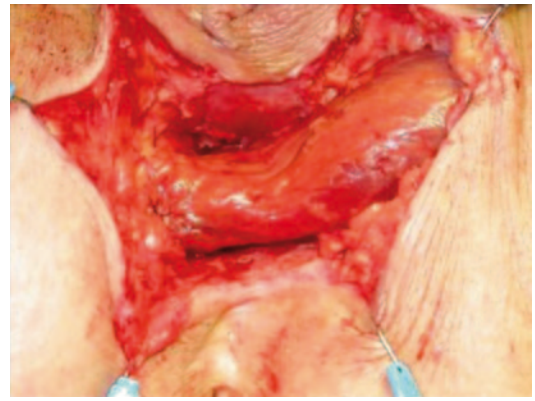

Fig. 35.5 The gracilis muscle being interposed between the rectum and urethra. (With permission from:Zmora et al. [15] © by Lippincott Williams & Wilkins)

and examination under anesthesia. Stoma closure is generally performed 12 weeks after the surgery, at which time the Foley catheter is also removed.

We reviewed our results with gracilis interposition flaps for rectourethral, rectovaginal, and pouch-vaginal fistulas [16]. Our results included 53 patients from 1995 to 2007 including 36 males with a rectourethral fistula and 17 females, 15 of whom had a rectovaginal fistula. Thirty of the 36 males had undergone treatment for prostate carcinoma. Five males required a second gracilis interposition flap for the following reasons: failure after an initial gracilis flap, intraoperative muscle necrosis, perineal sepsis requiring debridement, and persistent fistula. Only one of those males had a persistent fistula after two gracilis flaps; however, he eventually healed his fistula after a transanal rectal advancement flap. There were 23 complications in 17 patients: perineal wound infection, urethral stricture, prolonged perineal wound drainage, fever, urinary retention, urinary tract infection, perineal bleeding, penile cellulitis, deep venous thrombosis, thigh hematoma, thigh pain/numbness, and fecal incontinence following stoma reversal. Thus, our success rates were 78% after initial graciloplasty and 97% after secondary procedures. Table 35.1 includes a review of the success rates with graciloplasty in treating rectourethral fistulas.

Transanal techniques involve a full-thickness rectal advancement flap beyond the area of the fistula with simultaneous ligation of the fistula tract. Visualization for more proximal rectourethral fistulas has been augmented with the availability of transanal endoscopic surgery (TES). Transanal endoscopic surgery includes transanal endoscopic microsurgery (TEM) during which a large rigid anoscope is placed in the anus with subsequent insufflation of the rectum to allow visualization. Other variations of TES include placing a single-incision laparoscopic gel port into the anus with subsequent insufflation. The TES platforms present much improved visualization than standard transanal surgery. Full-thickness rectal advancement flaps with ligation of the fistula have been reported using TEM [22, 23]. A urethral stent may also be placed to span the fistula opening without primary closure of the urethral end with success [22].

A transsphincteric approach most commonly involves a posterior, or York-Mason, incision extending from the anal verge to the coccyx with division of the sphincter muscles as well as the posterior rectal wall [24–28]. The fistula tracts may then be either excised or ligated. This procedure has the risk of rectocutaneous or anocutaneous fistula and fecal incontinence and may not be the best option in patients at risk for poor wound healing.

Table 35.1 Review of gracilis interposition for repair of rectourethral fistula

Study	Year	Patients with gracilis interposition for RUF, *n*	Irradiated patients,*n* (%)	Success rate after initial gracilis interposition (%)	Final success rate (either repeat gracilis interposition or other fistula repair) (%)
Samalavicius et al. [31]	2012	1	1 (100)	100	100
Netsch et al. [32]	2011	1	0 (0)	100	100
Samplaski et al. [33]	2011	13	7 (54)	92	100
Gonzalez-Contreras [34]	2011	1	1(100)	100	100
Vanni et al. [35]	2010	68	36 (53)	87	100
Ulrich et al. [36]	2009	26	14 (54)	>94[a]	>94[a]
Gupta et al. [37]	2008	15	0 (0)	100	100
Wexner et al. [16]	2008	36	18 (50)	78	97
Rabau et al. [38]	2006	4	0 (0)	75–100[a]	75–100[a]
Bukowski et al. [39]	1995	1	0 (0)	0	100

RUF rectourethral fistula

[a] Exact success rate could not be determined. These papers evaluated both rectourethral and rectovaginal fistulas, but it is unclear to which group the persistent fistula(s) belong.

A transabdominal approach will allow repair of a rectourethral fistula if a proctectomy or prostatectomy is attempted [29, 30]. Open or laparoscopic approaches may be undertaken. Most transabdominal approaches described in the literature refer to radiotherapy-induced rectourethral fistulas rather than postoperative iatrogenic rectourethral fistulas.

This brief description of rectourethral fistula repairs sheds light to the numerous techniques that exist. It is important to individualize treatment options depending on the patient's comorbidities, expectations, and quality of life, in addition to the anatomic details of the fistula.

Conclusion

Prostatic urethral injury is a major risk of pelvic colorectal surgery, especially when involving reoperative surgery, irradiated tissue, bulky tumors, and obese males. Avoiding urethral injury requires a high awareness of the risk as well as prophylactic measures to try to reduce the risk. Such techniques include the use of a large urethral catheter or sound to palpate the urethra. Suspicion for injury can be intraoperatively tested with retrograde instillation of indigo carmine, methylene blue, and/or a retrograde urethrogram. Furthermore, retrograde urethography remains important both during and after surgery to diagnose the injury. In the unfortunate event of a prostatic urethral injury, a urology consult is highly recommended at the time of diagnosis for optimal management. A delayed rectourethral fistula may be treated by either a transperineal approach with a gracilis or dartos interposition flap or a transanal approach with a full-thickness rectal advancement flap.

Key Points on Avoiding Complications

1. Always be aware of the possibility of urinary injuries.
2. Be especially vigilant in cases of bulky tumors or history of pelvic irradiation.
3. Use a large Foley catheter to palpate the urethra.
4. Insert a urethral sound to palpate the urethra.
5. If concerned about a urinary injury, check prior to leaving the operating room.

Key Points on Diagnosing/Managing Prostatic Urethral Injuries

1. Inject methylene blue or indigo carmine either intravenously or retrograde through the urethra to check for a urethral injury.

2. If a urethral injury is diagnosed intraoperatively, aim to repair the injury at the initial surgery.
3. Obtain a urology consult at time of diagnosing a urinary injury.
4. Retrograde urethrography will best diagnose a urethral injury either intraoperatively or postoperatively.
5. With any urinary injury, the urine should be diverted with either a Foley catheter or a suprapubic catheter until the injury has healed.

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Vaginal Injury During Stapled Anastomosis

36

Feza H. Remzi and Volkan Ozben

Introduction

We have witnessed the evolution of the stapler technology in the field of colorectal surgery within the last three decades. Improvements in technical innovations have allowed the surgeons to be able to create easier and safer stapled ultralow colorectal (CRA), coloanal (CAA) and ileal-pouch anal anastomosis (IPAA). However, our innovative spirit of pushing the limits of low pelvic anastomosis on behalf of our patients has inevitably brought some complications with it. Vaginal injury during stapled anastomosis is a rare, but devastating complication which can result in severe consequences if it is not recognized and appropriately addressed at the time of surgery. The most common reasons for this complication are patient related factors such as narrow pelvis or reoperative pelvic surgery and more importantly lack of familiarity or respect for the pelvic anatomy and dissection by surgeons. In this chapter, we will share our experience on how to avoid vaginal injury, and when it happens how to fix this humbling and difficult complication.

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How to Avoid Vaginal Injury

Anatomically, vaginal injury during stapled anastomosis can be classified as high level that involves the proximal two-third and low level that involves the distal one-third of the vagina. The most common reason for high level vaginal injury is unintentional incorporation of the vagina into the stapled CRA or CAA due to inadequate dissection/mobilization of the rectovaginal septum. Therefore, it is important to dissect at least 2 cm or so in the rectovaginal septum below the level of the planned anastomosis.

During ultra-low stapled CRA, CAA or IPAA, the lower third of the vagina can iatrogenically be injured. A stapled ultra-low CRA/CAA or IPAA can be constructed using either a double- or a single-stapled technique. When technically feasible, double-stapled anastomosis is the preferred technique in our practice. When a stapled anastomosis is intended, we mark the level of the planned anastomosis by performing a digital rectal examination with the proximal interphalangeal joint resting at the anal verge and the tip of the digit corresponding to the anorectal ring. This maneuver, as shown in Fig. 36.1, helps us to identify where to place the linear stapler device for double-stapled anastomosis or purse-string sutures for single-stapled anastomosis. Also, bimanual examination (one finger placed in the anal canal and the other in the abdomen) can guide and orient us to the tumor location and the corresponding distal line of transection in patients undergoing ultra-low stapled CRA/CAA

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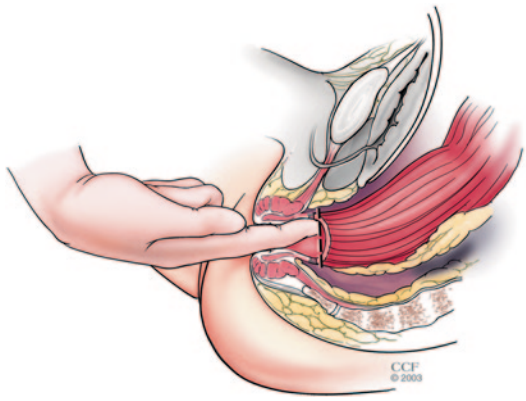

Fig. 36.1 Demonstration of the digital rectal examination. The *tip* of the finger corresponds to the anorectal ring where the linear stapler is placed for double-stapled anastomosis or purse-string sutured applied for single-stapled anastomosis. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2014. All rights reserved)

for rectal neoplasia. The double-stapled technique obviates the frustration of inserting purse-string sutures in the anorectum deep in the pelvis. The disparity of the size of the bowel lumen is also avoided. Double-stapled anastomosis is then performed using a stapler, which removes an additional 1 cm of the distal ring. This 1 cm of distal ring is the area of concern, where the vaginal wall can accidentally get incorporated into the staple line. For this reason, after inserting the circular stapler into the anorectal stump, it is important to advance the shaft of the stapler in a way that the trocar traverses posterior to the staple line. This can be facilitated by putting the index finger into the anorectal staple line area from the abdominal side and guiding the trocar just posterior to the staple line on the anorectal stump (Fig. 36.2).

Another maneuver to avoid vaginal injury is the retraction of the vagina anteriorly with lighted deep pelvic retractors. This helps prevent the redundant posterior vaginal wall from being accidentally incorporated within the staple line

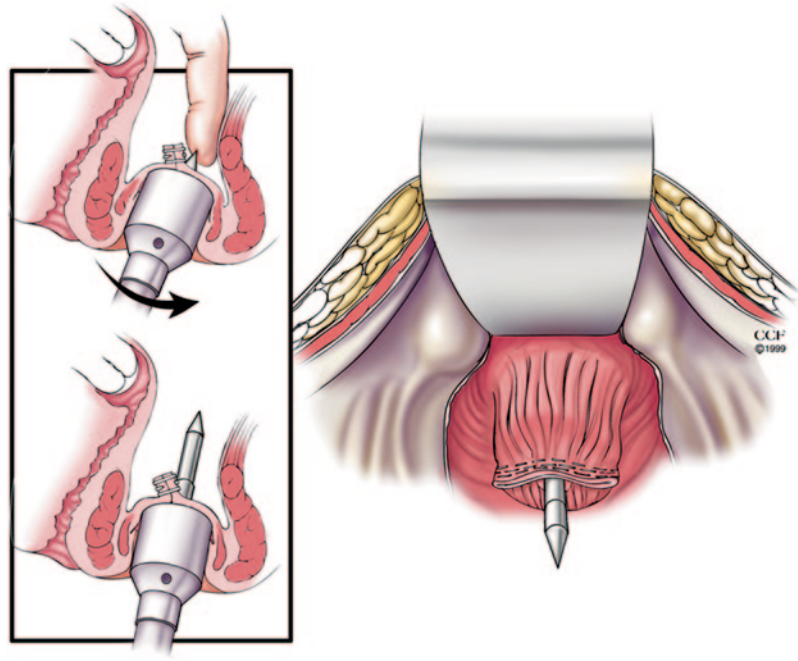

Fig. 36.2 In the double-stapled anastomosis, the trocar of the stapler should traverse just *posterior* to the staple line. This can be facilitated by putting the index finger from the abdominal side and guiding the trocar *posterior* to the staple line. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2014. All rights reserved)

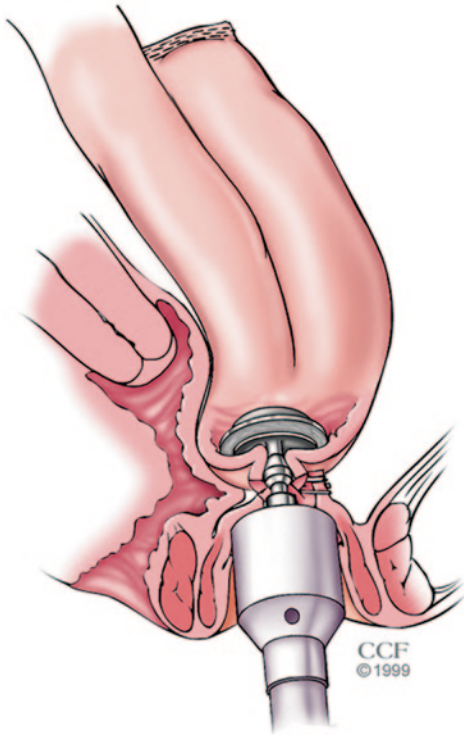

Fig. 36.3 Incorporation of the redundant posterior vaginal wall within the staple line during double-stapled anastomosis (this complication can be prevented by anterior retraction of the vagina with deep pelvic retractors). (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2014. All rights reserved)

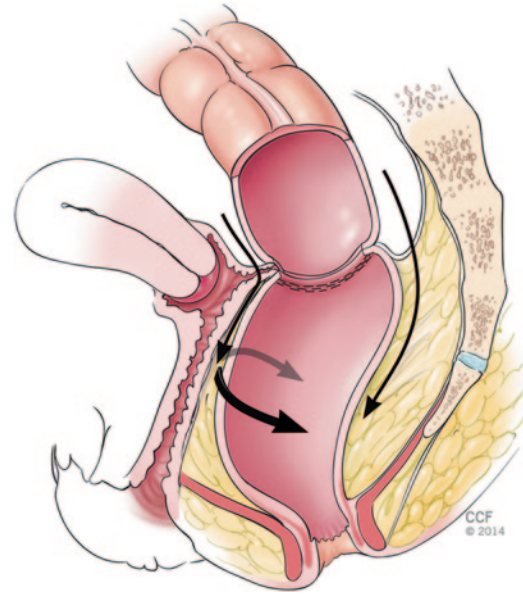

Fig. 36.4 A high-level vaginal injury due to inadequate mobilization of the rectum. In this circumstance, before disconnecting the anastomosis, the rectum should be fully mobilized posteriorly, laterally, and then anteriorly below the level of injury. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2014. All rights reserved)

(Fig. 36.3). In addition to these, vaginal bougies and/or obturators inserted via the perineal approach can delineate the anatomy, facilitate pelvic dissection and to avoid this complication in reoperative pelvic surgery.

How to Fix Vaginal Injury

Most of the time, a high-level vaginal injury is related to the inadequate anterior mobilization of the rectum. Normally, rectal mobilization requires a minimum of 2 cm anterior dissection below the level of planned anastomosis. Once this complication happens, the surgeon should take a pause and get a proper assistance. To fix the problem, complete exposure of the operative area should first be obtained even if this requires a conversion of a laparoscopic case to a full laparotomy. It would not be wise to tackle the area of injury first even though it seems tempting for the surgeon. The surgeon needs to strategize the operative plan. In this case, the vaginal injury has occurred due to inadequate rectal mobilization. Therefore, it is critical to fully mobilize the rectum and further separate the rectovaginal septum lower than the level of injury. In order to accomplish this, the rectum should first be further mobilized posteriorly and laterally and then the dissection should be continued to the anterior side below the level of injury (Fig. 36.4). Only then it is proper to disconnect the anastomosis, where the vaginal injury has occurred. Attempting to disconnect the anastomosis prematurely without full posterolateral and anterior rectal mobilization lower than the area of injury can further complicate the situation. This technique minimizes the risk of further injury and/or enlarging vaginal defect by identifying the proper tissue planes. Furthermore, it may also enable

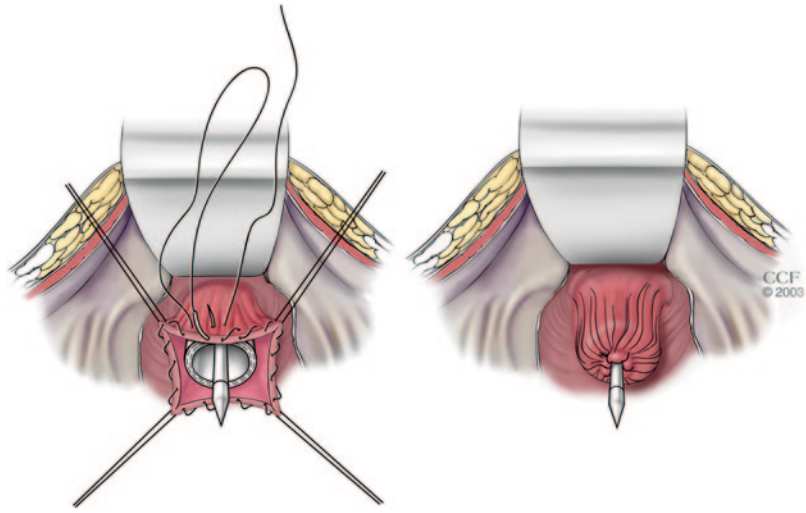

Fig. 36.5 For a single-stapled anastomosis, after the creation of a small proctotomy at the anterior rectal wall and placement of stay sutures, a purse-string is applied to the anorectal stump and tied down over the trocar. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2014. All rights reserved)

the surgeon to do a second attempt of a double-stapled anastomosis. If a second attempt of double-stapled anastomosis is not a possibility, then a single-stapled anastomosis remains a very good option as seen in Fig. 36.5. For this, after identifying the vagina and separating it off the anastomosis, a small proctotomy is made at the anterior wall and stay sutures are placed. Starting from the anterior wall, a purse-string suture is applied circumstantially around the anorectal stump by hand and tied down over the trocar, and then the gastrointestinal continuity is established by creating a single-stapled anastomosis. If the omentum is present, omental pedicle flap can be used to patch the vaginal site following its primary repair.

In the presence of low-level vaginal injury, however, the problem should be addressed with a perineal approach since it can be extremely difficult to handle the problem from the abdominal side. In the perineal approach, the anal verge is everted with radially placed sutures at four quadrants as a first step to facilitate exposure. Then, a small- or a medium-sized lighted anal retractor is placed into the anal canal, the anastomosis is taken down and separated from the vagina. Unless clinically indicated, there is no need to do a mucosectomy since this may further complicate the problem with reach issues and tension on the anastomosis itself. After the completion of the transperineal repair of the posterior vaginal wall, we suggest performing a hand-sewn ultra-low CAA or IPAA to the anal transitional zone.

Although it is important to repair this disastrous complication, it is also necessary for a surgeon to be able to recognize it at the time of the original surgery. For this reason, examination of the doughnuts for its intactness after the completion of anastomosis is very important. This also needs to be complimented by checking the integrity of anastomosis with air insufflation test. If there is any concern that the vagina is incorporated into the staple line, we strongly suggest taking down and re-doing the anastomosis as explained above. This complication is better avoided, and if it occurs, fixed at the time of original surgery rather than at a later date.

If the vaginal injury is not recognized at the time of original surgery and it presents itself within the postoperative 7–10 days, our

recommendation is to take the patient back to the operating room. We suggest repairing the vaginal injury and creating a proximal diverting ileostomy if it was not previously performed. However, if the complication presents after 10–14 days, we suggest creating a diverting ileostomy alone since any attempt to repair this complication in the presence of severe adhesions and inflammation would be futile and may potentially cause the patient to end up with a permanent stoma. Therefore, after a clear, transparent, and fair communication with the patient, surgical repair of this pathology can be performed 6 months after the initial operation.

Sometimes it requires certain surgical dexterity and skills to handle this complication. This may be the case either at the time of initial surgery or in delayed presentations. It is more than acceptable in these circumstances to receive more subspecialized help if it is available. If not, it would be wise to retreat and refer the patient for a more definitive repair 6 months after the initial laparotomy. Our teaching in our institution is to know when to retreat which is a sign of maturity and is not a sign of weakness!

In summary, vaginal injury during stapled anastomosis is a rare and potentially a devastating complication if it is not recognized and addressed properly. This can happen to any surgeon in their career. The aforementioned techniques and tips may avoid this pathology and help surgeons repair it appropriately when it occurs.

Key Points on How to Avoid Vaginal Injury

1. Adequate dissection of the rectovaginal septum below the level of planned anastomosis
2. Advancement of the stapler in the anorectum under the guidance of the index finger
3. Extrusion of the trocar of the circular stapler posterior to the staple line
4. Anterior retraction of the vagina with lighted deep pelvic retractors during anastomosis
5. Use of vaginal bougies or obturators to delineate the anatomy and dissection in reoperative surgery

Key Points on How to Diagnose and Manage Vaginal Injury

1. Examination of the doughnuts for intactness and/or checking the integrity of anastomosis
2. Complete exposure of the operative area and circumferential mobilization of the rectum below the level of injury
3. Redo double-stapled anastomosis (if not possible, creation of a single-stapled anastomosis)
4. Transperineal repair of the vagina and hand-sewn ultra-low anastomosis in the presence of low-level injury
5. Tailoring surgical repair according to the time of its clinical presentation

Management of Rectovaginal Fistula

37

Daniele Scoglio and Alessandro Fichera

Introduction

A rectovaginal fistula (RVF) is defined as an abnormal epithelial-lined connection between the rectum and vagina. It represents a debilitating condition for patients and a challenge for surgeons. Successful management of RVFs must take into account a variety of variables including the etiology, size, location of the fistula, and patient's comorbidities. RVFs are caused by a variety of conditions, including obstetric injury, cryptoglandular infection, inflammatory bowel disease, rectal or vaginal surgery, radiation, neoplasia, or trauma [1].

Patients with RVFs typically present with complaints of passage of flatus or feces from the vagina. Recurrent urinary tract infections and vaginitis with malodorous vaginal discharge may also be the presenting complaint.

RVFs most commonly communicate with the posterior vaginal wall. Classification of the fistula helps to determine the appropriate therapy. Based on the size, fistulas less than 2.5 cm in diameter are considered small; those greater than 2.5 cm are described as large. In addition, fistulas can be classified as low, middle, or high on the basis of their location. Fistulas that are in close proximity to the posterior vaginal fourchette are considered low. High fistulas are in proximity to the cervix, and those that occur in between the cervix and fourchette are considered middle RVFs. The fistulas that develop distal to the dentate line are referred as anovaginal fistulas (Fig. 37.1).

Examination under anesthesia is critical to locate the fistula, assess the quality of surrounding tissue and the presence of associated pathology, with high fistulas being the most difficult to diagnose. A palpable depression in the anterior midline of the rectum, or a visible pit like defect could be the only appreciable sign if the fistula is small. These changes may be palpable or visible on anoscopy. On vaginal examination, the darker mucosa in the fistula track may be apparent, contrasting with the light vaginal mucosa [2]. There may be visible stool or signs of vaginitis. Probing the tract is very painful and should only be done under anesthesia to avoid creating false tracts. An assessment of anal sphincter integrity and function will assist in surgical planning. This may be attainable with a good history and physical examination; however, some women may have difficulty in distinguishing incontinence from fistulous drainage. Incontinence may be caused by the fistula, an underlying disease state, or anal sphincter defect. Determining the cause of incontinence is important prior to operative intervention for a RVF [3, 4]. Supplemental studies may be necessary to confirm the presence of a fistula or to determine the extent of underlying disease.

Endorectal and transvaginal ultrasounds may be used to identify a low fistula tract [5, 6]. Alternatively, a vaginal tampon can be inserted

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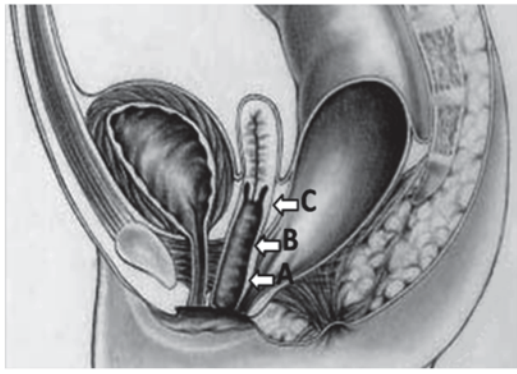

Fig. 37.1 Rectovaginal fistula sites. **a** Low, **b** mid, **c** high. (Modified from: http://en.wikipedia.org/wiki/File:Rectovestibular_fistula_in_females.jpg by adding arrows, letters, and a legend. Under creative commons attribution 2.0 generic license, we are free to modify it:This is an open access article distributed under the terms of the creative commons attribution license (http://creativecommons.org/licenses/by/2.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited)

followed by instillation of a methylene blue enema. The tampon is removed after retaining the enema for 15–20 min. If there is no staining, the diagnosis of RVFs is highly unlikely. More proximal fistulas are best diagnosed with vaginography, a barium enema or computed tomography(CT)-scan with rectal contrast. An endoscopy is necessary if inflammatory bowel disease is suspected. Biopsies under anesthesia are useful in patients with history of prior radiation to rule out malignancy. Manometry may be used to determine functional sphincter defects in the absence of an anatomic defect. Patients with fistulas arising as a result of an obstetrical injury should be routinely evaluated for anatomic sphincter defects. Rectal surgery has often been associated with RVFs. Iatrogenic fistulas are reported in up to 10% of low rectal anastomoses [7, 8]. A risk factor appears to be the use of double stapling technique [7, 9, 10]. The use of pre- or postoperative external beam radiation plays a role in fistula development and impairs healing [11].

A spontaneous healing is very rare with the exception of Crohn's disease (CD) more recently with the use of anti-tumor necrosis factor (TNF) therapy, and surgical treatment is usually indicated due to the impact on the quality of life. The choice of the surgical approach is controversial and the results of surgical approaches are highly variable. Furthermore, the majority of published data on RVF pertains to CD [12–16].

The surgical approaches available are numerous, and they vary based on the etiology, location, size, quality of the surrounding tissue, and previous attempted repairs. Surgical approaches can be classified as either local or transabdominal. Local repairs are most useful for low to middle RVFs and include transanal, transvaginal, and perineal approaches. Abdominal operations are usually reserved for high RVFs and may incorporate laparoscopy. The use of healthy muscle or vascularized tissue for transposition is often recommended.

General Principles

Timing is an important part of the surgical decision-making process. In the face of infection or inflammation, it is critical to allow resolution prior to repair. Antibiotic therapy, anti-TNF, or immunosuppressive medications (in case of CD) play an important role in surgical optimization. While a recommended period of 3–6 months on medical therapy has been suggested, surgery should proceed only when surrounding tissues appear reasonably healthy. The use of fecal diversion in preparation to definitive repair or as an adjunct to the repair is also highly controversial and often reserved for recurrent cases after failed surgical treatment, in the presence of CD or after radiation. Preoperatively, the patient undergoes mechanical bowel preparation and receives antibiotics. Procedures may be performed under local anesthetic with sedation, but spinal or general anesthesia is typically preferred. Patients are positioned based on the approach: i.e., for a vaginal approach the patient is placed in a lithotomy position versus prone jackknife position for a transanal approach with exposure facilitated by taping the buttocks or using a Lone Star retractor. The anal canal and vagina are prepared with povidone-iodine solution and a urinary catheter

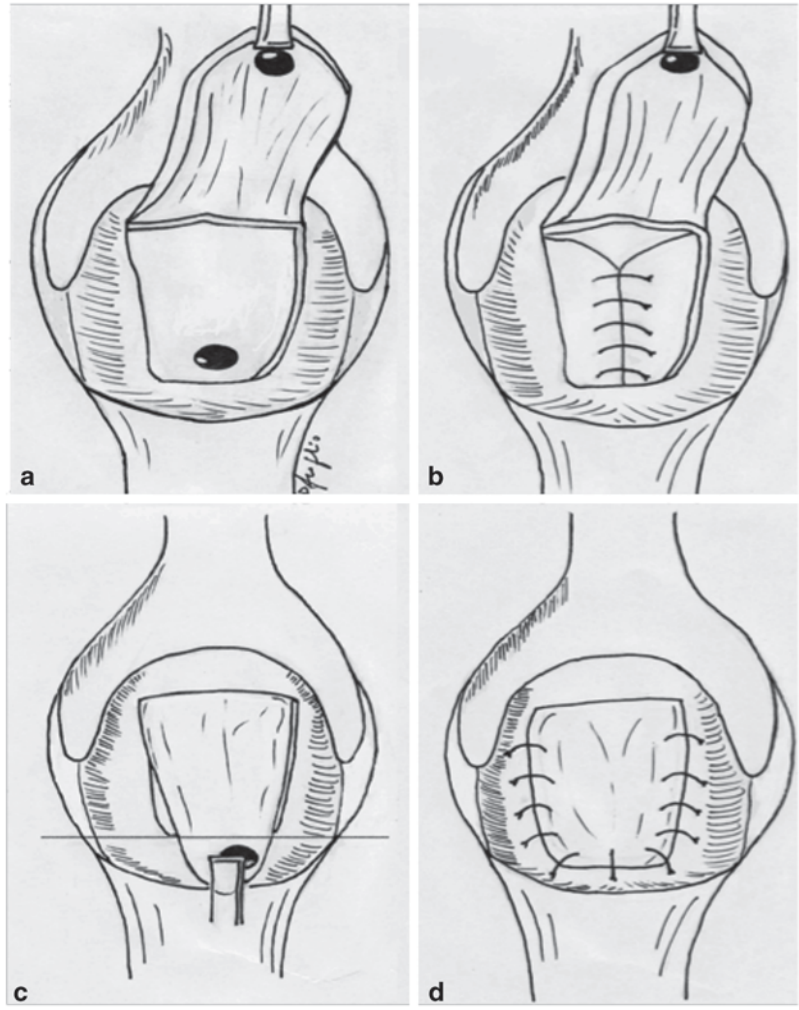

Fig. 37.2 Mucosal advancement flap technique. **a** A flap is created that includes mucosa, submucosa, and muscular layer; **b** curettage and closure of the internal opening; **c** the distal part of the flap including the rectal opening is excited; **d** the flap is advanced to close the defect without tension. (Courtesy of Dr. Daniele Scoglio)

is placed. Patients who require abdominal procedures are placed in the lithotomy position.

Local Repair

Mucosal Advancement Flap Repair

Advancement flaps are the most popular transanal procedure among colorectal surgeons. Many variations exist; however, the general principle remains the same: excision and closure of the rectal portion of the fistula and coverage with a vascularized mucosal flap on the high-pressure side of the fistula. The tract is identified by palpation and probing. The fistula tract is debrided and excised. A flap is created that includes mucosa, submucosa, and muscle placed over re-approximated rectovaginal septum (RVS). The flap base should be at least 2–3 times the width of the apex to ensure adequate vascular supply. The flap mobilization should continue 4–5 cm cephalad to the fistula defect. These principles ensure a tensionless suture line (Figs. 37.2 and 37.3). Success

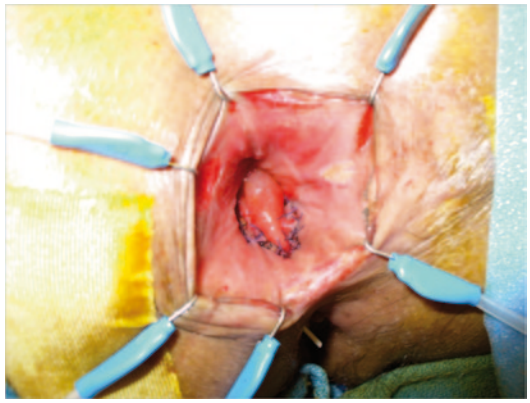

Fig. 37.3 Mucosal advancement flap; intraoperative picture.The well-vascularized broad-based flap covers the anal opening of the rectovaginal fistula

rates vary from 41 to 96% (Table 37.1) [3, 17–22]. This wide discrepancy may be explained by differences in technique as well as patient selection. Complications are minor and infectious/ischemic in nature. In patients reporting associated incontinence, which is usually secondary to injury to the sphincter mechanism, a sphincteroplasty can be concurrently performed; thus, both correcting the underlying sphincter defect and interposing vascularized muscle in the RVS and perineum.

Endorectal Advancement Flap with Muscular Plication (Anterior Levatorplasty)

A similar approach is the advancement flap with plication of the muscular layer. An anterior transverse incision is made distal to the internal opening extending to the submucosa, and a U-shaped flap consisting of mucosa and submucosa is prepared. The dissection is carried out in a cephalad direction until the entire flap can be easily advanced distally. The distal part of the flap, including the internal opening, is then excised. The remaining track is curetted and the internal opening is closed with a figure-of-eight stitch using a reabsorbable suture (3.0 Vicryl). A transverse plication of the muscular layer, internal anal sphincter and/or rectal muscular layer depending on the height of the fistula is made using an absorbable running suture. Finally, the mucosal–submucosal flap is advanced to cover the muscular plication and closed without tension with interrupted absorbable. This approach can be used to treat RVFs without an anal sphincter defect. The goal is to create a second layer of well-vascularized tissue, incorporating healthy tissue under the flap. With this technique, de Parades et al. [23] reported a success rate of 65%.

Transanal Sleeve Advancement Flap

This technique was described for the first time by Hull and Fazio in 1997 [24] to treat anovaginal fistula in patients with mild Crohn's proctitis. It is an invasive procedure that involves mobilization and resection of the distal rectum. Re-anastomosis, usually via a transanal manual suture, is performed following the removal of the fistula-bearing area. The procedure is primarily used in patients with significant rectal-wall defects due to chronic inflammatory bowel disease or following radiation therapy. In their study, Hull and Fazio performed five sleeve advancement flaps. Three of the five patients had stomas for fecal diversion. Two stomas were closed without recurrence and the third patient had a recurrence, then a repeat sleeve advancement flap before a successful stoma closure. Of the two patients without fecal diversion, one went on to have a total proctocolectomy.

Table 37.1 Various success rates of rectovaginal fistula repair from selected series

Author	Year	Patients#	Success (%)
Wise [17]	1991	34	96
Kodner [18]	1993	71	88
Ozuner [19]	1996	52	65
Tsang [3]	1998	27	41
Sonoda [20]	2002	37	43
Mizrahi [21]	2002	32	56
Ellis [22]	2007	39	59

Transvaginal Repair

Transvaginal (TV) approach is suitable for small low RVF. The vaginal mucosa is incised around the fistula ostium, and the fistula is closed with sutures imbricating the soft tissue towards the anorectum. The vaginal mucosa is then re-approximated. Rahman et al. [25] described their results in 39 patients undergoing TV repair for low RVF and reported a 100% success rate with this approach. This is a particularly appealing approach in patients with CD as dissection in the diseased rectum can be avoided. Bauer et al. [26] reported their results for 13 patients with CD who underwent repair of RVF by a TV approach. All patients had a diverting intestinal stoma either as part of the initial step in the staged management of intractable perianal disease or concurrent with the repair of the RVF. Each of the patients had low or middle septal fistulas. Fistulas were eradicated in 12 of the 13 women and did not recur during the follow-up period, which averaged 50 months (9–68 months).

Fistulotomy

The use of fistulotomy to treat RVFs is associated with a prohibitive rate of fecal incontinence and is mentioned only to discourage its application.

Ligation of Intersphincteric Fistula Tract

A recently popularized surgical treatment for fistula in ano has been adapted to treat RVF. The ligation of intersphincteric fistula tract (LIFT) involves dissection in a bloodless plane between the internal and external anal sphincters beyond the fistula tract. The tract is then ligated and closed on both the rectal and perianal side. The intersphincteric dissection is then closed at the skin. High success rates after LIFT treatment of fistula in ano are encouraging (60–94%) [27, 28], but experience with LIFT treatment of RVF is still limited.

Biological Agents: Fibrin Glue and Fistula Plug

Although there have been various reports of successful outcomes in treating anorectal fistulas with biological agents such as fibrin glue [29] and fistula plug [30], the literature is limited to small series. In one small study, four of five patients with RVFs treated with fibrin glue were healed [31]. In different series of reports by Loungnarath et al. [32] ,there was one successful outcome in three patients treated with fibrin glue for RVF. A commonly used type of bioprosthetic fistula plug is made from porcine intestinal submucosa. It is placed through the RVF tract and it is trimmed at both the rectal and vaginal ends when it exceeds the length of the fistula. The plug is then secured with absorbable sutures in a figure-of-eight fashion on the rectal side and the vaginal side is left open for drainage. Experience with this technique in patients with RVFs is limited [33]. Trials that compare rectal mucosal flap advancement to bioprosthetic plug placement for the treatment of fistula in ano are ongoing [34]. Smaller studies show that bioprosthetic plugs are more successful in the treatment of simple anorectal fistulas compared with the complicated ones [35]. Recent modifications to the bioprosthetic to accommodate anatomic features of a RVF may make this approach more successful [36]; however, additional experience is needed to determine the efficacy of bioprosthetics in the use of RVF treatment.

Miscellaneous

The use of autologous stem cells to treat RVFs [37], as well as circular stapler, which has only been published in one case report, are other two options to treat RVFs [38]. Furthermore D'Ambrosio et al. [39] reported the first case series for the treatment of RVFs by transanal endoscopic microsurgery and Lamazza et al. [40] suggested the use of endoscopic-covered stent to treat patients with RVFs and fecal diversion.

Tissue Transfer Procedures

The purpose of tissue transfer procedures in patients with RVFs is to provide healthy, tension free, well-vascularized tissue to support the repair. A multitude of tissue transfers are described including the gracilis, rectus, gluteus, and bulbocavernosus muscles [41–45]. We describe the two most widely used techniques.

Gracilis Muscle Interposition Flap

The gracilis muscle is mobilized based on the proximal major pedicle of the medial femoral circumflex artery after ligation of the distal non-dominant vascular pedicle. A subcutaneous tunnel is created between the thigh incision and the perineum, and the distal end of the muscle is tunneled under the skin to the perineal wound. The gracilis is interposed between the rectum and vagina without tension after the fistula is closed. The proximal end of the muscle is tunneled between the rectum and vagina and tacked 3 cm above the suture lines of both the rectal and vaginal defects and down to the opening of the perineal wound. Meticulous hemostasis is achieved. The thigh and perineal wounds are closed primarily after placing drains. The gracilis muscle is an excellent option,because it is a functionally rudimentary muscle, and thus expendable without noticeable functional deficits. Furthermore, it is easily mobilized with adequate length, and has a dominant vascular pedicle proximally that is convenient for perineal transposition allowing transfer of the distal end to the upper RVS without tension on its vascular pedicle. Several studies have shown high success rates as when the gracilis is used to close RVFs [41, 46, 47].

Zmoraet al. [41] reported their experience with gracilis muscle interposition. The authors included five patients with a RVF and one patient with a pouch-vaginal fistula who underwent this repair with favorable results. All patients had fecal diversion as a step preliminary to or concurrent with fistula repair. Five of the six repairs healed completely after the reversal of the fecal diversion. One patient with severe crohn'sproctitis failed and had a persistent RVF.

Martius Flap

The principles of repair involve transposing a pedicle graft harvested from the labia majora through a subcutaneous tunnel [48]. The graft overlies the rectal closure and separates the rectal and vaginal walls, filling in the dead space and stimulating tissue growth and healing. Patients with uncontrolled perineal sepsis or severe fecal soiling should undergo fecal diversion. Repair of the fistula should not be attempted until perineal sepsis and inflammation resolves. A vertical incision is made in the perineum or in the posterior vaginal wall (Fig. 37.4) and is carried out to the inferior margin of the fistula. Local anesthetic is injected into the RVS for hemostasis and tissue dissection. The posterior vaginal wall is sharply mobilized from the rectum. Wide mobilization of the rectum and vagina is necessary so that a multilayer closure can be performed, and reapproximation of the tissue surfaces can occur without any tension. Local anesthetic is injected into the labia majora. A vertical incision is made in the labia majora to expose the bulbocavernosus fat pad. The borders of dissection include the labial crural fold laterally, the labia minora and the bulbocavernosus muscle medially, and the Colles' fascia covering the urogenital diaphragm posteriorly. A flap harvest is accomplished in a lateral to medial fashion. For RVF repair, the blood supply to the graft is based on the posterior vessels, which includes the perineal branch of the pudendal artery. The entire thickness of the fibro adipose flap is included in a small Penrose drain. Gentle downward traction is applied to aid in the dissection. The graft is transected superiorly. The operator should not divide the pedicle graft until it has been determined that adequate length has been developed. A hemostat is then used to transfer the fibro adipose pad from the harvest site, through the tunnel, to the level of the fistula repair. It's very important not to twist the graft, and to ensure that it is properly oriented. The fistula tract is excised. The vaginal wall is re-approximated with reabsorbable sutures. This should be a tension free repair. The rectal edges are also freshened up and the rectal mucosa is approximated with absorbable sutures. The flap sits between the rectum and the vagina. The sphincter muscles are re-approximated. The flap is gently sutured into position. Hemostasis is obtained, the wound is irrigated, and the perineal skin is then closed. A small drain is left to keep the wound open. The labial skin is closed in two layers with absorbable sutures. A Penrose drain is left at the inferior border of the incision for drainage. Success rates range from 60 to 100 % [44, 45, 49–52].

Kin et al. [48] reported a series of five patients with a mean age of 48.4 years (range 32–64).

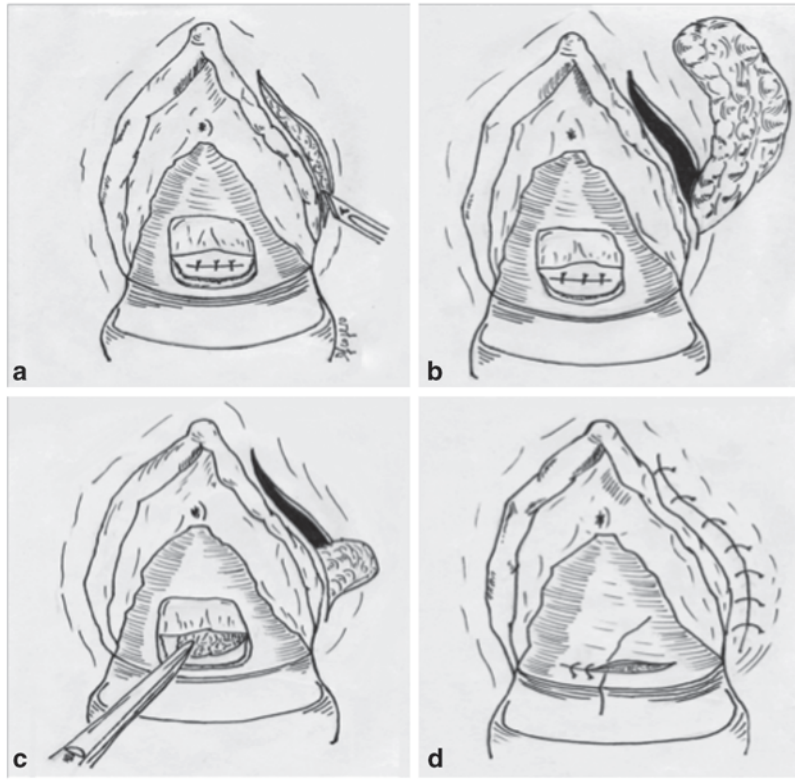

Fig. 37.4 Martius flap technique. **a** Curved incision of the posterior vaginal wall and suture of the fistula; vertical incision in the labia majora to expose the bulbocavernosus fat pad, **b** exposition of the fibro-adipose pad, **c** the pad is transferred from the harvest site, through the tunnel, to the level of the fistula repair, **d** final suture of the vaginal wall and the labia majora. (Courtesy of Dr. Daniele Scoglio)

Etiologies of the fistulas were: obstetric, iatrogenic (after hysterectomy), CD, cryptoglandular, and idiopathic. The patients had undergone a mean of 2.6 (range 1–5) prior repairs. Of the total of 13 prior attempted repairs, eight were advancement flaps, two were episio-proctotomies, two were fistula plugs, and one was an interposition mesh graft. Three of the five had diverting ileostomies prior to the Martius flap procedure; one underwent diverting ileostomy at the time of the Martius flap procedure. The time from the first symptoms to the first attempted repair was a mean of 14.4 months (range 2–31 months). All repairs involved either sphincteroplasty or perineoplasty in addition to the flap repair. Mean follow-up was 25.6 months (range 3–44). There were no cases of wound complications, recurrence, or functional complications such as dyspareunia. Three of the four patients who had undergone diverting ileostomy have undergone ileostomy reversal. Patients often have associated asymptomatic sphincter defects that should be repaired at the time of fistula repair.

White et al. [44] performed 14 Martius procedures on 12 patients with radiation-induced RVFs. Eleven patients had successful closure of their fistulas with this procedure, and no operative complications occurred. Aartsen and Sindram [45] reported results in 20 patients with radiation-induced RVF. In this study, nine procedures were done without and 14 procedures with a Martius flap. After a mean follow-up of around 10 years, the success rate of fistula repair was 5 of 9 (55 %) and 13 of 14 (93 %), respectively.

Abdominal Procedure

High RVFs are usually approached through an abdominal procedure. There are several approaches, and this type of repair depends on the location, etiology, and quality of the affected tissues. If the tissues surrounding the rectum and vagina are minimally affected, dissection of the RVS with simple closure of each fistula opening in several layers can be performed. The coloanal sleeve anastomosis procedure, described by Parks et al. [53], involves the dissection of the rectum below the fistula site with the mobilization of descending and sigmoid colon with a coloanal anastomosis in the setting of a mucosectomy. The need for a mucosectomy is negated with the advent of the double-stapled approach. Nowacki [54] reported functionally good results in 18 of 23 patients undergoing the procedure for radiation-induced RVFs. In addition, Cooke and Wellsted [55] reported a 93% success rate in 55 patients. Another approach to dealing with the radiation-induced RVF is the patch anastomosis reported by Bricker and Johnston [56]. First described in five patients, the technique essentially relies on the proximal part of the colon as a vascular pedicle graft, used as a patch to close the rectal defect and to provide circumference to relieve any associated stricture. Supplying the area with a sound, vascular sigmoid pedicle graft, improves the tissue vitality locally; it restores rectal function to a near normal pre-radiation level and preserves the previously intact sphincter muscles. Steichen et al. [57] reported the repair using stapling devices with good results. The use of laparoscopic approaches has been reported only in a few case reports [58–60]. Schwenk et al. [58] reported on a case in which laparoscopic resection of a high RVF with primary intracorporeal anastomosis and an omental flap was performed with a good outcome. Kumaran et al. [60] reported on a successful repair of a high RVF performed laparoscopically. However, further studies involving larger numbers are needed to state conclusively that laparoscopic approaches are safe and feasible.

Transperineal Omental Flap

With the transperineal omental flap, the greater omentum is first mobilized, beginning at the hepatic flexure and extending to the oral third of the greater curvature of the stomach maintaining the arterial arcade so that the omentum arterial supply is preserved. The second step is the transabdominal mobilization of the rectum and vagina. If a simultaneous deep anterior rectal resection is planned, the mobilization of the rectum is performed circularly in the typical manner. At the level of the anterior peritoneal reflection, an incision is made and the rectovaginal space is opened up. Ventral displacement of the vagina with a vaginal manipulator may be helpful in facilitating the dissection in the correct plane. An excessive tension may lead to larger defects and should be avoided. Then debridement of the fistula tracts is performed. The wound edges are approximated by interrupted absorbable sutures. When a rectal resection is indicated, the level of the resection is determined by the underlying pathology as well as the location of the fistula. It is important to avoid overlapping suture/staple lines that significantly increase the risk of recurrence.

A transrectal and/or transvaginalomental flap reconstruction is then performed during the perianal part of operation. A horizontal perineal skin incision is performed directly above the sphincter. Further dissection results in the opening of the rectovaginal space from the perineal access as well. The mobilized greater omentum is carefully delivered in the space through the defect. Proper flap orientation is critical to assure excellent vascularization of the flap. The omentum is then secured to the subcutaneous tissue within the neoperineum. Schloericke et al. [61] from Germany have described for the first time this technique and have reported a success rate of 100% at a median follow-up of 22 months in a group of nine patients affected by low- or mid- RVFs. Eight of the nine patients received were diverted. Minor complications were observed in two patients such as prolonged postoperative ileus and pulmonary complication. Delayed wound healing, urinary retention, and fecal impaction were not observed. Major complications included an

anastomotic leak after low anterior resection that was treated conservatively and a persistent fistula repaired by a combined plug placement and mucosal advancement flap.

Perioperative Management

Wound Management and Perioperative Complications

Complications following RVF surgery are generally similar to those following other anal procedures [62]. Primarily repair of RVFs is associated with a risk of local infection and subsequent suture dehiscence resulting in persistence/recurrence of the fistula. Relevant postoperative complications include dyspareunia resulting from vaginal stenosis due to scar formation [63]. It has been reported in up to 25 % of sexually active patients [41, 64].

Postoperative Dietary Manipulation

Dietary postoperative management after complex RVF repair is the subject of ongoing controversy. It is the general belief that avoiding the passage of stool through a fresh wound may benefit the healing process. This particularly applies to cases, where a sphincter repair has been performed. No definitive data on this topic are currently available. The same is true for the role of perioperative and/or postoperative antibiotic use [29].

Fecal Diversion

While a diverting ostomy is rarely required in the context of anal fistula surgery [65], the rate is much higher in RVFs, although no definitive studies are currently available. Fecal diversion is beneficial in the presence of fecal soiling and active inflammation. A stoma may already be in place for the treatment of the primary pathology. The social, physical, and psychological burden on the patient resulting from local inflammation and the amount of fecal discharge through the vagina is an important consideration.

Conclusion

Various surgical procedures have been described with variable results. Initially and most commonly, the RVFs are approached through the perineum. The transperineal approach allows simultaneous anal sphincter reconstruction. The use of a mucosal advancement flap repair is appropriate for simple RVFs. Its success rate depends on the etiology of the fistula, with better results in patients with obstetrical injuries than in patients with inflammatory bowel disease or radiation induced fistulas. Higher failure rates have been reported in patients who have undergone two or more previous repairs. Closure can also be achieved through the interposition of autologous tissue (Martius flap, gracilis muscle) or biomaterials. An autologous tissue is predominantly used in complex or recurrent fistulas. In high fistulas, abdominal approaches are more commonly used.

Key Points to Avoid Complications

1. Timing of surgery. Operating on a patient with active inflammation and undrained sepsis will invariably lead to intraoperative bleeding and postop infection resulting in failure of the repair.
2. Mechanical bowel prep. Adequate intraoperative visualization is mandatory to properly dissectin the right plane and achieve hemostasis.
3. Proper position on the operating table. If approaching the patient from the rectal-site-prone jackknife position is critical, likewise if approaching through the vagina, the patient should be in lithotomy position.
4. Meticulous hemostasis during the dissection and when leaving the operating room. Hematomas will invariably lead to failure of the flap.
5. Consulting with the appropriate specialists to assist you in the procedure (i.e.,gynecology, plastic surgery, reconstructive urology, etc.).

Key Points on Diagnosis and/or Managing Complications

1. Increasing pain following the surgery should prompt an examination under anesthesia with the drainage of the hematoma and/or sepsis.
2. Pelvic magnetic resonance imaging (MRI) will aid in diagnosing a problem, but it should be considered only complementary to surgical intervention.
3. Consider fecal diversion to limit sepsis and further disruption of the repair.
4. In the presence of postoperative perianal sepsis, a broad-spectrum antibiotics should be considered.
5. In the presence of septic postoperative complication, adequate debridement, management of associated comorbidities (i.e.,Crohn's disease), nutritional support, and consideration for fecal diversion are all effective strategies to optimize timing of further surgery for a definitive repair.

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Management of Presacral/ Pelvic Bleeding

38

Sanket Srinivasa and Andrew G. Hill

Introduction

Presacral or pelvic bleeding is a rare but potentially catastrophic intraoperative surgical emergency, which may be encountered during rectal dissection. It is characterised by high-volume bleeding, which is difficult to control with conventional means and can lead rapidly to hypovolaemic shock and death. The reported incidence varies from 4.6 to 9.4% in open surgery, and it is likely that the incidence is equivalent during laparoscopic and robotic resection [1, 2]. Even in high-volume institutions, this incidence may equate to an individual surgeon dealing with significant pelvic bleeding as infrequently as once every year. The uncommon nature of this problem, however, makes it imperative that all surgeons who operate in the pelvis, particularly those who may not do so regularly, understand the basis, significance and prompt management of this problem and formulate an individualised plan in line with personal preference and availability of necessary aids within their institution (Fig. 38.1).

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Anatomy

The vascular anatomy of the pelvis is variable. Cadaveric studies have demonstrated inconsistent anatomical variations even when studying relatively small samples [3]. Significant bleeding, however, occurs from either the presacral venous plexus or the basivertebral veins. The two are linked and provide a connection between the inferior vena cava and the vertebral venous system. Vascular injury results in pronounced bleeding since the veins are part of an avalvular system. The veins are intrinsically friable due to their low-pressure, high-capacitance characteristics. Moreover, since patients are often in the modified Lloyd-Davis position for access to the pelvis, the distal presacral veins that are most vulnerable to injury lie in the lowest position and may have 2–3 times higher hydrostatic pressure than the inferior vena cava [4]. During in vitro experiments, the rate of bleeding from a vein 2–4 mm in diameter has been shown to be over 1 l/min [4].

The presacral venous plexus is formed by the middle sacral, lateral sacral and communicating veins and is the distal continuation of the anterior branches of the external vertebral venous plexus. The basivertebral veins penetrate sacral foramina from S3 to S5 and penetrate through the spongiosa of the sacral bone via a series of canals acting as a venous sinus [4]. The intrasacral canal venous plexus can be considered to be a terminal part of the vertebral venous system, thereby explaining the massive bleeding seen upon injury. Since the

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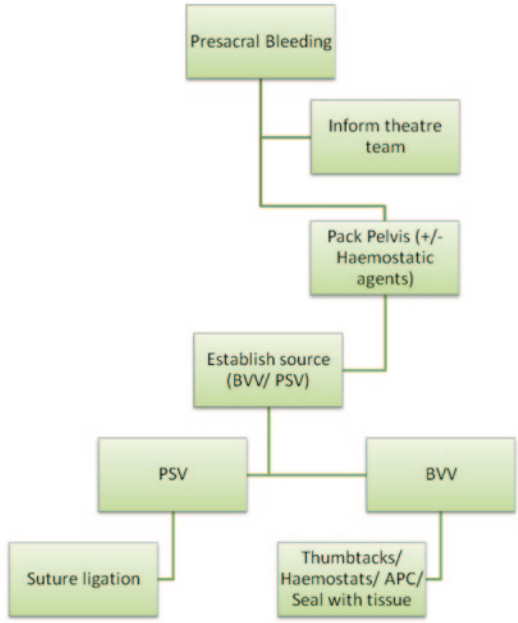

Fig. 38.1 Algorithm for management of presacral bleeding. *PSV* presacral veins, *BVV* basivertebral veins, *APC* argon plasma coagulation. Note that the techniques used for BVV bleeding can also be used for PSV bleeding

adventitia of the veins is blended to sacral periosteum at the foraminal opening, when the veins are lacerated during dissection, they retract into the sacral foramen. The basivertebral veins end in the presacral venous plexus anteriorly.

Patterns of Injury

As mentioned above, the key anatomical structures that contribute to significant bleeding lie posteriorly in the pelvis. Thus, a breach in the presacral fascia increases the risk of injury to venous structures with consequent bleeding. Therefore, although anterior rectal mobilisation can be more technically challenging, the risk of bleeding is greatest during posterior rectal dissection.

An oncologically sound operation requires dissection between the fascia propria of the rectum and the presacral fascia to ensure a total mesorectal excision (TME) [5]. However, this can be difficult for a number of reasons. It can be difficult to visualise the correct anatomical plane in patients who have had preoperative radiation or previous pelvic surgery with secondary adhesions. Recurrent or advanced malignancy can pose similar problems. Obese patients or those with a narrow pelvis can pose difficulties in achieving optimal access. Moreover, for surgeons beginning to perform laparoscopic or robotic TME, the learning curve may also lead to inaccuracies in dissection. A higher rate of intraoperative bleeding has been demonstrated in the context of laparoscopic colonic resection, and previous reports have also suggested that surgeon's inexperience may contribute to an increased risk of pelvic bleeding [2, 6].

Qinyao et al. have demonstrated the patterns of injury encountered during rectal dissection [4]. This includes the now largely abandoned practice of blunt mobilisation of the rectum posteriorly. Other reasons include laceration of the presacral fascia or clamping bleeding vessels on the presacral fascia and avulsing them with or without periosteum. The authors make a specific distinction between injury to the presacral venous plexus or to basivertebral veins [4].

It is important to acknowledge that increasing surgical intervention for advanced or locally recurrent pelvic malignancies has led to more radical and *en bloc*, non-anatomical resections. These operations are of longer duration and are characterised by greater blood loss in general and resections including sacrectomy, or pelvic sidewall dissections may involve high-volume, brisk bleeding due to non-traditional patterns of injury [7]. Nonetheless, the principles of management remain the same.

Management

The likelihood of encountering significant pelvic bleeding is highest in a patient with numerous unfavourable characteristics (obese, narrow pelvis, advanced malignancy). Thus, the operation is likely to be difficult to begin with, and it is likely that by the time bleeding is encountered, the surgeon may already be physically tired and

stressed. The literature has consistently demonstrated that checklists improve outcomes in a stressful situation [8]. As such, it is important to have a structured plan.

Prior to engaging in specific technical manoeuvres described below, the situation first needs to be acknowledged. Troublesome bleeding in the pelvis is a constant hindrance but does not impede progress nor compromise the patient. Significant bleeding, however, should be verbally acknowledged. This is important since all members in operating room may not be able to see the operation or may not be aware of the gravity of the situation. It is possible that the fellow or resident either performing or assisting in the operation may not have encountered significant pelvic haemorrhage before [9]. It will thus be necessary for the surgeon to take over the operation and organise the assistants in the most useful position (e.g. opposite the surgeon or in between the patient's legs) as per their seniority. An escalation in hierarchy should also be conducted with other members of staff in theatre. The most senior nurse should take over as the scrub nurse if not already involved, and multiple unscrubbed nurses should be available as a number of uncommonly used tools may need to be acquired expediently. Similarly, the anaesthesiologist should be informed directly.

Role of the Anaesthesiologist

Once the anaesthesiologist has been informed, acute circulatory support can be considered to have been delegated. Though the practical role of the surgeon is to control the bleeding, it is important to be familiar with the strategies at the disposal of the anaesthesiologist.

The focus of the anaesthesiologist will include initial measures including ensuring optimal intravenous access and volume resuscitation. This may lead to more intensive monitoring for the acute period and also in anticipation of the likely necessity of admission to the high dependency unit or intensive care unit.

Volume replacement may include activation of the massive transfusion protocol or component blood replacement in line with institutional practice. Serial thromboelastograph measurements may also be important to guide blood product replacement alongside advice from a haematologist [10].

Tranexamic acid may also help limit the magnitude of bleeding. Recent evidence suggests that tranexamic acid reduces bleeding in gastrointestinal surgery with no increase in the incidence of thromboembolic events [11]. Anecdotal experience also suggests that use during pelvic exenteration decreases surgical 'ooze'.

Role of the Surgeon

Once the operating team has been suitably organised, the pelvis should be packed. At this time, more help should be obtained from a colleague if possible. The importance of an experienced first assistant and the potential advantage of a hitherto uninvolved person cannot be overstated.

The injury now needs to be localised and illumination and proper exposure is crucial especially since a hallmark of this type of bleeding is gushing blood form the pelvic floor with a near-undetectable bleeding point. A practical solution to obtain optimal illumination is that the operating surgeon should utilise a headlight. Exposure can also be facilitated by expedient removal of the specimen whilst the area remains tamponaded with packs. If the bleeding point cannot be reliably detected, pressure should be maintained for 15–20 min. The temptation to re-examine the area ahead of this interval should be resisted, and the time should be used to formulate a plan and obtain necessary equipment. The pressure effects of packing may also be complemented with commercially available fibrin-based haemostatic agents [12]. A combination of haemostatic matrices (e.g. FloSeal, Baxter, USA) and absorbable haemostatic products (e.g. Surgicel Fibrillar, Ethicon, USA) may be used.

It is important to determine whether the bleeding has resulted from an injury to the presacral

venous plexus or to a basovertebral vein. If the bleeding point can be controlled by compressing the surrounding veins, there has been an injury to the presacral veins. If the bleeding is abated only by direct compression, it is from an injury to a fine or large-calibre basivertebral vein.

Injury to the presacral venous plexus can often be successfully managed with suture ligation ensuring that it is performed over intact presacral fascia and the bites are deep enough to contain presacral veins but also surrounding deep connective tissue so that the stitches hold traction [13].

Injury to the basivertebral veins can be managed with thumbtacks over the sacral foramen or by breaking the sacral foramen with a blunt-ended instrument [4]. A number of authors have reported the successful use of thumbtacks to stop presacral bleeding [14, 15]. It is inexpensive and technically straightforward unless the bleeding arises from veins near S3 or S4 as the curvature of the distal sacrum can make access difficult. Thumbtack displacement and chronic pain have been reported though these are secondary issues when confronted with life-threatening bleeding [16, 17].

Lou et al. have also described "welding" an epiploic appendix to the bleeding point with cautery whilst Saurabh et al. have reported successful management of bleeding with the use of argon plasma coagulation [2, 18]**.** Both techniques have been reported in the context of open surgery but could be applicable to minimal-access surgery. Rectus muscle tamponade has also been described as a strategy and is broadly similar to the use of the epiploic appendix though the former has been reported to lead to subsequent necrosis and abscess development [19].

Other strategies that have been successfully used include the application of bone wax, Teflon pledgets, expandable breast implant sizers or saline bags and haemostatic agents [16, 17, 20, 21]. Ligation of the internal iliac veins is usually futile since this will obstruct blood flow in the pelvic venous plexus, obturator veins and gluteal veins. As a result, blood flow will be redirected to the injured veins via the lateral or anterior sacral veins.

A number of strategies have been described in the literature. However, practical application of these techniques in an individual situation is limited by the surgeon's familiarity and comfort and availability of required tools within the institution. The listed strategies cannot be exhaustively worked through due to the rapidity of the bleeding. Rather, it is up to the individual to decide upon a few which he/she can employ in a systematic manner.

If the bleeding cannot be controlled despite all attempts, the pelvis should be packed and the operation abandoned. The patient should be transferred to the intensive care unit with a planned relook laparotomy when the patient has stabilised. Assistance from interventional radiologists may also be helpful for angioembolising any vessel showing extravasation of contrast though this is unlikely to be helpful due to the bidirectional nature of flow and redundant pathways contributing to bleeding.

Minimal-Access Surgery

Many of the techniques described above can be utilised during laparoscopic or robotic resection. The initial differences upon encountering significant presacral bleeding relate to the view, which may in fact be superior to open surgery, and identification of the bleeding point (Fig. 38.2). Port placement may preclude direct pressure over the sacrum, and extra ports should be inserted as appropriate to maintain direct pressure in an ergonomic fashion. Since the view during laparoscopic or robotic surgery may be highly magnified, the bleeding may appear even more voluminous. The other disadvantage is that it may not be possible to remove the operative specimen as quickly as during open surgery.

The specific strategies used successfully in the literature include argon plasma coagulation in a 'point and shoot' manner [18]. Germanos et al. have described the use of haemostatic agents to

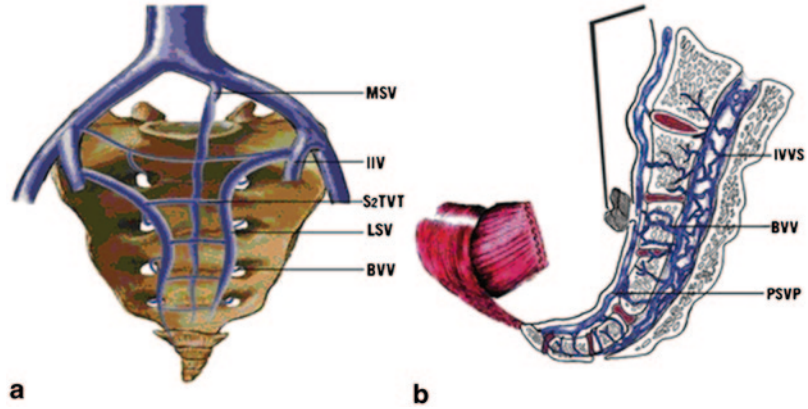

Fig. 38.2 Presacral bleeding. *MSV* middle sacral vein, *IIV* internal iliac vein, *LSV* lateral sacral vein, *BVV* basivertebral vein, *PSVP* presacral venous plexus, *IVVS* intervertebral venous system. (Reproduced with permission from [13] © Springer 2013)

control presacral bleeding [16]. Although their case reports are in the context of open surgery, a similar strategy of using haemostatic matrixes and fibrin-based haemostatic gauze may be applicable and technically straightforward in minimal-access surgery.

Suture ligation may also be used but will only be useful if the bleeding arises from the presacral venous plexus. It also requires advanced laparoscopic skills, and its applicability may be limited by unfavourable, non-ergonomic working angles with conventional port placement.

A simple algorithm reported in the literature involves a trial of local compression with gauze or an absorbable haemostat followed by attempted sealing of the bleeding point with either an omentum or an epiploic appendix. The graft is obtained using bipolar diathermy and then held in place with grasping forceps with monopolar diathermy to seal it in place. The third stage of the authors' algorithm was to use a bovine pericardial graft and attach it to the source of bleeding with endoscopic tacking devices [22].

Strategies used in minimal-access surgery are broadly similar to those used in open surgery, and the principles have been partially derived from liver bleeding during laparoscopic cholecystectomy. Although presacral bleeding can be safely managed laparoscopically or robotically, prolonged periods of time should not be spent attempting to control the bleeding without converting to open surgery.

The Postoperative Period

The patient should remain in a monitored environment, and their ongoing fluid and blood requirements should be managed to prevent the lethal triad of hypothermia, coagulopathy and acidosis. Patients may benefit from ongoing doses of tranexamic acid and antibiotics (though there is no evidence for this). Anticoagulation with heparin or equivalent should be withheld. The family should be informed.

Lastly, given the rarity of the event, a debriefing session should be held for all members involved. This is particularly valuable for junior members of staff. The benefit of an even an informal debriefing session is to discuss prevention and management in detail whilst also potentially resulting in system improvements as necessary.

Summary

Presacral bleeding is a rare but clinically significant event in open- or minimal-access pelvic surgery. It usually results from injury to either the presacral venous plexus or the basivertebral

veins. Conventional means to stop bleeding are usually unsuccessful. The management of this problem requires the active participation of the whole operating theatre team. Successful technical strategies involve localising the bleeding point, identifying whether the bleeding has arisen from the presacral venous plexus or basivertebral veins and employing appropriate strategies in a systematic manner in line with the surgeon's preference and availability of necessary tools within the institution.

Key Points

1. Correct identification of the TME plane, especially posteriorly
2. Pack the pelvis and identify source of bleeding
3. Inform operating room staff and get additional help if possible
4. Differentiate between injury to the presacral venous plexus and basivertebral veins
5. Follow a structured plan based on injury type—suture ligation/haemostatic agents/thumbtacks etc.

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Breakdown/Non-healing of Perineal Wound

39

Justin M. Broyles, Jonathan E. Efron and Justin M. Sacks

Introduction

Malignancies of the anorectum, vagina, and other soft tissues in anogenital region are the most common reason for perineal resection. Commonly employed procedures include the traditional abdominoperineal resection (APR), intersphincteric resection, pelvic exenteration, and low anterior resection (LAR). Although there is a trend toward more sphincter preserving surgery for rectal cancer, traditional APR is still used in 15–25 % of patients with rectal cancer [1].

The perineum is one of the more difficult sites in the human body to reconstruct after surgical obliteration due to the significant volume of dead space, close proximity of multiple organs, high bacterial counts, and the subjection to direct pressure in both the sitting and recumbent positions. Cancer patients receiving tumor extirpation in this anatomic location often have undergone neoadjuvant chemotherapy and/or radiotherapy to downstage their disease, which further impacts wound healing. As a result, wound complications are frequently encountered in these patients, with rates ranging from 40 to 65 % (Fig. 39.1) [1–4].

Primary closure of large perineal defects can be associated with unacceptable wound-healing complications ranging as high as 65 % [2–4]. Other common surgical complications include hematoma, seroma, abdominal and/or perineal hernia, fistulization, and nonhealing wounds [1]. Such complications can lengthen hospital stays, decrease mobility, prolong time to adjuvant therapy, and increase patient morbidity.

In an attempt to mitigate the occurrence of such complications, many plastic and reconstructive surgeons advocate the use of a pedicled, vascularized soft-tissue flap coverage to close large perineal defects [3, 4]. Utilizing a vascularized, soft-tissue flap will assist in obliterating dead space and this has shown to improve wound-healing outcomes by decreasing incisional tension while increasing vascular supply, oxygenation, and delivery of cytokines and growth factors. In the current chapter, we aim to provide a comprehensive overview of the various reconstructive options for perineal defects to educate the reader on how to prevent as well as treat perineal wounds in an effort to maximize patient outcomes in these challenging cases.

Disclosures: Dr. Justin M. Sacks is a speaker/consultant for LifeCell Corporation. Branchburg, NJ.

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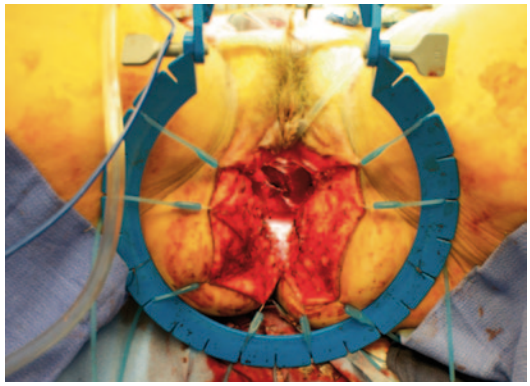

Fig. 39.1 Large perineal defect demonstrating vast dead space and exposed viscera

Preoperative Evaluation

The physiologic status of the patient must be considered and balanced with the overall reconstructive plan. The long-term prognosis of the patient must also be taken into account as well. Reconstruction to improve quality of life should be considered even in a palliative scenario. If possible, an accurate assessment of the wound or planned surgical site should be performed in the preoperative setting and may be facilitated by an examination under anesthesia.

Medical Comorbidities

A thorough review of the patient's past medical history should be performed to risk-stratify each patient using conditions that increase the relative risk of infection and/or wound-healing problems. Smoking has been shown to affect microcirculatory blood flow and soft-tissue healing and should be discontinued a minimum of 4 weeks prior to surgical intervention if possible [5]. Patients undergoing major reconstructive efforts require optimization of nutritional parameters prior to intervention [6–8]. If enteral feeding is not possible preoperatively, postoperative enteral or parenteral nutrition should be administered with protein supplementation.

Radiation Therapy

Radiation therapy induces tissue injury through changes in the microcirculation of the defect and its surrounding areas, leading to decreased perfusion and impaired wound healing [4]. The reconstructive surgeon should be cognizant of the timing, dosage, and location of any prior or planned radiation and not limit debridement of radiated tissue. Additionally, the surgeon should utilize tissue outside the field of radiation for flap reconstruction.

Chemotherapy

Neoadjuvant chemotherapy can significantly impair wound healing and should be considered when selecting reconstructive options. The plastic and reconstructive surgeon should work closely with the medical oncology team to determine if and when the patient will require adjuvant chemotherapy, as wound-healing complications can potentially delay onset to therapy.

Imaging

Preoperative evaluation with imaging modalities such as computed tomography (CT) and/or magnetic resonance imaging (MRI) could be obtained to evaluate the integrity of the surrounding soft tissue and vascular anatomy. While these adjuncts are not essential, they can assist the surgeon in surgical planning.

Timing of Reconstruction

The timing of perineal reconstruction is most often dictated by the status of the tumor and surgical margins. Certain factors such as advanced age, multiple comorbidities, or the need for locoregional control with adjuvant radiotherapy must also be considered in the timing. Primary reconstruction carries a significantly decreased rate of

Table 39.1 Classification of perineal defects by anatomic location

Anatomic structure(s) involved	Missing tissue components
Vaginal vault	S, MS, ST
Vulvoperineal surface	MS, ST
Scrotum	S, ST
Penis	S, MS, ST
Perineum and pelvic support musculature	S, ST (extensive)
Sacrum/pelvic rim	S, ST, +/− osseous involvement

S skin, *MS* mucosal surface, *ST* soft tissue

wound-healing complications and is preferred to delayed reconstruction in defects located in other areas of the body [9, 10]. Delayed reconstruction, while not optimal, is occasionally unavoidable for defects with extensive soft-tissue deficits or patient instability. If a patient requires delayed reconstruction, a negative pressure closure device is the preferred temporizing measure until definitive reconstruction can be performed at a later time.

Classification of Defect

Acquired perineal defects should be classified according to what structures are missing and/or compromised. This will allow the reconstructive surgeon to employ the correct reconstructive modality in an effort to replace damaged tissue with tissue that is most similar to that which is missing. The classification of perineal defects is listed in Table 39.1.

The size of the defect and types of missing tissue should be assessed for viability. Potential flap donor sites should be evaluated for adequate rotational length. If there is a potential for microvascular free tissue transfer, recipient donor vessels should be evaluated for patency. If these vessels are unavailable or greater length is required, arteriovenous loop can be created if needed. However, most perineal defects can be reconstructed with the use of local flaps typically from the abdominal wall, thigh, or buttock region.

Reconstructive Surgical Tenants

The core principles underlying reconstructive algorithms used by plastic and reconstructive surgeons are to progress from simple to more complex reconstructions on the basis of the specific wound requirements. The goal for each reconstruction is to provide a tension-free closure that obliterates all dead space which replaces the defect with tissue that is most similar to what is missing. The adage is “like with like.”

Local tissue flaps enable surgeons to reconstruct soft-tissue defects with similar tissue from an adjacent location. Axial pattern flaps are based on named blood vessels and are the mainstay of perineal reconstruction. Axial pattern flaps can be fasciocutaneous (deep muscle fascia with overlying skin), myocutaneous (muscle with skin), and myofasciocutaneous (muscle with deep fascia and overlying skin), which will enable reconstructive surgeons to repair defects with tissue that is similar to the resected tissue.

Microvascular free tissue transfer involves harvesting a tissue construct and its named blood supply from a distant region of the body and placing it into a defect using microvascular anastomosis between the flap’s donor vessels and the patient’s recipient vessels. Most cases are performed under magnification provided by a surgical microscope. The decision to use a particular flap is based on the requirements for replacing missing skin, adipose tissue, fascia, and muscle. The primary advantage of microvascular free

tissue transfer is that tissue of a quality similar to that of the resected tissue can be moved from a remote part of the body, thereby enabling optimal aesthetic and functional outcomes. This also allows irradiated or infected tissue to be removed and replaced with soft, pliable, and vascularized tissue from a different part of the body, outside of the field of injury. Drawbacks of free tissue transfer are related to donor site morbidity and the potential for longer operative times.

Adjuncts to Flap Surgery

Negative Pressure Wound Therapy

Negative pressure-assisted closure can provide for temporary coverage in soft-tissue perineal defects when definitive reconstruction is either delayed or not required. When utilized appropriately, this device can promote neo-vascularization, decrease edema, and increase local granulation tissue as well as providing contractile force at wound edges [11]. This modality is often used to prepare the wound bed for definitive reconstruction with soft-tissue flaps in a delayed fashion if immediate surgical intervention is not possible. Additionally, it can also be used to promote healing by secondary intention in partial-thickness defects.

Tissue Expansion

Tissue expansion is a process in which an inflatable prosthetic implant with a silicone shell is used to expand local and regional tissues so that they can eventually be advanced into the wound in a delayed fashion. The inflatable implant is inserted at the time of tumor extirpation or during a second procedure. At subsequent office visits, saline is injected through an integrated or remote port to gradually expand the implant. Once the tissue has been sufficiently expanded, it can be advanced into the defect in a second surgical procedure. Because tissue expansion takes time, the method is not feasible for immediate perineal reconstruction that requires immediate coverage of hollow viscous or neurovascular structures. Risks of tissue expansion include infection, extrusion, and rupture of the implant [12]. Additionally, the sequential expansion of the prosthesis can be uncomfortable to the patient and requires multiple office visits to obtain satisfactory expansion.

Biologic Tissue Matrices

Commercially available biologic tissue matrices (BTMs) currently come from five different sources: human dermis, porcine dermis, porcine small intestinal submucosa, bovine dermis, and bovine pericardium [13]. BTMs claim to induce early revascularization capacity in an effort to provide soft-tissue coverage and resist infection. For perineal reconstruction, BTMs can be used in a multitude of capacities including the creation of pelvic diaphragms to prevent visceral herniation into low perineal defects. Additionally, BTMs can be used to reinforce abdominal site donor defects in an effort to decrease bulge and hernia formation in the face or prior irradiation or concurrent ostomy placement.

Characterization of Axial Pattern Flaps (Table 39.2)

Rectus Abdominis Muscle

The pedicled vertical rectus abdominis (VRAM) flap is a versatile flap based on the deep inferior epigastric system. The flap can be harvested as a muscle-only, myocutaneous flap, or perforator flap with a large skin paddle. All but the largest of myocutaneous flaps can still allow for primary closure of the donor site. However, as previously mentioned, synthetic or BTM reinforcement may be required to prevent subsequent complications. The flap has a robust vascularity and abundant soft-tissue bulk that can be used to obliterate the vast amounts of dead space seen with large APR defects [14–17]. Butler et al. demonstrated that despite the overall complication rate not being significantly different between primary closure and VRAM flap reconstruction, patients who

Table 39.2 Commonly employed pedicled flap options for perineal reconstruction

Flap name	Blood supply	Area of use
Rectus abdominis	Inferior epigastric artery	Total perineal reconstruction/posterior vaginal wall
Gracilis	Medial circumflex femoral artery	Smaller perineal defects
Gluteus maximus	Superior gluteal artery	Posterior/inferior perineal defects
Pudendal	Posterior labial artery	Vaginal vault defects
Anteriolateral thigh	Descending branch of lateral circumflex femoral artery	Total perineal reconstruction

underwent VRAM reconstruction experienced significantly lower incidences of perineal abscesses (9 vs. 37%) and major wound dehiscence (9 vs. 30%) (Fig. 39.2) [17].

Advantages of the VRAM are seen in the ability to provide robust, vascularized tissue into the defect that is outside of the field of radiation. The large, vertical skin paddle is particularly useful when reconstructing the contour of the posterior vaginal wall. Alternatively, this flap can be tubed to create a neovagina if the entire vaginal vault has been obliterated. In many cases, the donor site is already exposed during tumor extirpation negating the need for a second incision and donor site (Fig. 39.3).

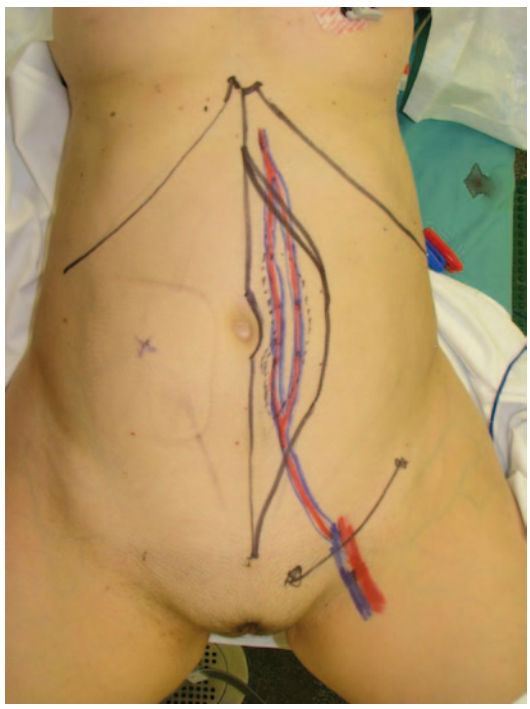

Fig. 39.2 Surface anatomy of VRAM (vertical rectus abdominis) flap displaying arterial pedicle

Disadvantages of this flap are inherently related to the anatomic location of the donor site. If the patient is not undergoing a concurrent midline laparotomy, flap harvest obligates the patient to undergo an anterior approach, which can lead to herniation, bulge formation, wound-healing complications, and/or injury to the surrounding viscera. Furthermore, this flap should not be harvested at the site of planned ostomy placement to allow the new stoma to be anchored into the rectus abdominis muscle. Finally, the vascularity of the VRAM is questionable in the presence of prior ostomy placement through the rectus abdominis muscle and should be avoided if at all possible.

Gracilis Muscle Flap

The pedicled gracilis muscle flap is a versatile flap based on the medial circumflex femoral artery in the proximal thigh. The flap can be harvested as a muscle-only or a myocutaneous flap with a small skin paddle. The flap has minimal donor site morbidity and can be harvested bilaterally if additional soft-tissue bulk is required.

Advantages of the gracilis flap include a relative ease of dissection with minimal donor site morbidity. The ample pedicle length coupled with a relatively linear muscle design allows for the flap to be tailored fitting a variety of defects. It is particularly useful for obliterating fistulous tracts between the rectum and vagina or urethra with an excellent success record [18, 19].

Disadvantages of the gracilis muscle flap are related to flap size and dimension. Often times, even when harvested bilaterally, the gracilis flap

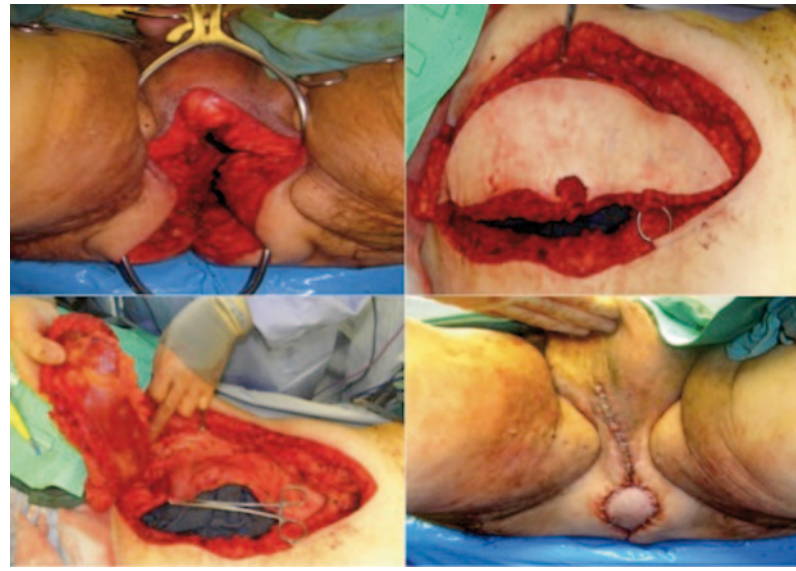

Fig. 39.3 VRAM (vertical rectus abdominis) coverage of perineal defect

is not large enough to obliterate very large perineal defects. Furthermore, the distal tip of the myofasciocutaneous flap can be rather bulky with questionable venous return leading to venous congestion and wound-healing problems.

Gluteus Maximus Muscle

The gluteus maximus muscle is typically harvested as a muscle-only flap, but can be harvested as a myocutaneous flap if needed. The flap is based on the superior gluteal artery and has a short axis for rotation, rendering it useful only for defects posterior perineum [20, 21]. The superior half of the muscle is less useful for perineal reconstruction, but may provide durable coverage for sacral defects. The inferior half of the muscle is able to provide coverage for the ipsilateral ischium as well as extending down to the posterior most aspect of the perineum [22].

The gluteus maximus flap provides a robust, relatively large amount of vascularized muscle and fascia. The donor site of the flap can be closed with relative ease using a V to Y advancement closure. Because the flap has such a large muscle component, the gluteus maximus is prone to denervation atrophy. Additionally, the proximity to the sciatic nerve can provide for a potential source of morbidity during dissection. Finally, the flap is less useful for anterior defects as the arc of rotation is insufficient to reach areas of the anterior perineum.

Pudendal Flap

The pudendal flap, also known as the Singapore flap, is a local fasciocutaneous flap that is based on the posterior labial vessels of the proximal, inner thigh. The flap can be harvested as a sensate flap based on the posterior labial branch of the pudendal nerve, making it an ideal solution for vaginal vault reconstruction. These flaps can be harvested unilaterally or bilaterally and are able to provide thin, sensate, fasciocutaneous coverage of smaller defects of the anterior and lateral vaginal walls [23, 24].

Advantages of the pudendal flap are revealed in the flap's thin, sensate flap design. Additionally, the inner thigh provides a well-tolerated donor site with minimal morbidity. This flap does not provide vascularized muscle, and therefore, there is little mobility restriction seen postoperatively. Disadvantages are seen in the fact that this is a smaller flap that is not well suited to provide coverage for larger perineal defects. Additionally, this flap is in close proximity to the perineum and may be compromised in the setting of neoadjuvant radiotherapy.

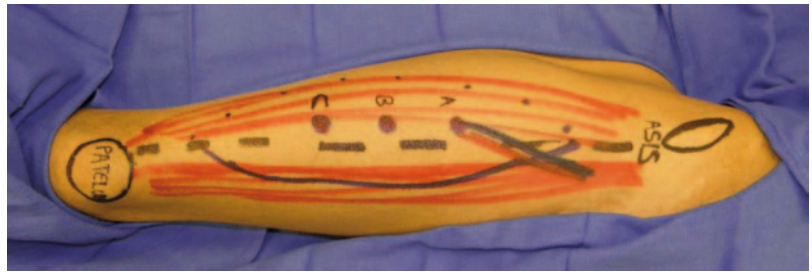

Fig. 39.4 Surface anatomy of ALT (anteriolateral thigh) flap displaying arterial pedicle

Anteriolateral Thigh Flap

The anteriolateral thigh (ALT) flap has traditionally been described as a free flap rather than a pedicled flap and has been used to reconstruct a wide variety of defects in the pelvis, perineum, and lower abdomen [25]. The flap is harvested as a fasciocutaneous flap based on the descending branch of the lateral circumflex femoral artery. In addition to a relative ease of dissection, the flap can provide vast amounts of skin and fascia while allowing for minimal donor site morbidity (Fig. 39.4) [25, 26].

Advantages of the ALT flap include a reliable dissection which can provide an abundance of vascularized skin and fascia. The flap has a reliable vascular pedicle with a wide arc of rotation. If additional soft-tissue bulk is required for dead space obliteration, the ALT can be harvested as a myofasciocutaneous flap with vastus lateralis (Fig. 39.5).

Disadvantages of the ALT flap are best visualized with corpulent patients where increasing the amount of adipose tissue and fascia can limit mobilization into the perineum. Furthermore, the larger flaps, which are required for vast dead space obliteration, can be prone to venous congestion and wound-healing difficulties.

Postoperative Care

Ambulation

In an effort to mitigate the thrombotic effects of surgery as well as potentially offload pressure on the wound closure and flap, ambulation is recommended on the first postoperative day. If medical and/or surgical comorbidities preclude

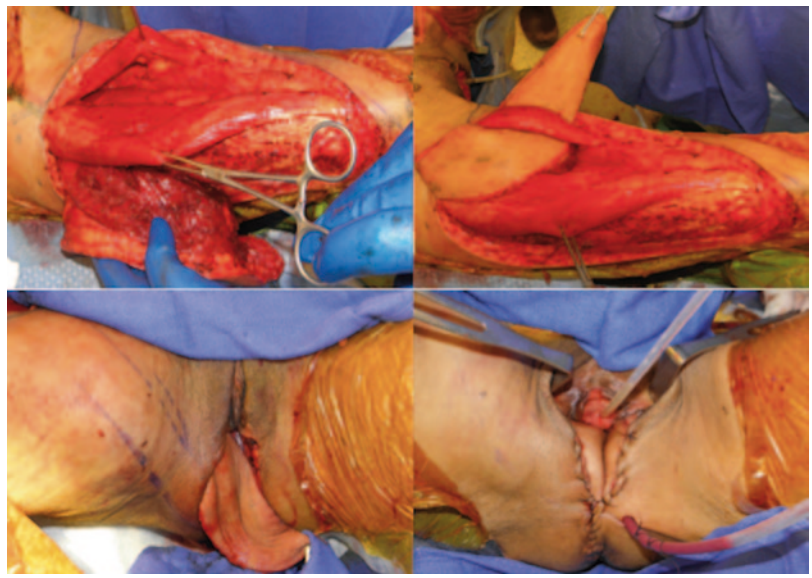

Fig. 39.5 ALT (anteriolateral thigh) flap for perineal reconstruction

mobilization, the patient should be turned every 2 h to decease the incidence of ischemic ulcer creation as well as to offload incisional pressure. In our practice, a combination of early ambulation as well as instructing the patient to resist sitting in a chair is used for a minimum of 2 weeks postoperatively. Using this strategy, prolonged pressure on the incision is avoided and the potential for subsequent flap necrosis is mitigated.

Drain Management

When closing wounds over an area of tumor extirpation, a vast amount of dead space is invariably created. It is critical for the reconstructive surgeon to mitigate this dead space with a combination of vascularized soft tissue and closed-suction drains. The placement of closed-suction drains will assist in the elimination of seroma and hematoma formation and should be left in place until each drain produces less than 30 ml of exudate per day over a span of 3 consecutive days. These drains should be removed in sequence, rather than simultaneously.

Complications

Complications rates in patients requiring soft-tissue coverage of viscera and/or require adjuvant therapy are devastating to the patient and the surgical teams. The most commonly encountered complications include seroma, hematoma, wound infection, and flap failure. In patients where soft-tissue fluid collections are suspected, imaging studies such as CT or MRI are indicated to evaluate the location and extent of the suspected collection. If there is any indication of infection, culture directed, broad-spectrum antibiotics should be started and sharp debridement of all necrotic tissue should be performed.

Flap failure, either partial or complete, can occur for a myriad of reasons and should generate an operative evaluation of the flap to interrogate the potential for reversible problems. Small wounds can generally be managed conservatively with dressing changes and/or negative pressure wound therapy. Larger wounds, which may dictate prolonged wound care regimens, should be evaluated in the operating room, and sharp debridement with additional flap closure may be indicated.

Aggressive management with debridement of devitalized tissue, wound care, and culture-specific antibiotics will typically allow all wounds to heal secondarily following flap reconstruction. Perineal wounds closed primarily in the setting of prior radiotherapy have a much higher rate of complications leading to persistent drainage and potential fistula formation. These sequelae are mitigated through careful analysis of the wound bed and appropriate reconstructive techniques.

Summary

Perineal reconstruction with pedicled fasciocutaneous or myofasciocutaneous flaps can be performed safely, with acceptable complication rates in the presence of contamination, compromised soft-tissue vascularity, and radiotherapy. For optimal results multidisciplinary teams should work in concert to properly evaluate the patient and discuss ideal treatment scenarios.

Key Points: Preventing Complications

1. Communication between the plastic and reconstructive surgery, surgical oncology, and medical oncology teams is of the upmost importance when planning surgery. Adequate communication allows for the surgical teams to provide full disclosure to the patient with regard to potential donor site morbidity. Additionally, this allows for proper preoperative imaging and evaluation of potential flap donor sites to reconstruct the perineum.
2. When closing wounds over the perineal area, it is critical to identify structures that must be covered with vascularized tissue. Local muscle flaps based on axial pattern blood supplies are optimal to obliterate dead space and cover hollow viscous organs within the surgical field.

3. Attempting closure of large perineal wounds in a primary fashion without a muscle flaps will led to higher rates of wound dehiscence, seroma, and infection. The surgeon should obliterate all associated dead space in the surgical wound with both vascularized tissue and closed-suction drains. Preventing hematoma and seroma formation is an important component to the success of any wound closure.
4. When reconstructing soft-tissue defects of the perineum, it is critical to maintain a wound bed free of devitalized tissue. Scar tissue and devitalized adipose and muscle fascia will act as a nidus for infection and should be removed with sharp debridement.
5. Patients and surgical teams should be advised to offload all pressure onto the wound closure site. Aggressive, early ambulation should be initiated to prevent ischemic pressure necrosis of the closure.

Key Points: Managing Complications

1. Early, postoperative venous congestion of soft-tissue flaps should prompt the surgical team to evaluate the reconstruction in the operating room for any potentially reversible causes of ischemia to prevent total or subtotal flap loss.
2. Signs or symptoms of infection around the reconstructed area should be visualized radiographically to evaluate for the presence of hematoma, seroma, or abscess so that the appropriate management may be performed within a timely fashion.
3. If possible, enteral or parenteral nutritional supplementation should begin in the perioperative setting with protein supplementation to ensure adequate wound-healing potential.
4. Small areas of incisional dehiscence are not uncommon in larger reconstructions and should be managed conservatively with dressing changes and/or negative pressure wound therapy.
5. Large areas of wound dehiscence should prompt operative evaluation to evaluate the integrity of the flap and the potential need for revisionary procedures.

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Complications After TEM (Transanal Endoscopic Microsurgery) and TAMIS (Transanal Minimally Invasive Surgery)

40

Maria Widmar and Julio Garcia-Aguilar

Background

Decades before advances in antisepsis, perioperative care, and surgical technique made the combined abdominal/perineal excision of the rectum possible, the extraperitoneal portion of the rectum was accessed by simple diagnostic and therapeutic interventions. Removal of the entire rectum and mesorectum, first without and later with preservation of the sphincters, soon became the optimal treatment for patients with distal rectal cancer. However, these operations have always been associated with significant morbidity and long-lasting functional sequelae. Local treatment of cancer of the extraperitoneal portion began to gain popularity in the 1950s, as an alternative to complete removal of the rectum in patients with early-stage tumors, or those considered unsuitable for a major operation.

For years, the local excision of rectal tumors was performed through a posterior parasacral incision popularized by Kraske in the nineteenth century, by the transsphincteric approach described by York-Mason, or transanally as described by Parks. The parasacral and transsphincteric approaches provide relatively good exposure of the distal rectum, particularly of the anterior wall. However, they are associated with significant morbidity, in particular rectocutaneous fistulae (in the parasacral approach), sphincter dysfunction, and anal incontinence (in the transsphincteric approach). The transanal approach, while safer than the parasacral or transsphincteric, is a technically challenging procedure and allows access only to tumors located in the distal rectum.

The first transanal endoscopic platform, known as transanal endoscopic microsurgery (TEM), was introduced in the 1980s by Gerhard Buess. Its purpose was to facilitate local excision (LE) and extend the indications for LE to tumors located in the mid- and even the upper rectum. Commercialized by The Wolf Corporation (Richard Wolf Medical Instruments Corp., Vernon Hills, IL), the TEM platform includes a number of large bore-operating proctoscopes, a specifically designed insufflation system and instruments, and binocular optics that provide tridimensional visualization. The equipment is complex and expensive and is available at only a limited number of institutions. The Storz Company (KARL STORZ GmbH & Co., Tuttlingen, Germany) later developed a simplified transanal endoscopic operation (TEO) platform, which also uses large bore-operating proctoscopes but takes advantage of the insufflation, instrumentation, and optics of conventional laparoscopy. This platform, while less expensive than TEM, utilizes less sophisticated instrumentation and does not provide tridimensional visualization. In recent years, surgeons have adopted the access device used in single-port laparoscopy for

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transanal minimally invasive surgery (TAMIS). Similar to TEO, TAMIS utilizes conventional laparoscopic insufflation, instrumentation, and optics. A number of groups are now using the *da Vinci*® Surgical System, a robotic platform (Intuitive Surgical, Inc.®, Sunnyvale, CA), to enhance visualization and precision during TAMIS.

A number of studies have demonstrated the advantages of LE compared to conventional rectal cancer surgery: faster recovery; lower morbidity; minimal bowel, urinary, and sexual dysfunction; and, in many patients, avoidance of a stoma. However, LE—at least when performed using the conventional transanal approach—provides inferior oncologic results compared to radical surgery for stage I rectal cancer [1–4]. Local recurrence is higher for patients with T1 and T2 tumors treated with LE; for patients with T2 tumors, long-term survival is lower compared to TME. The combination of adjuvant or neoadjuvant chemoradiation with LE for T2 tumors may improve the results compared to LE alone, but these approaches are still under investigation [5–9]. A number of reports indicate that LE of rectal cancer performed with TEM, TEO, and TAMIS is associated with a lower risk of local recurrence compared to TAE [10–12]. However, most studies comparing different techniques are small, retrospective case series using historical controls.

In spite of the uncertain oncological results, the fact is that the proportion of early-stage rectal cancers treated by LE continues to increase worldwide. As the indications for these procedures expand, and as their use in patients who have undergone neoadjuvant radiation increases, knowledge about diagnosis and management of the associated complications is of high importance.

Complications of TEM and TAMIS

The proportion of patients developing complications after TEM, TEO, and TAMIS is low, compared to radical surgery. The types of complications are similar to those observed after TAE; however, complications related to penetration into the peritoneal cavity are more common after TEM, TEO, or TAMIS, as these techniques allow local excision of tumors located in the intraperitoneal portion of the rectum. The reported overall complication rate ranges from 6 to 20% [10, 13–15]. These estimates come mostly from the TEM literature, as there are still relatively few series reporting outcomes after TAMIS. The complication rate appears to be higher in patients who have undergone neoadjuvant chemoradiation therapy (CRT) [16]. In a study by Marks and colleagues in 2008, the wound dehiscence rate was significantly higher in radiated versus non-radiated patients (25.6% vs. 0) [17]. Though a majority responded to conservative management, 1 of the 11 patients required a diverting colostomy.

The most frequently reported complications are fever, urinary retention, rectal bleeding, sepsis, suture line dehiscence, rectovaginal fistula, penetration into the peritoneal cavity, rectal pain, temporary incontinence, and anorectal stenosis [1–39]. In nearly all of the studies, urinary retention and bleeding were the most common complications.

Pelvic abscess and sepsis are relatively uncommon complications of TEM and TAMIS. However, their occurrence may necessitate reoperation including temporary or permanent diversion. Severe pain requiring readmission has been attributed to these complications. In instances where TME is necessary after LE, pelvic sepsis and the resulting inflammation may further complicate dissection. Tables 40.1 and 40.2 summarize the literature on surgical complications after TEM or TAMIS.

Postoperative Fever

A high temperature in the immediate postoperative period is common. However, in most patients this is temporary and is not necessarily followed by the development of other septic complications. The cause of early postoperative fever is unknown, but may be related to transient bacterial translocation immediately after the procedure.

Table 40.1 Select TEM (transanal endoscopic microsurgery) studies

	Kumar [24]	Perez [16]	Lezoche [15]	Bignell [20]	Tsai [28]	Allaix [25]	Bach [18]	Guerrieri [8]	Buess [14]
Patients (*n*)	325	36	135	262	269	300	424	588	326
Indication:(*cancer, benign, both*)	Both	Both	Cancer	Both	Both	Both	Cancer	Both	Both
Complications (*%*)	10.5	44	10.4	13	21	7.7	14.9	11.4	16
Mortality (*%*)	0.3	0	0	0.8	0	0	1.4	0	0
Septic complications (*n*)	10	20	10	8	26	11	18	54	NR
Dehiscence	0	17	9	0	3	5	0	36	3
Abscess/pelvic sepsis	2	–	1	7	–	–	5	–	–
Peritoneal entry	9	–	–	–	20	13	9	16	–
Missed peritoneal entry	1	1	–	1	–	1	1	–	–
Fistula	1	2	–	0	–	5	2	2	2
Fever UO	–	–	–	–	2	–	–	–	–

Table 40.2 Select TAMIS (transanal minimally invasive surgery) studies

	Albert [10]	Lee [36]	Bridoux [37]	Barendse [38]	Lim [39]
Patients (*n*)	50	25	14	11[a]	16
Indication: (*cancer, benign, both*)	Both	Both	Both	Both	Both
Complications (*%*)	8	4	21	7.7	0
Mortality (*%*)	0	0	0	0	0
Septic complications (*n*)	1	0	1	0	0
Dehiscence	–	–	–	–	–
Abscess	–	–	–	–	–
Peritoneal entry	1	–	0	–	–
Missed peritoneal entry	–	–	–	–	–
Fever UO	–	–	1	–	–

[a] 2 converted to TEM (transanal endoscopic microsurgery), 2 had concurrent TMEs (total mesorectal excisions)

Wound Dehiscence

The need for closure of the rectal wound during LE in the extraperitoneal portion of the rectum is controversial. The potential advantages of wound closure include securing hemostasis and reducing fecal contamination. The chief disadvantage is the potential creation of a dead space that may become a perfect environment for the development of septic complications. The enhanced visualization and new instrumentation provided by TEMS, TEO, and TAMIS platforms facilitate suturing and knot-tying or clipping. As a consequence, rectal wounds are almost always closed watertight after TEM or TAMIS excision. The closure can be done as a running suture, which is facilitated by clips instead of knot-tying, or with interrupted sutures (Fig. 40.1).

The reported rate of wound dehiscence ranges from 0 to 15 % and can lead to complications such as stenosis and fistula [16, 18, 19]. The true rate of wound dehiscence is probably higher because only symptomatic patients undergo rectal examination in the early postoperative period. Wounds located closer to the dentate line, particularly in patients who have received neoadjuvant chemoradiation, are more likely to dehisce [7, 17]. Table 40.3 describes the treatment for wound dehiscences in each of the major TEM and TAMIS studies discussed above. In the study by Perez et al., 9 of 11 readmissions within 30 days of TEM excision were due to severe pain secondary to wound dehiscence [16]. Furthermore, all patients

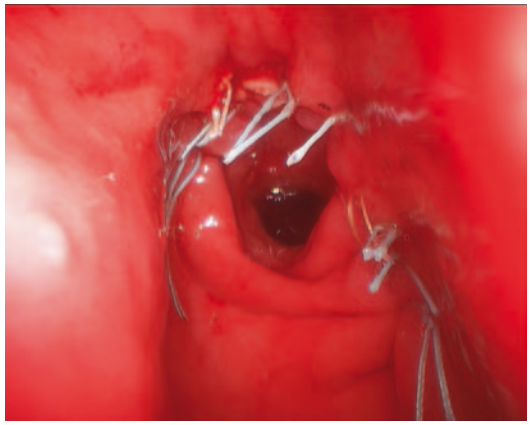

Fig. 40.1 Rectal wounds are almost always closed watertight after TEM or TAMIS excision. The closure can be done as a running suture, which is facilitated by clips instead of knot-tying, or with interrupted sutures

with late complications had been diagnosed with early wound dehiscence. Lezoche et al. described partially dehisced suture lines in 9 of 135 patients (6.7%), all of which were resolved with antibiotic enemas and "occasionally by fasting and parenteral nutrition" [15].

Rectal Pain

Persistent anal and rectal pain is a common complaint, particularly in patients with low rectal cancer treated with chemoradiation. In the ACOSOG Z6041 trial investigating the treatment of T2N0 rectal cancer with preoperative chemoradiation and LE, 8% of patients complained of grade 3 anal pain [7]. This has been attributed to the dehiscence of a wound close to the anal canal, which, in contrast to the rectal wall, has rich somatic pain innervations. The pain often persists for several weeks until the dehisced wound heals [16]. A diverting temporary ostomy should be considered in patients with very low rectal tumors who have undergone radiation. A diverting temporary ostomy should be considered even in those who have not had radiation, depending on the size of the lesion and the amount of tension expected after closure. Some surgeons have also adopted the routine use of antibiotics for an extended period following excision of very distal tumors [20].

Peritoneal Perforation

Peritoneal perforation during TEM, TEO, and TAMIS occurs at a median rate of 4.8%, although this ranges from 0 to 32% in the literature [21]. During excision of anterior tumors, this rate may be even higher, especially in those located above 9 cm, where entry into the peritoneum should be expected [19, 22]. The consequences range from postoperative pain or distention to intraabdominal sepsis. On a practical note, peritoneal perforation compromises adequate visualization by evacuating the necessary pneumorectum for TEM, TAMIS, and TEO procedures. The most feared complication is peritonitis caused by the seeding of the abdominal cavity with rectal luminal

Table 40.3 Outcomes after wound dehiscence/failure of closure

	Kumar [24]	Perez [16]	Lezoche [15]	Tsai [28]	Allaix [25]	Guerrieri [26]
# Cases	1	17	9	4	5	36
Management						
Non-operative	0	16	9	2	0	35
Operative	1	1	0	2[a]	2	1
Transanal	–	–	–	–	NR	1
Abdominal	1	1	–	2	NR	–
Ostomy	1	1	–	–	NR	–
Radical resection	–	–	–	–	NR	–

NR not reported

[a] Both patients had peritoneal entry, which was repaired during the primary surgery

Table 40.4 Outcomes after peritoneal entry

	Kumar [24]	Perez [16]	Bignell [20]	Tsai [28]	Allaix [25]	Bach [18]	Guerrieri [26]	Albert [10]
# Cases	10	1	1	20[a]	13	9	16	1
Diagnosis					NR			
Intraoperative	9	0	0	20		9	16	1
Missed	1	1	1	0		0	0	0
Intraoperative management					NR			
Conversion	0	–	–	0		1	1	0
Transanal repair	9	–	–	20		6	14	1
Radical surgery	0	–	–	0		1	1	0
Ostomy	0	–	–	0	0	2[b]	0	0
Postoperative management			NR		NR	NR		
Transanal repair	9	0		–			–	–
Radical surgery	0	0		–			–	–
Ostomy	0	0		–	0		–	–
Conservative	1	1		–			–	–
Mortality	0	0	1	0	0	0	0	0

NR not reported
[a] Also listed in wound dehiscence
[b] Intraoperative or postoperative identification not specified

content. There, were early concerns regarding the possibility of disseminating cancer cells into the peritoneal cavity after peritoneal perforation. As outcomes after TEM, TAMIS, and TEO continue to be studied, there is currently no evidence that peritoneal perforation compromises oncologic outcome [21]. In a multinational study specifically examining the effect of peritoneal perforation on outcomes in 888 patients, Baatrup et al. demonstrated no increase in long-term oncologic failure [23].

Entry into the peritoneal cavity is typically recognized during surgery by sudden loss of, or difficulty maintaining, pneumorectum. The overall risk of peritonitis is low, provided that the perforation is recognized intraoperatively and the peritoneal defect and rectal wound are securely closed. This can typically be accomplished transanally, though a transabdominal repair, either open or laparoscopic, may be necessary if the peritoneal or rectal wound closure is suboptimal.

So-called "missed" perforations may present in the postoperative period with increasing pain, pneumoperitoneum, or in some cases, evidence of intraabdominal sepsis. Both conservative treatment and surgical approaches are described in the literature. When reoperation is necessary, either transanal repair or transabdominal washout can be attempted. The decision to divert is made on a case-by-case basis and depends on the patient's clinical status, the timing of presentation, and the degree of contamination of the peritoneal cavity. It is likely that "missed" perforations requiring reoperation are also more likely to require proximal diversion, compared to those recognized intraoperatively due to the increased peritoneal contamination. Table 40.4 describes the sequelae and treatment of patients with peritoneal perforation.

The possibility of a peritoneal penetration emphasizes the importance of mechanical bowel preparation and the use of prophylactic antibiotics in patients undergoing TEM, TEO, or TAMIS—particularly for tumor located in the mid- and upper rectum. Patients with peritoneal

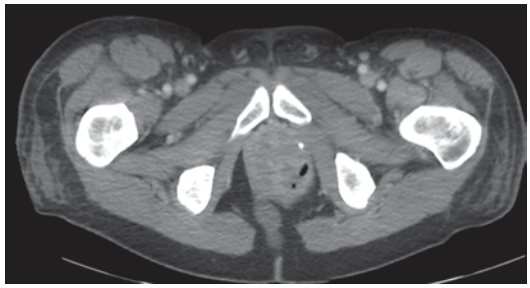

Fig. 40.2 CT scan showing pelvic abscess

perforations should be admitted to the hospital for observation.

Pelvic Phlegmon and Abscess

Clinically apparent pelvic sepsis or abscesses are relatively uncommon after TEM, TEO, and TAMIS, with rates below 1% reported in most series (Tables 40.2 and 40.3). This is significantly lower than the rate of wound dehiscence. Considering the high bacterial load present even in the mechanically prepared bowel, it is surprising how few dehiscences progress to frank sepsis or abscess.

Pelvic sepsis is characterized by persistent fever, malaise, rectal or pelvic pain, anal discharge, and urinary retention. The white count is typically elevated, and the abscesses can be visualized on imaging studies such as CT scan (Fig. 40.2). Inspection of the rectum often reveals a partially dehisced wound with purulent drainage. Most patients respond to antibiotic therapy, but some may require drainage through the rectum, which is achieved by enlarging the opening of the suture line. In general, percutaneous drainage is not recommended because it may result in an extrasphincteric fistula-in-ano. Special attention should be paid to abscesses located anteriorly in female patients as these may drain spontaneously through the vagina, resulting in rectovaginal fistulae. Some patients with more advanced sepsis may require temporary diversion. A study by Bignell in 2009 revealed seven cases (2.7%) of pelvic sepsis and abscess after TEM excision following neoadjuvant CRT. Five of these seven patients (71.4%) required a temporary diverting stoma, while two improved with conservative therapy [20]. As is the case in wound dehiscence, Bignell provided evidence that pelvic sepsis and abscess are more likely to occur in LE of lesions located within 2 cm of the dentate line.

Fistula

The rarest of septic complications after TEM and TAMIS is fistula formation, with a rate of less than 0.5% reported in most studies [14, 16, 18, 24–26]. In the studies described above, 11 rectovaginal fistulae, 1 rectovesical fistula, and 1 rectoseminal vesicle fistula were reported. In general, these were treated surgically, with the exception of a fistula from the rectum to the seminal vesicle, which resolved with antibiotics alone.

It is important to recognize that, with the increasing use of TEM and TAMIS for more advanced disease, we may see more fistula formation associated with operating on the irradiated rectum. Fistulae after rectal surgery are the result of a combination of factors. Wound dehiscence and infection are known instigators. In our experience, unrecognized electrocautery injuries can also act as culprits. In a female patient, it is important to recognize the thin septum between the anterior rectum and the vagina, as this can be easily violated with Bovie or ultrasonic dissection. If malignancy is not suspected, mucosectomy may be preferable to full-thickness excision [25].

While clinical presentation of a fistula is often delayed, it is important to keep some contributing factors in mind. Wound dehiscence, wound infection, and radiation all contribute to fistula formation. As is true in wound dehiscence and abscess, if a thermal injury is recognized intraoperatively, both diversion and a prolonged course of antibiotics should be considered for appropriately selected high-risk patients.

Bleeding

The rate of rectal hemorrhage after TEM, TAMIS, and TEO is 1–10% in most studies [7, 13, 18, 20, 25, 27]. Rates of significant bleeding, requiring either transfusion or reintervention, range from 1.7 to 2.7% [13, 20, 28]. Bleeding can occur in the

immediate postoperative period, or it may have a delayed presentation; at least one study reports rectal hemorrhage up to 2 weeks after surgery [28].

Management of postoperative hemorrhage depends on the clinical presentation. Minor bleeding in a clinically stable patient can be observed, with blood transfusions as necessary. Major hemorrhage or hemorrhage presenting in the late postoperative period should prompt examination under anesthesia, as it may be associated with wound dehiscence. When possible, placement of additional sutures or reinforcement of the wound will control bleeding. The application of electrocautery or energy devices such as Ligasure to bleeding points, along with rectal packing, is also successful in some cases.

Achieving optimal hemostasis intraoperatively is the key to preventing these complications. Watertight wound closure may prevent hemorrhage. Though this is still debated in the literature, multiple studies report episodes of postoperative hemorrhage significant enough to require operative management, during which the finding was a wound dehiscence [13, 20, 29]. Several authors have also advocated use of the harmonic scalpel instead of electrocautery for improved hemostasis. This technique has the added benefit of better visualization because it is free of the smoke associated with electrocautery [20, 30].

Incontinence

Fecal incontinence and anorectal dysfunction after TEM and TAMIS have been a serious concern since the introduction of these techniques. Early reports of decreased function after TEM raised logical concerns, because the TEM platform is 40 mm in diameter and may be used for a prolonged period in resecting larger, more proximal tumors [31]. Numerous studies have investigated the impact of TEM on functional, anatomical, and physiological outcomes [28, 32]. Parameters such as postoperative sphincter defects can be diagnosed by endorectal ultrasound, while changes in resting and squeeze pressure, and rectal pudendal nerve terminal latency potentials, can be assessed by physiological studies [33, 34]. These investigations have identified two risk factors for decreased anorectal function after TEM: long operative times (>2 h) and preexisting anorectal dysfunction. Despite the measured incidence of sphincter defects (29%) and decreased resting pressure postoperatively, long-term fecal continence was not affected in these patients. Tsai and colleagues reported on their experience with 269 patients undergoing TEM, demonstrating a 4.1% rate of fecal continence deterioration after surgery. However, nearly 82% returned to baseline within 4–8 months. At least two studies have examined patient-reported fecal incontinence using the validated Fecal Incontinence Severity Index and the Fecal Quality of Life questionnaires [32, 35]. Neither study found that TEM had any impact on quality of life or fecal continence, as assessed at 6 weeks and up to 2 years after surgery.

Conclusion

Complications after TEM and TAMIS are frequent and typically easy to treat. Septic complications, though rare, can lead to long-term sequelae and decreased quality of life. When these occur, the benefit of LE over TME for stage I rectal cancer is significantly impacted. Clear pitfalls related to the rectal anatomy exist, and these should be avoided. Cautious use of electrocautery, careful assessment of wound closure, and intraoperative recognition of peritoneal perforation are all important factors in minimizing complications.

Key Points: Avoiding a Complication

1. All patients should receive preoperative bowel preparation. This greatly facilitates visualization and potentially minimizes contamination, if the peritoneum is accidentally entered during surgery.
2. The peritoneum should be closed if accidentally opened.
3. The defect in the rectal wall should be closed when feasible.

4. Hemostasis is of paramount concern in these patients, given the proximity of the operative field to important vascular structures posteriorly and laterally, and the inability to visualize these directly after the defect is closed.
5. Avoid creating a large presacral cavity after closure of the rectal wall, as this may become a space for fluid accumulation or abscess formation.
6. Recognition of the thin rectovaginal septum and urethra anteriorly necessitates cautious use of electrocautery.

Key Points: Managing/Diagnosing Septic Complications

1. Loss of appropriate insufflation of the rectum indicates possible entry into the peritoneal cavity.
2. Maintain a high suspicion for wound dehiscence, given how common this is. Prompt treatment often requires an examination under anesthesia and antibiotic therapy.
3. In the rare setting of prolonged symptoms associated with wound dehiscence or non-healing, proximal diversion may be necessary.
4. For low rectal tumors within 2 cm of the dentate line—especially in patients who have undergone neoadjuvant chemoradiation—consideration should be given to routine postoperative antibiotics. In select patients, a temporary diverting ostomy may be necessary.

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Parastomal Hernia

41

Erin M. Garvey and Kristi L. Harold

Abbreviations

PH	Parastomal hernia
cm	Centimeter
CT	Computed tomography
BMI	Body mass index
APR	Abdominoperineal resection
RCT	Randomized control trial
CI	Confidence interval
mm	Millimeter
ePTFE	Expanded polytetrafluoroethylene

Overview

Stomas are created for a number of emergent and elective gastrointestinal disease processes including colorectal cancer, fecal incontinence, constipation, diverticulitis, bowel obstruction, bowel ischemia, inflammatory bowel disease, and anal fistula. This chapter will provide an overview of parastomal hernias and explore the diagnosis, management, and prevention of this difficult clinical entity.

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Definition and Classification

A parastomal hernia (PH) can be defined as a protrusion in the vicinity of a stoma or as the abnormal protrusion of abdominal cavity contents through the abdominal wall defect resulting from colostomy, ileostomy, or ileal conduit creation [1, 2]. This chapter will focus on PHs relating to colostomies and ileostomies. A number of classification systems for PH have been proposed based on clinical, radiographic, or intraoperative findings but none have been accepted universally (Table 41.1) [3–6]. The classification systems have been criticized for including types that do not fulfill the definition of a hernia and for not including the presence of a concomitant incisional hernia. More recently, the European Hernia Society met to review the existing classification systems and expanded upon the definitions proposed by Gil and Szczepkowski to include a size cutoff of 5 centimeters (cm), but this new system has not yet been validated clinically [2].

Incidence

The incidence of PH has a broad range of 0–80 % and can vary based on the definition used, the method of diagnosis, and the surgical approach at time of stoma creation [7–9]. Cingi et al. noted an incidence of 52 % on physical exam, which increased to 78 % with the addition of computed tomography (CT) scan [10]. The incidence for end and loop colostomies are 4–48.1 % and 0–38 %, respectively, and are 1.8–28.3 % and 0–6.2 % for end and loop ileostomies, respectively [11].

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Table 41.1 Classification of parastomal hernias

Author year	Classification basis	Types	Clinical validation
Rubin [3]	Intraoperative findings	I: true PH	
		Ia: interstitial	No
		Ib: subcutaneous	
		II: intrastomal hernia	
		III: subcutaneous prolapse	
		IV: pseudohernia	
Devlin [4]	Intraoperative findings	I: interstitial hernia	Yes
		II: subcutaneous hernia	
		III: intrastomal hernia	
		IV: peristomal hernia (stoma prolapse)	
Moreno-Matias [5]	CT findings	0: peritoneum follows the wall of the bowel forming the stoma, with no formation of a sac	Yes
		Ia: bowel forming the colostomy with a sac < 5 cm	
		Ib: bowel forming the colostomy with a sac > 5 cm	
		II: sac containing omentum	
		III: intestinal loop other than bowel forming the stoma	
Gil and Szczepkowski [6]	Physical exam	I: isolated small PH	Yes
		II: small PH with cIH (without significant abdominal wall deformity)	
		III: isolated large PH (with significant abdominal wall deformity)	
		IV: large PH with cIH (with significant abdominal wall deformity	
Smietanski [2]	Intraoperative findings	I: PH < 5 cm without cIH	No
		II: PH 5 cm with cIH	
		III: PH > 5 cm without cIH	
		IV: PH > 5 cm with cIH	
		P: primary PH	
		R: recurrent PH	

PH parastomal hernia, *cIH* concomitant incisional hernia

Laparoscopic stomas with less than 1-year follow-up had a PH incidence of 0–6.7%, and the incidence was 6.7–12% for trephine stomas with 1-year follow-up [12]. The incidence reported from retrospective studies likely only captures those patients with symptomatic PHs, thus underestimating the true incidence. One series detected an 18% rate of asymptomatic PH [5]. Most PHs develop within the first 2 years after stoma creation with one series reporting development within 8 months of surgery [5, 13].

Pathophysiology

The true pathogenesis of hernia formation is not understood but there has been speculation relating to loss of tensile strength due to alterations in the type of collagen production. Junge et al. studied the ratio of type I to type III collagen in explanted meshes from inguinal and incisional hernias and found a significantly lower ratio in those meshes explanted for recurrence as compared to those explanted for chronic pain or infection [14]. A

similar lower ratio of type I to type III procollagen mRNA was seen in skin fibroblasts of hernia patients as compared to control groups [15]. Type I collagen is characteristically found in mature scar or fascia whereas type III collagen represents a less mechanically stable form found in the early phases of wound healing [16]. It has been hypothesized that alterations in collagen synthesis due to mutations within regulatory elements could be responsible for the "hernia disease phenotype" [17].

Risk Factors

Given the above hypothesis on collagen abnormalities, the presence of other hernias is a known risk factor for PH development [18, 19]. Increasing patient age, with some studies citing age > 60 years, is also a risk factor [18–23]. Female sex has also been shown to increase the risk of PH development [22, 23]. Conceivably, stoma aperture size, if created too large, can lead to PH formation [20, 23]. Comorbidities including obesity, chronic obstructive pulmonary disease, hypertension, and ascites were independent risk factors for PH development [12, 22]. PH prevalence more than doubled in one cohort study comparing those patients with a body mass index (BMI) ≥30 versus <30 and was also higher in another study when patients' waist circumference exceeded 100 cm [24, 25]. On the other hand, another study showed no significant risk between PH development and BMI or waist circumference [23]. Stomas are often created in patients with inflammatory bowel disease, and there has been a higher risk of PH noted in patients with Crohn's disease versus ulcerative colitis [26]. Risk factors for surgical site infections and wound dehiscence in general include smoking, diabetes mellitus, cardiovascular or pulmonary comorbidities, amount of blood loss, and type of surgery performed with the highest odds ratio (OR) for colorectal surgery [27]. The type of stoma created can also impact the rate of PH development with the highest rates occurring in colostomies compared to ileostomies with loop ileostomies having the lowest rates of PH [11, 28].

Complications

Complications associated with PH can be mild or severe ranging from abdominal discomfort to intestinal perforation requiring emergent laparotomy [10]. Approximately 30% of patients require repeat surgical intervention for PH related to bleeding, difficulty with appliance fit, fecal leakage, obstruction, and/or strangulation [29, 30]. Accordingly, recommended indications for repair include ileus, incarceration, or problems with appliance fit [31]. There have also been rare case reports of incarcerated stomach and gall bladder within PHs [32–35].

Prevention

Preoperative Considerations

Preoperative risk factor modification to reduce the likelihood of PH can be a challenge. The majority of patient characteristics associated with increased risk of PH including sex, age, presence of other hernias, or certain comorbidities are nonmodifiable. Tobacco cessation can be encouraged and efforts can be made to lose weight or optimize diabetes control preoperatively; however, these strategies cannot be employed for emergent procedures warranting ostomy creation.

Operative Considerations

In an early study, there was a significantly lower rate of PH when the stoma was brought out through the rectus abdominus muscle versus lateral to it [36], but more recent studies have concluded that stoma site, fascial fixation, or closure of the lateral space have no effect on PH formation [10, 12, 18, 19, 37]. A meta-analysis of 1071 colostomy patients showed a lower rate of PH with extraperitoneal colostomy creation compared to intraperitoneal colostomy [38]. The main interest in PH prevention is investigating the role of prosthetic mesh. The use of prophylactic mesh to prevent PH was reported as early as 1986

by Bayer et al. who had no PHs over a 4-year follow-up period in 43 patients who underwent placement of Marlex mesh (Phillips Petroleum Company, Bartlesville, OK) during colostomy creation [39]. Following Bayer's success, there have since been many observational studies that have evaluated the efficacy and safety of prophylactic mesh placement. Figel et al. demonstrated no mesh complications and no PH recurrences in 16 patients who underwent placement of a bioprosthetic mesh with a median follow-up of 38 months [40]. Gogenur et al. demonstrated no infectious complications, an 8% rate of minor complications, and an 8% rate of PH recurrence in 25 patients who had polypropylene mesh placed in the onlay position with a median follow-up of 12 months [41]. A small series of intraperitoneal onlay of polyvinylidene mesh during laparoscopic abdominoperineal resection (APR) showed no mesh-related complications, infections, or PH recurrence at a mean follow-up of 6 months [42]. A study by Nagy et al. evaluated the polypropylene hernia system large device in 14 cases after APR with sigmoid colostomy and noted no PH recurrence in the first postoperative year [43]. Marimuthu et al. studied a polypropylene monofilament mesh with a circle cut in it for the stoma placed preperitoneally without stitches in 18 patients and found no PH at a mean follow-up of 16–17 months. One patient required revision for stoma necrosis on postoperative day one and subsequently developed a wound infection, but no other complications were noted [44]. A prospective study of preperitoneal polypropylene mesh placed in 42 patients with a mean follow-up of 31 months demonstrated a PH incidence of 9.52% (4/42) [45]. Cost-effectiveness of mesh prophylaxis has also been studied by Lee et al. who looked at mesh prophylaxis in 60-year-olds who underwent APR with end colostomy for rectal cancer and found mesh prophylaxis to be less costly and more effective compared to no mesh for those patients with stage I–III rectal cancer [46]. A multicenter randomized control trial (RCT) by Hauters et al. evaluated 20 patients who underwent laparoscopic and open APR and had an intraperitoneal onlay mesh placed. One patient presented with mild stoma stenosis and one patient (5%) had a stoma bulge that was confirmed as a PH on CT scan [47]. Another RCT found decreased presence of radiographic PH in patients who had a lightweight intraperitoneal/onlay mesh placed during laparoscopic APR compared to those without mesh (50 versus 93.8%, $p=0.008$) [48]. The three RCTs by Hammond, Janes, and Serra-Aracil have been the most cited papers on the topic of PH prevention. In 2008, Hammond et al. published a RCT of 20 patients undergoing defunctioning stomas with a porcine-derived collagen implant placed in the sublay position in 10 of the patients. With a median 6.5-month follow-up, there were no PHs in the mesh group compared to 30% (3/10) in the nonmesh group, and there were no complications [49]. Janes et al. evaluated 54 patients undergoing permanent colostomy creation (27 patients with a conventional stoma and 27 with placement of a sublay large-pore light weight polypropylene and polyglactin mesh) and found a lower rate of PH 4.8% (1/21) in the mesh group compared to 50% (13/26) in the nonmesh group at 12-month follow-up. There were no infectious complications [50]. A 5-year follow-up study again revealed a lower rate of PH in the mesh group at 13.3% (2/15) versus 81% (17/21) in the nonmesh group ($p<0.001$) [9]. The RCT by Serra-Aracil evaluated 54 patients undergoing end colostomy for distal rectal cancer and utilized a sublay lightweight mesh in 27 patients. At a median 29-month follow-up, there were fewer PHs in the mesh group at 14.8% (4/27) compared with 40.7% (11/27) in the nonmesh group ($p=0.03$), and the morbidity between the two groups was similar [51]. In 2012, Sajid et al. and Shabbir et al. performed systematic reviews of the RCT literature. Sajid et al. analyzed the three RCTs by Janes, Hammond, and Serra-Aracil encompassing 128 patients who underwent colorectal resections with stoma creation (64 patients in the mesh group versus 64 patients in the nonmesh group), and found an OR of 1.0 (95% confidence interval [CI] 0.36–3.2, $p=1.0$) for developing postoperative complications and an OR of 0.11 (95% CI 0.05–0.27, $p<0.00001$) for developing a PH with the use of mesh [52]. Shabbir et al. reviewed 27 RCTs and excluded all but the same three RCTs as the Sajid paper.

This review demonstrated an incidence of PH of 12.5% (8/64) in the mesh group compared to 53% (34/64) in the control group ($p<0.0001$). There were no differences in mesh-related complications between the two groups [53]. A similar systematic review that included the same three RCTs but also three prospective observational studies and one retrospective study also found a lower rate of PH in the mesh group at 7.82% (14/179) versus 55% (32/58) in the nonmesh group with similar morbidity during a follow-up period ranging 1–83 months [54]. All three systematic reviews concluded that the use of prophylactic mesh at the time of stoma creation can reduce the incidence of PH. A multicenter RCT in the Netherlands known as the PREVENT trial is currently underway and is evaluating whether prophylactic lightweight monofilament polypropylene mesh in a preperitoneal, retromuscular position reduces the incidence of PH formation in patients undergoing elective formation of permanent end colostomies via an open procedure. Follow-up is scheduled for 3 weeks,; 3 months; 1, 2, and 5 years postoperatively [55].

Diagnosis

History and Physical Exam

In a series by Moreno-Matias, 27 of the 33 patients (85%) with clinically detectable PHs had associated symptoms including pain on exertion, interference with irrigation devices, or detachment of the appliance with changes in position [5]. A study of the French federation of ostomy patients found 76% patients suffered symptoms related to PH including pain, difficulty with appliance fit or leakage [21]. Physical exam can show bulging with a Valsalva maneuver or palpation of a fascial defect [10], but one study demonstrated low interobserver reliability in diagnosing PH based on patient history and clinical examination [56]. Median length of time between the formation of the stoma and the diagnosis of the PH was 44 months (0–331 months) in one study [57].

Imaging

Imaging can be used as an adjunct to clinical exam in diagnosing PH and, as previously mentioned, may increase the rate of PH detection [5, 10, 23]. However, some PH may not be detected by CT scan [5, 56]. Janes et al. recommended performing CT scans in the prone position and demonstrated good correlation between clinical and radiographic diagnoses when doing so [58]. Contrast can be administered via the stoma to better delineate the anatomy and patency of the bowel. Intrastomal ultrasonography utilizing a 9 MHz probe with rectal setting and render mode enabled the real-time identification of fascia, bowel, rectus muscle, and mesh and had the added benefit of evaluating the patient in the upright and supine positions [59]. As with all ultrasound, diagnostic utility is dependent on availability, operator experience, and equipment quality. Magnetic resonance imaging is rarely needed for PH diagnosis but can be considered in the case of diagnostic uncertainty or in the presence of contraindications to ionizing radiation and should include the diffusion-weighted imaging sequence [60].

Management

Nonoperative Management

Nonoperative management may be attempted pending the patient's level of discomfort or the severity of the PH complications. Expert consultation with a stoma nurse, if available, can be helpful. A flexible appliance can mold to uneven contours of the skin, and aperture size should leave no more than a 2–3 mm rim around the stoma [61, 62]. Protective skin sealants may improve appliance adhesion and stoma belts may improve appliance security [63]. Similarly, abdominal binders may relieve the discomfort caused by the PH [63].

Operative Management

Open Approach

The various approaches to open PH repair include primary fascial repair, stoma reversal, stoma relocation, or repair utilizing a mesh material. Stoma reversal is not an option in every clinical situation. Primary fascial repair after hernia sac reduction results in recurrence rates of 46–100% [3, 64–67]. Local fascial repair has the theoretical benefit of minimizing morbidity by avoiding a laparotomy but overall complication rates associated with this repair have been reported at 50% [3]. A 2012 systematic review by Hansson et al. deemed fascial repair outdated due to an overall morbidity rate of 22.6, 11.8% surgical site infection and 69.4% rate of recurrent PH [68]. Stoma relocation can result in recurrent PH in 0–76.2% of patients [3, 64–66, 69–71]. Stoma relocation can carry the added risk of a laparotomy and thus create three potential sites for hernia formation; however, in one series, 76% of stoma relocation cases were successfully accomplished without a laparotomy [64]. Incisional hernia development at the site of the prior stoma can occur in as many as 50% [60]. Overall complication rate for stoma relocation was 88% [3].

Given the high recurrence and complication rates for the above approaches, the use of prosthetic mesh material has gained in popularity. The mesh can be placed in a number of anatomical locations including onlay, inlay, sublay and intraperitoneal. In the onlay technique, the mesh is placed extraperitoneal, on the top of the musculofascial layer. A recent systematic review demonstrated an overall morbidity rate of 12.7%, 1.9% surgical site infection, 2.6% mesh infection, 8.2% rate of other complications, and an 18.6% recurrent PH rate with the onlay technique [68]. The inlay method of placing the mesh within the fascial defect and suturing it to the fascial edges has been abandoned. In the sublay technique, the mesh is placed in a retromuscular or preperitoneal space either via an incision around the stoma, to the side of the stoma, or via a vertical incision that can enable mesh coverage of the midline anterior abdominal wall. A wound infection rate of 4.8%, no mesh infections or other complications, and a 6.9% recurrent PH rate have been reported with the sublay technique [68]. Sugarbaker was the first to introduce an intraperitoneal mesh repair in 1985 describing a technique of securing the mesh circumferentially around the entire fascial defect with the exception of lateral to the stoma allowing for the creation of a flap valve [72]. This technique was 100% successful in his series of seven PHs with a 4–7-year follow-up period [72]. A retrospective review of 20 paracolostomy hernia repairs using the open Sugarbaker technique resulted in 5% wound infection and 15% recurrence rate [73]. An alternative intraperitoneal technique is the keyhole method in which a small hole corresponding to the size of the stoma is cut out of the mesh to enable the stoma to pass through while still covering the entirety of the fascial defect as described in van Sprundel's study [74]. A review of this study and three others resulted in an overall morbidity rate of 22%, wound infection rate of 2.2%, and a recurrent PH rate of 9.4% [68]. There have been a number of studies evaluating the outcomes of each of the techniques; however, most studies consist of a very small case series of patients. Table 41.2 shows the outcomes for those studies with greater than or equal to ten patients.

Laparoscopic Approach

Laparoscopy has the added benefit of limiting the potential sites for new hernia formation. Similar to open intraperitoneal repairs, a modified Sugarbaker and the keyhole technique can be utilized laparoscopically in addition to a combination of the two methods known as the sandwich technique. The sandwich technique utilizes two pieces of mesh; the first in a fashion similar to the keyhole technique with an additional piece of mesh covering the first piece of mesh and the remaining abdominal wall [75]. The 2012 Hansson review evaluated 11 laparoscopic PH repair studies which demonstrated a 3.6% conversion to open, 4.1% iatrogenic bowel injury, overall morbidity of 17.2%, 3.3% wound infection, 2.7% mesh infection, and 11.6% recurrence rate for the Sugarbaker technique versus 34.6% recurrence for the keyhole technique versus 2.1%

Table 41.2 Outcomes of open parastomal hernia repairs with greater than or equal to ten patients

Study	No of repairs	Type of repair and mesh	Recurrence (%)	Complications excluding recurrence (%)	Infection (%)	Mean follow-up (range)
Onlay						
Steele et al. [79]	58	"Stove pipe hat" polypropylene	26	20.6	3	50.6
Geisler et al. [80]	16	Nonabsorbable	63	–	13	39
de Ruiter and Bijnen [81]	46	Central ring enforced polypropylene mesh prosthesis	15.9	–	Early 4.3 Late 2.3	60 (12–156)
Luning and Spillenaar-Bilgen [82]	16	Keyhole -Polypropylene -Polyethylene -Vicryl and Central ring enforced polypropylene mesh prosthesis	19	12.5	6.2	33 (6–110)
Heo et al. [83]	17	Prolene	11.8	17.6	0	29.6
Smart et al. [84]	27	Acellular porcine dermal collagen mesh	55.6	7.4	3.7	16.6[a] (0.2–39.3)
Sublay						
Egun et al. [85]	10	Keyhole Polypropylene	0	70	20	54 (22–69)
Longman and Thompson [86]	10	Keyhole Polypropylene	0	10	0	30[a] (2–40)
Guzman et al. [87]	25	Keyhole Polypropylene	8	16	8	12 (8–24)
Liu et al. [88]	34	Polypropylene	6.3	26.5	3	32 (6–75)
Fei [89]	11	Modified sublay keyhole Polypropylene	9	27	0	23.5 (11–39)
Intraperitoneal						
Hofstetter et al. [90]	13	Keyhole PTFE	0	0	0	–
Stelzner et al. [73]	20	Sugarbaker/ Rives-Stoppa ePTFE	15	20	5	42 (3–84)
van Sprundel and van der Hoop [74]	15	Keyhole ePTFE	6.7	0	26.7	29[a] (5–52)

ePTFE expanded polytetrafluoroethylene[a] Denotes median follow-up

recurrence for the sandwich technique, although the latter was based solely on one series of 47 patients [68]. The Sugarbaker technique resulted in a significantly lower PH recurrence rate compared to the keyhole technique (OR 2.3, 95% CI 1.2–4.6, $p=0.016$) [68]. Table 41.3 shows the outcomes of laparoscopic PH repair studies with greater than ten patients.

It is our preference to perform the laparoscopic modified Sugarbaker technique for PH and recurrent PH repairs. A first-generation cephalosporin is given within 1 h of the incision. Laparoscopic monitors are positioned on both sides of the patient. After induction of general anesthesia, the patient is placed in the supine position with both arms tucked and a Foley catheter is placed into the bladder, if needed. An additional Foley catheter is placed into the ostomy to allow for easy identification of the correct loop of intestine, which can be helpful in the case of dense adhesions. The abdomen, stoma, and additional Foley catheter are prepped and then covered by an Ioban drape (3M Company, St. Paul, MN). A Veress needle placed subcostally in the left upper quadrant in the midclavicular line is utilized to gain access to the peritoneal cavity. Once adequate pneumoperitoneum is obtained (15 mm Hg of carbon dioxide), a 5-mm Optiview port is used to enter the peritoneal cavity laterally, on the side opposite of the stoma. Two additional 5-mm trocars are placed in the lateral position near the Optiview port. External manipulation of the Foley catheter in the ostomy can help to identify the loop of bowel ending in the ostomy and can guide lysis of adhesions accordingly (Fig. 41.1). Once adhesiolysis is complete, the hernia contents, with the exception of the stoma, can be reduced. Now the entire abdominal wall and the hernia defect, including any coexisting ventral or incisional hernia defects, can be visualized and measured. Spinal needles are used to mark the extent of the defect at the superior, inferior, and lateral most aspects. A laparoscopic ruler is then inserted to measure the extent of the defect from superior to inferior spinal needles for length and from lateral to lateral spinal needles for width. The defect is also measured and marked on the patient's abdominal skin to assist with centering the prosthesis later in the procedure (Fig. 41.2). The size of mesh is selected based on the defect measurements and allowing for a 5-cm overlap beyond all fascial edges. The mesh is then trimmed to the appropriate size. We, like the majority of studies in Table 41.3, utilize expanded polytetrafluoroethylene (ePTFE, Gore DUALMESH; W.L. Gore, Flagstaff, AZ). The textured surface of the mesh is marked to identify the superior and inferior portions of the mesh. A single Gore-Tex transfascial suture (CV-0) is placed at the edge of the mesh on the three of the four sides that are not associated with the stoma. Two Gore-Tex transfascial sutures are placed on the fourth side on either side of where the stoma will lay creating a mesh flap valve. A 5-mm trocar is then placed in the lateral abdomen on the ipsilateral side of the stoma. A 12-mm trocar is placed through the hernia defect where it will later be covered by the mesh repair to prevent the risk of trocar site hernia. The two marked edges of the mesh are rolled tightly toward one another, and an additional mark is made on the rolled mesh for orienting purposes. A grasper is placed through the ipsilateral trocar and is brought out through the 12-mm trocar where it grasps the mesh helping to guide it into the abdomen (Fig. 41.3). The mesh is unrolled utilizing two graspers and oriented according to the earlier markings. The open jaws of an atraumatic bowel grasper are used to measure a 5-cm overlap from the edge of each of the fascial defects and these areas are marked with new spinal needles. A suture passer is used to pass the transfascial sutures through the sites marked by the new spinal needles while being careful to avoid the stoma as it traverses the edge of the mesh (Fig. 41.4). The mesh flap valve is crafted such that the stoma crosses the lateral or inferior edge. The transfascial sutures are secured with hemostats rather than tied until the most ideal mesh coverage and placement has been achieved. A laparoscopic tacker is used to secure the mesh in place circumferentially with the exception of around the stoma (Fig. 41.4). Additional Gore-Tex transfascial sutures are placed with a suture passer every 4–5 cm around the mesh. The transfascial sutures are tied with their knots in the subcutaneous tissues, and the skin is freed

Table 41.3 Outcomes of laparoscopic parastomal hernia repairs with greater than ten patients

Study	Type of repair and mesh	No of repairs	Conversion (%)	Recurrence (%)	Complications excluding recurrence (%)	Infection (%)	Median follow-up (range)
LeBlanc et al. [91]	Sugarbaker/ Keyhole ePTFE	12	0	8.3	33	0	20[a] (3–39)
Berger and Bientzle [75]	Sugarbaker/ Sandwich ePTFE and polyvinylidene fluoride	66	1.5	12	10.6	4.5	24 (3–72)
Mancini et al. [77]	Sugarbaker ePTFE	25	0	4	12	8	19 (2–38)
McLemore et al. [92]	Sugarbaker/ Keyhole ePTFE	19	–	10.5	63	11	20[a]
Craft et al. [93]	Sugarbaker/ Keyhole ePTFE	21 (incl. 9 IC)	0	4.8	48	14	14 (1–36)
Berger and Bientzle [94]	Sandwich polyvinylidene fluoride	47 (+297 IH)	0	2	–	1.2 (entire 344 pt cohort)	20
Hansson et al. [95, 96]	Keyhole ePTFE	54	14.5	37	14.4	3.6	36 (12–72)
Pastor et al. [97]	Sugarbaker/ Keyhole PTFE	12	8.3	33.3	33.3	25	13.9
Liu et al. [98]	CK parastomal patch	24	25	4.2	33	0	27[a] (6–39)
Wara and Andersen [78]	Keyhole Polypropylene and PTFE	72	4	3	22	4.2	36 (6–132)
Mizrahi et al. [76]	Keyhole Bard CK parastomal hernia patch polypropylene and ePTFE	29 (incl. 1 IC)	6.9	46.4	17.2	3.4	30 (12–53)

ePTFE expanded polytetrafluoroethylene, *incl.* including, *IC* ileal conduit, *IH* incisional hernia, *pts* patients[a] Denotes mean follow-up

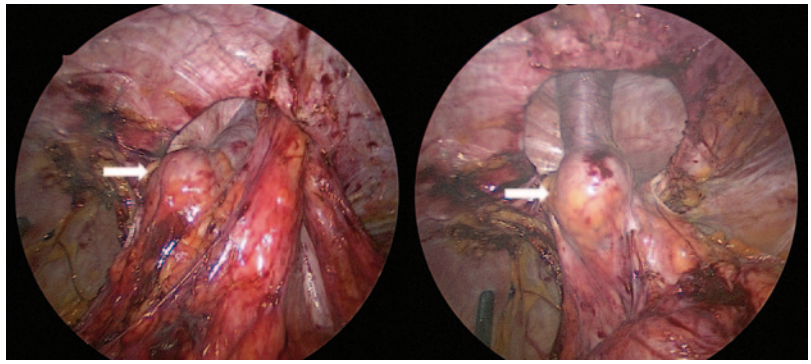

Fig. 41.1 Foley catheter balloon (*white arrow*) placed in the ostomy helps to localize the correct loop of intestine, especially during adhesiolysis

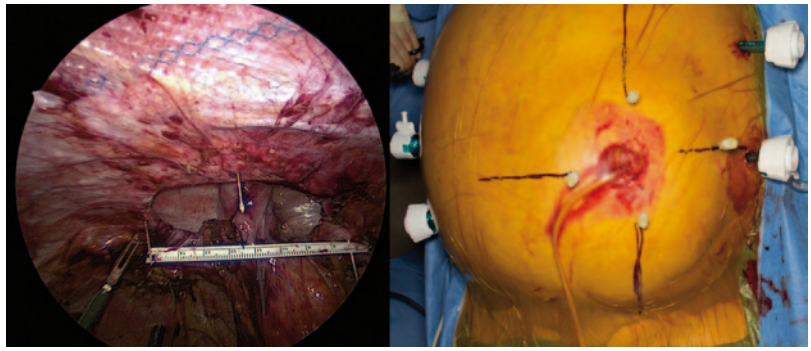

Fig. 41.2 A laparoscopic ruler is used to measure the hernia defect size (*left*) as delineated by externally placed spinal needles (*right*)

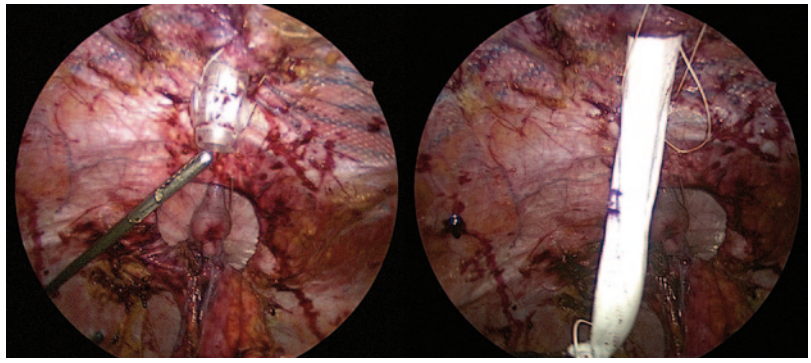

Fig. 41.3 A grasper is placed into the trocar on the ipsilateral side of the stoma and brought through the 12-mm port (*left*) to guide the mesh into the abdomen (*right*)

from the knot with a hemostat. The trocar sites are closed with 4-0 monocryl suture and the stab incisions from the suture passer are closed with skin adhesive. Final repair is shown in Fig. 41.5.

Postoperative Complications

The overall complication rate for PH repair has been reported as high as 65 % [57]. Complications

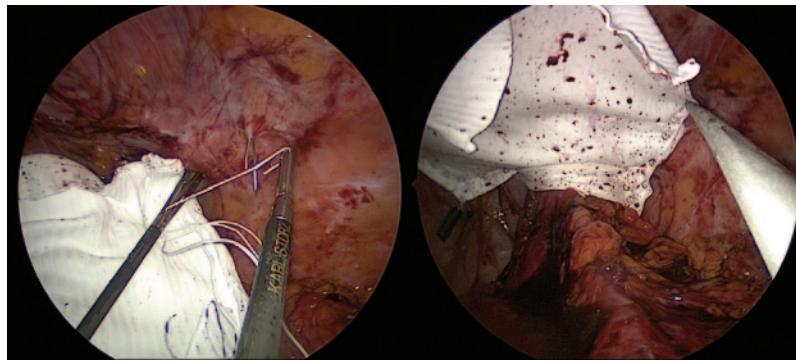

Fig. 41.4 The transfascial sutures are pulled through at a point allowing for a 5-cm overlap of the mesh from the fascial edge (*left*) and the mesh is further secured into place with a tacker (*right*)

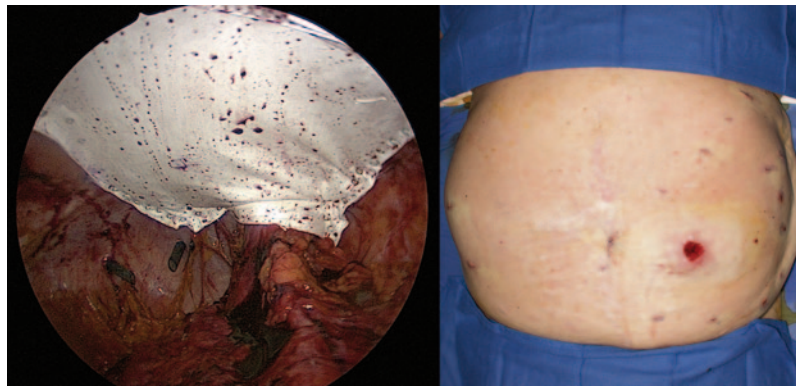

Fig. 41.5 View of the final sugarbaker repair internally (*left*) and externally (*right*)

include infectious (wound infection, mesh infection, abscess, urinary tract infection), stoma complications (necrosis, stenosis, obstruction, bleeding), intraoperative (enterotomy either recognized or unrecognized), general postoperative complications (ileus, cardiopulmonary), recurrence, and death. Logistic regression analysis from the 2012 Hansson systemic review demonstrated a significantly increased risk of recurrence and wound infection for primary suture repair compared to the other techniques. Interestingly, primary suture repair aside, the other open techniques did not differ compared to the laparoscopic approach with respect to mesh infection, overall postoperative morbidity, or recurrence. Mortality rates range from 3 to 7% and are higher in emergent compared to elective cases [7, 57, 75–78].

Management of Recurrent Parastomal Hernias

Repair of recurrent PHs poses the same challenges as initial PH repair, and the data for recurrent repairs are limited. In Sugarbaker's original description, six of the seven PHs in his series were recurrent PHs, and he reported 100% success rate [72]. In another study; however, fascial repair failed in all cases, stoma relocation failed in 71%, and fascial repair with prosthetic material failed in 33% [3]. We approach recurrent PH much the same as for initial PH with a laparoscopic modified Sugarbaker technique as described above.

Key Points: Diagnosing/Managing Parastomal Hernia

1. Parastomal hernia is almost an inevitable occurrence after stoma creation with an incidence reported as high as 80%.
2. Imaging with CT scan, particularly in the prone position or with the Valsalva maneuver, or with intrastomal ultrasonography can be used as an adjunct to clinical diagnosis.
3. One-third of patients with parastomal hernia end up undergoing reoperation usually for bowel obstruction or incarceration or due to poor appliance fit.
4. For open repairs, the use of mesh in a sublay or intraperitoneal position is favored.
5. For laparoscopic repairs, the Sugarbaker technique has a lower recurrence rate at 11.6% versus the keyhole technique at 34.6%.

Key Points: Avoiding Parastomal Hernia Complications

1. Many risk factors for parastomal hernia are nonmodifiable including age, female sex, and comorbidities such as chronic obstructive pulmonary disease, hypertension, or Crohn's disease, but risk factors such as increased body mass index, tobacco use, and diabetes control should be optimized as much as possible, especially for elective cases.
2. Primary fascial repair of parastomal hernias carries an increased risk of wound infection and recurrence and should be avoided.
3. The use of prosthetic mesh in parastomal hernia repairs decreases the rate of recurrence.
4. The use of prophylactic prosthetic mesh has been shown to decrease the rate of parastomal hernia development and has not been associated with increased infectious complications.
5. The data on managing recurrent parastomal hernias is limited but repair with prosthetic mesh is advised.

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Stoma Retraction/Ischemia/Stenosis

42

Eugene F. Foley

Introduction

Despite the many advances in complex intestinal surgery over the last 50 years, there remain many clinical situations in which temporary or even permanent intestinal diversion is required. Unfortunately, the incidence of stoma-related complications remains high, and the morbidity related to these complications can be substantial [1–3]. The common recognized stomal complications include ischemia, stricture formation, retraction, fistula formation, prolapse, and peristomal herniation [1, 4, 5], all of which may be manifested by substantial pouching difficulties leading to peristomal dermatitis and considerable functional loss and frustration for patients. These difficulties can at times be great enough to substantially reduce the overall benefit to patients of an otherwise appropriate and effective operative invention. This chapter will specifically address the former three complications, ischemia, stricture formation, and retraction, which share a common set of etiologies and risk factors. In fact, these complications are simply different manifestations of the same underlying pathology, and as such, the principles important in their prevention and repair are the same.

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Etiology/Incidence/Risk Factors

Stoma ischemia, stricture, and retraction are fundamentally related to the presence of one or both of the well-recognized phenomena which affect satisfactory healing broadly in intestinal surgery: ischemia and tension. Whether a patient develops retraction, stricture, or acute full thickness ischemia and necrosis in the early postoperative period is simply dictated by the degree of tension and ischemia on the bowel used to create the stoma. The reported incidence of acute ischemia and necrosis ranges from 1 to 10%, stricture formation 2–15%, and retraction 5–15% [1, 4]. A number of perioperative factors have been implicated in effecting the rates of these complications, although there is a substantial amount of variability and inconsistency reported in the literature. Factors contributing to these complications that have been suggested by individual authors are listed in Table 42.1. The type and location of the intestinal stoma may influence the risk of tension and ischemia. In general, the transverse mesocolon is much longer than the left or sigmoid colon mesentery, making these complications less frequent with a transverse colostomy than with a left or sigmoid colostomy [6, 7]. This anatomic feature, however, has been implicated as the reason for increased rates of ostomy prolapse and hernia formation in transverse colostomies [8]. Similarly, the blood supply and mesenteric length of the terminal ileum in most patients are more favorable than the left colon, making ischemia and tension less likely in a terminal ileostomy. Obesity can play a big role in the frequency of these complications [9, 10] and may affect them in two specific ways. First, the mesentery in most obese

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Table 42.1 Factors implicated as risk factors for ostomy ischemia, retraction, and stenosis

Ostomytype
Ileostomy vs. colostomy
Transverse vs. left-sided colostomy
Loop vs. end ostomy
Emergency surgery
Patient factors
Obesity
Diabetes

Table 42.2 Operative considerations to reduce ostomy tension and ischemia

Full mobilization to the bowel and mesentery to the midline
Lateral attachments
Posterior attachments
Flexures
Omentum
Divide mesentery central to the marginal vessels
Consider upper abdominal ostomy placement if patient obese
Consider more proximal diversion
Transverse colon
Ileum
Convert loop to end or “end loop” ostomy

patients is short, and its fat content tends to make it less elastic, making it more difficult to reach the skin surface for the creation of an ostomy without tension. Second, the abdominal wall in obese patients is much thicker, contributing to the challenge of creating a tension-free ostomy. A loop ostomy may be more difficult than an end ostomy to bring to the surface without tension as the mesenteric vessels tend to be the major tether limiting the reach of the ostomy, and these are less commonly divided and freed with a loop ostomy than with an end [7]. Certain underlying patient characteristics may also contribute to the likelihood of these complications, including the patients’ age, underlying vascular health, smoking, and diabetes. Furthermore, data suggest an increase in stoma ischemia and retraction with emergency vs. elective procedures [10, 11]. Finally, an underlying diagnosis of Crohn’s disease may lead to an increased rate of long-term retraction and stenosis due to the presence of recurrent disease at the ostomy [9, 12].

Prevention

Efforts to reduce the incidence of stoma ischemia, retraction, and stricture are primarily focused on attempts to technically mitigate tension and ischemia at the intestinal cutaneous anastomosis. A number of techniques may be helpful and are listed in Table 42.2, but several deserve some comment. First, it is critical to recognize that the creation of a healthy stoma is crucial to the success of the operation and at times can be very challenging. As such, it demands the same degree of attention, time, and effort as the other important components of a gastrointestinal operation. Unfortunately, this essential understanding can be commonly lost, particularly at the end of a complex and difficult operation where there is an “emotional letdown” once a challenging resection is complete. A number of specific technical steps may require consideration to create a healthy ostomy, particularly in difficult circum-

stances, and each of these may take some time and careful thought. The overall technical goal is to be able to reach a well-vascularized piece of intestine to the skin surface without tension. To do so, the bowel should first be fully mobilized and rotated on its mesentery to the midline. For the left colon, this may involve fully dividing the lateral attachments (White line of Toldt), in some cases fully mobilizing the splenic flexure and the posterior mesenteric attachments to the retroperitoneum. For the terminal ileum, this may involve fully freeing the entire distal small bowel mesentery off of the retroperitoneum to the level of the duodenum. Upon completion of these maneuvers, the bowel should not be tethered by anything other than its mesentery. It should be kept in mind that full mobilization and freeing the associated mesentery off the retroperitoneum can often add substantial mobility to the intestine and be all that is required. In many cases, this mobilization alone is sufficient to be able to bring the bowel to the skin without tension and is ideal because significant mesenteric blood flow had not been divided. If the bowel is still not adequately mobilized at this point, it will be tethered by its mesenteric blood supply alone, and decisions regarding mesenteric division will need to be made. Careful identification of the major feeding vessels as well as the marginal, pericolic vessels should be made prior to any division. If the mesentery requires division, this division should be done close to the root of the mesentery, central to the marginal or pericolic vessels that will ultimately be the source of the blood supply to the stoma. Mesenteric diversion in the periphery close to the bowel wall will sacrifice the marginal vessels' perfusion of the bowel leading to ischemia. If these mobilization measures are still inadequate, consideration of the use of a transverse colostomy or terminal ileostomy might be appropriate, as these structures tend to have longer, more mobile mesenteries. Furthermore, positioning the ostomy aperture in the upper abdomen may be helpful, as the abdominal wall of even very obese patients is usually much thinner in the upper rather than mid- or lower abdomen. Finally, as noted previously, if there is undue tension on a loop ostomy, consideration of converting it to an end ostomy with some mesenteric division may be of benefit. Additional mobility may also be achieved by conversion of the loop ostomy to an "end loop" as described by Hebert [13], which creates the ostomy aperture on the antimesenteric side of the bowel, rather the end, which is less tethered by the mesenteric vessels. Table 42.2 highlights the technical considerations and the order in which I think about them when creating an ostomy under difficult circumstances.

Recognition/Assessment/Severity/Therapy

When concern about stoma ischemia and retraction arises in the early postoperative period, the first question that needs to be considered is the possibility of full thickness intestinal ischemia proximal to the fascia. A glass test tube may be gently inserted into the stoma aperture and often is quite helpful in differentiating superficial mucosal sloughing from full thickness ischemia involving bowel deep to the fascia. Additionally, progressive peristomal inflammation or signs of systemic sepsis may indicate full thickness stomal necrosis. If full thickness necrosis to the fascia is suspected, the patient requires urgent reoperation with laparotomy and recreation of the ostomy to prevent intraabdominal intestinal perforation and sepsis. Ostomy revision should be done with the technical considerations discussed in the "Prevention" section in mind. If the ischemia is more superficial or distal to the fascia, usually expectant management is warranted, although the more severe the ischemia or retraction, the more likely the need for eventual elective ostomy revision. Occasionally, in the absence of full-thickness ischemia proximal to the fascia, a decision for early revision is made with the goal of reducing the likelihood of future stenosis requiring later revision. Factors which may influence the decision to return for early ostomy revision under these circumstances include the clinical state of the patient and the difficulty of the initial stoma creation. Furthermore, if the stoma is temporary, expectant management with acceptance of temporary poor ostomy function

that will resolve with ostomy closure may be a reasonable alternative to early reoperation. In general, in the absence of deep full-thickness ischemia mandating urgent reoperation, non-operative, expectant management is usually undertaken in the immediate postoperative period.

Perioperative ischemia or tension not severe enough to require urgent early reoperation may result in chronic problems with stoma stenosis or retraction. Initial non-operative interventions may be tried. Bowel slowing and thickening medications and the use of convex pouching may improve minor-to-moderate pouching difficulties related to retraction. Some authors have advocated the use of catheterization for stenotic colostomies as a mean of controlling partial obstruction or pouching difficulties [14]. Serial dilations of strictured stomas has been suggested, but the literature is quite mixed on the long-term effectiveness of dilation, and many authors do not advocate it [14,15]. I personally have not found this to be effective for most patients with strictured stomas.

The indications for elective surgical repair of these difficulties essentially revolve around the need for symptomatic relief of associated partial intestinal obstruction with stenosis and difficult pouching with retraction. Operations considered for stoma stenosis may be categorized into local, peristomal revisions and in-depth, transabdominal revisions. The selection of approach is based on the degree of pathology. If the stricture is quite superficial, involving the very distal end of the bowel and the mucocutaneous junction only, local repair may be adequate. Strictures that are longer and extend more proximally in the bowel will often require the more extensive transabdominal approach [1,2, 14, 15]. Categorizing the depth of pathology can usually be done by physical exam in the office. If there is healthy, soft bowel just inside a superficial stricture, I will often attempt a local repair. Many different techniques have been described for local stoma stricture revision, from simply excising the stricture with advancement of the bowel and recreation of the mucocutaneous junction, to more complex approaches involving local skin flap mobilization and peristomal skin "plasties." V-Y advancement flaps, "W-plasties," and "Z-plasties" have all been described to surgically correct stomal stenosis [4, 14, 16]. There appears to be no clear cut data favoring one approach over another, with the length and extent of the stricture and surgeon experience being the important factors influencing the choice of specific approach.

A stricture of longer than several centimeters indicates a longer segment of intestinal ischemia, and usually this problem requires a transabdominal approach, with intraabdominal mobilization of additional non-ischemic intestine to allow a vascularized piece of intestine to the skin level without tension. The technical considerations for this operation are analogous to those discussed in the "Prevention" section.

The major indication for surgically repairing stoma retraction is to improve difficult pouching related to the retraction that cannot be managed acceptably with conservative measures of bowel content thickening, slowing, and advanced enterostomal therapy care. Some authors advocate a first attempt at local repair, with circumferential peristomal dissection of the bowel from the abdominal wall and recreation of the ostomy aperture [15, 17]. I personally have found this approach often unrewarding, especially for those patients with anything other than a mild retraction, as it is often difficult to free up enough bowel with a local dissection to relieve significant tension and retraction. Under most circumstances, I have found that significant retraction will eventually require a transabdominal approach to further mobilize intraabdominal intestinal length to reach the skin without tension. If a local repair is planned, I do agree with authors suggesting preparing the patient for the possibility of a laparotomy if adequate mobilization cannot be achieved with local dissection alone [14]. Preoperatively, a decision about the suitability of the stoma position on the abdominal wall should be made. As previously stated, lower abdominal wall ostomies often transverse thicker abdominal walls and may contribute to retraction and pouching problems. Furthermore, the placement of an ostomy in a skin fold may exacerbate the pouching problems related to retraction. Careful preoperative enterostomal therapy evaluation is essential to optimizing ostomy positioning on the abdominal wall, and this is particularly true for a

planned ostomy revision. In addition to consideration of stoma repositioning, the technical goal of this operation is to more adequately mobilize intraabdominal, non-ischemic bowel to allow for its tension-free anastomosis to the abdominal wall skin, again as specifically described in the "Prevention" section.

Conclusions

The common complications of peristomal ischemia, retraction, and stenosis are clinical manifestations of differing degrees of the same pathologic entities of ischemia and tension. Specific technical considerations can and should be made at the time of ostomy creation to reduce their incidence and the often substantial patient morbidity associated with them. Once present, the specific clinical scenario dictates the timing and nature of their surgical correction.

Five Keys Points in Diagnosing and Managing Stenosis, Retraction, and Ischemia in an Ostomy

1. Insertion of a test tube into the ostomy aperture may assist in differentiating superficial and subfascial stoma ischemia.
2. Subfascial ischemia requires urgent reexploration to repair.
3. The duration of planned diversion is a major factor in deciding when to reoperate on a superficially strictured or retracted stoma.
4. Most strictured stomas involving more than simply the skin or distal 1–2 cm of bowel will require a laparotomy and intraabdominal mobilization to repair.
5. Superficial skin strictures may be surgically repaired with peristomal skin flap mobilization.

Five Key Points on How to Avoid Tension and Ischemia in an Ostomy

1. Full bowel mobilization:
   - mobilize the bowel and mesentery to the midline;
   - lateral attachments;
   - posterior attachments;
   - flexures; and
   - omentum.
2. Divide mesentery central to the marginal vessels.
3. Consider upper abdominal ostomy placement if patient obese.
4. Consider more proximal diversion:
   - transverse colon and
   - Ileum.
5. Convert loop to end or "end-loop" ostomy.

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Incontinence After Lateral Internal Sphincterotomy/ Fistulotomy

43

Heather Rossi and David Rothenberger

Introduction

Incontinence is defined as the involuntary loss of feces or intestinal gas through the anal canal. Severity ranges from the occasional leakage of stool or gas to the complete loss of bowel control. Normal continence is maintained by complex interaction of the anal sphincter muscles and pelvic floor innervation. Extreme diarrhea and other diseases can result in incontinence despite an intact anatomic and neural pelvic floor but most often, incontinence is due to disruption of the normal anatomy and/or neurophysiology [1]. Such disruption may be due to the unintended sequelae of sphincterotomy and/or fistulotomy.

The anal sphincter is composed of the internal anal sphincter (IAS) and the external anal sphincter (EAS). The IAS is a 0.3–0.5-cm thick continuation of the circular smooth muscle layer of the rectum and the EAS is 0.6–1.0-cm thick continuation of the levator ani muscles. The IAS is primarily involuntary, fatigue-resistant slow-twitch smooth muscle, while the EAS is a voluntary, striated muscle. The IAS contributes 70–85 % of the resting pressure and is therefore primarily responsible for maintaining anal continence at rest [2]. The anal endovascular cushions of the anal mucosa may produce pressures up to 9 mmHg and contribute 10–20 % of anal resting tone [3]. The IAS is also responsible for the sampling reflex of the rectum. Relaxation of the IAS permits rectal contents to come in contact with the anal mucosa. The sampling reflex allows for the discrimination of flatus and stool. This discrimination results in the passage of flatus while maintaining continence to stool [4]. The EAS is primarily responsible for the squeeze pressure or voluntary control of the passage of stool from the anus. Damage to the IAS or endovascular cushions may lead to a decrease in the resting pressures and passive incontinence, seepage of stool, or impaired sampling reflex. Damage to the EAS may cause voluntary loss of control and/or urge related defecatory dysfunction.

Lateral Internal Sphincterotomy

An anal fissure is a tear in the mucosa of the anal canal distal to the dentate line and extending to the anal verge. The majority of fissures are acute, located in the midline posteriorly, have an equal prevalence in men and women, not related to a specific disease state, and resolve with conservative management within 6–8 weeks. A chronic anal fissure (CAF) is generally defined as a tear that has extended through the submucosa, to expose the IAS. It is often associated with a sentinel perianal skin tag distally and/or a hypertrophied

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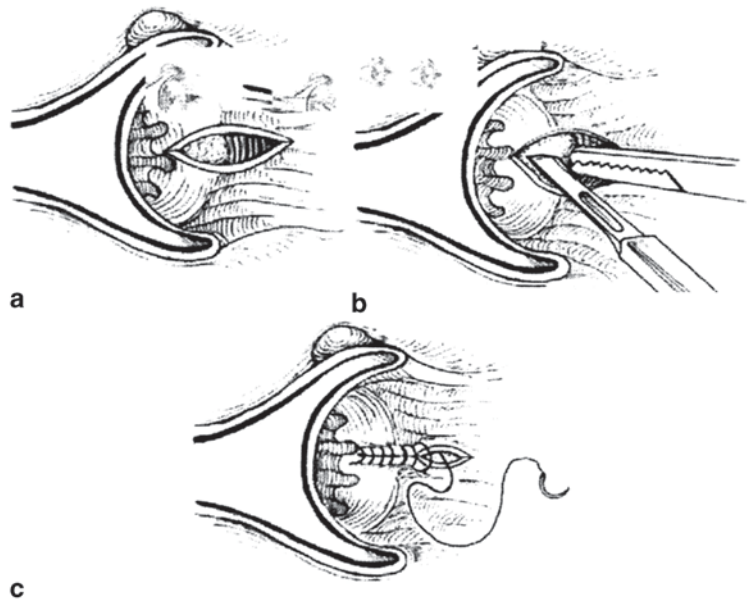

Fig. 43.1 Open lateral sphincterotomy. **a** Radial skin incision distal to the dentate line exposing the intersphincteric groove. **b** Elevation and division of the internal sphincter. **c** Primary wound closure. (With permission from [67] © Springer)

anal papilla proximally. Some authors also suggest that the definition of CAF should include being present for at least 6 weeks [5–7]. Lateral internal sphincterotomy (LIS) continues to be the most effective first line surgical treatment for patients with CAF who fail medical management [8, 9]. Hypertonia of the IAS is thought to be the pathophysiology of CAF. Manometric and Doppler studies of patients with CAF have demonstrated persistent high pressures and decreased perfusion of the IAS [10, 11]. Doppler studies have demonstrated improved blood flow to the anoderm following LIS and fissure healing rates of 90–100 %. Up to 30 % or more of these patients experience some sort of incontinence, most of it temporary and most incontinence related to flatus [10, 12, 13]. However, some studies have demonstrated that the incidence of incontinence may increase with time and long-term incontinence rates might be higher than reported [9, 14, 15].

Sphincterotomy for the treatment of CAF was first described by Brodie in 1835 and was popularized by Eisenhammer in 1951. The initial description of the technique involved complete division of the internal sphincter [16]. However, the high incontinence rate associated with this technique led to various tailored approaches including limiting division of the distal internal sphincter to the length of the fissure [17–19]. A randomized prospective trial comparing traditional and tailored sphincterotomies was performed in 2005. Continence was significantly worse in those patients whose sphincter was divided to the dentate line [20].

Several techniques for sphincterotomy have been described. Classically, a posterior midline internal sphincterotomy to divide the internal sphincter in the bed of the posterior fissure was the operative procedure of choice. Development of a posterior keyhole deformity, postoperative pain, and prolonged healing has been associated with this procedure. Increased levels of postoperative incontinence when compared to LIS have also been reported. For these reasons, posterior sphincterotomy is rarely used today [21–24].

LIS involves partial, lateral division of the IAS. Both an open and closed (subcutaneous) technique has been described. The open technique involves either a vertical or radial incision in the intersphincteric groove (Fig. 43.1). The internal sphincter is identified and divided under direct vision. The closed technique involves advancing a small blade through the anoderm into the intersphincteric groove with blind division of the IAS (Fig. 43.2). Similar healing rates have been reported following both techniques, but some suggest the closed technique is associated with a more rapid recovery [23–27].

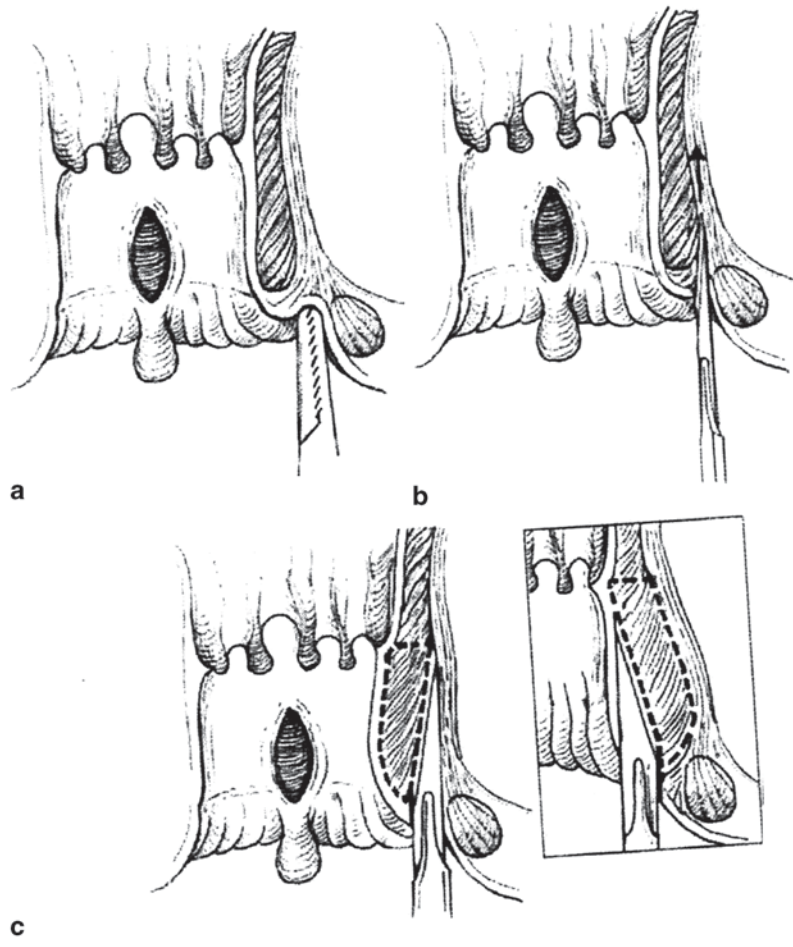

Fig. 43.2 Closed lateral internal sphincterotomy. **a** Location of the intersphincteric groove. **b** Insertion of the knife blade in the intersphincteric plane. **c** Lateral to medial division of the internal anal sphincter (inset: medial to lateral division of the muscle). (With permission from [67] © Springer)

Healing rates for CAF following LIS have been reported as high as 95% [28–30]. Reported incontinence rates vary from 0 to 50% [27, 30–34]. This wide variance had been attributed to multiple factors including surgical technique (open versus closed), length of LIS, type of anesthesia (local versus general), previous anorectal surgery, obstetric history, and inadvertent injury to EAS (Table 43.1) [9]. Perhaps the most important factor underlying the wide variation of reported incontinence rates following sphincterotomy is methodology of assessing the outcomes. Common methodological deficiencies include lack of clear definition of incontinence, failure to include the number of patients operated versus those surveyed, inadequate or poorly defined length of follow-up, use of nonstandardized or nonvalidated questionnaires, and failure to use nonbiased, objective examination of sphincter function. Of note, a recent Cochrane review (2011) evaluating the operative procedures for fissure-in-ano concluded that the combined analyses of open versus closed LIS show little difference between the two procedures in fissure persistence and risk of incontinence [35]. However, in regard to short- and long-term follow-up,

Table 43.1 Factors responsible for wide variance noted in incontinence rates following LIS

Surgical technique (open versus closed)
Length of LIS
Type of anesthesia (local versus general)
Previous anorectal surgery
Obstetric history
Inadvertent injury to EAS

Table 43.2 Risk factors for incontinence following LIS

Age over 40
Female gender
History of vaginal delivery
Anterior fissure
Synchronous anorectal procedure
Operative technique

Nyam et al. (1999) reported a 45% incontinence in the short-term outcome, decreasing to <11% in long-term follow-up [33]. Lewis et al. (1988) reported a 17% incontinence rate. This was only temporary in two-thirds of these patients [25]. The overall risk of incontinence in randomized surgical trials is reported to be about 10% and is mostly incontinence to flatus [36].

A 2012 meta-analysis identified subsets of individuals more prone to continence disturbances after sphincterotomy for fissure. These include age over 40, female gender, history of vaginal delivery, anterior fissure, addition of a synchronous anorectal procedure, and operative technique (Table 43.2) [15]. Preoperative anal manometry and endoanal ultrasonography should be considered in those high-risk patients to help delineate and define any possible preexisting sphincter injury and associated sphincter weakness.

Murad-Regadas et al. (2013) conducted a prospective observational cohort study to determine the proportion of the IAS that may be divided during LIS in continent women without predisposing them to fecal incontinence [37]. 3D-endo anal ultrasound was used to evaluate the extent of the surgically divided portion of the IAS. Postoperative continence was objectively assessed via the Cleveland Clinic Florida score. They found that follow-up continence scores were significantly correlated with the extent of sphincter division. Continence was significantly better in those women whose sphincter division was less than 25% versus those women with division of 25% or more. Garcia-Aguilar et al. (1998) found that the IAS defects were wider in patients with incontinence than in those who were continent but this was not significant [38].

Fistulotomy

The goal of surgical treatment for anal fistula is eradication of the fistula tract without compromising sphincter function. Fistulas can be classified as "simple" or "complex." "Simple" fistulas are of cryptoglandular infection, are usually distal intersphincteric or distal transsphincteric and can be treated by lay open fistulotomy with reported success rates reported over 90% [39]. Those "simple" fistulas that involve proximal (high) intersphincteric or transsphincteric tracks are more difficult to manage. Fistulotomy of such proximal anal fistulas is associated with lower healing rates and higher rates of incontinence. "Complex" fistulas including those arising from noncryptoglandular origin such as those associated with perianal Crohn's disease, those persisting or recurring despite prior surgical interventions, and those of cryptoglandular origin that crosses >30–50% of the external sphincter, are anterior in a female, are associated with multiple tracts, develop in an individual with some degree of existing fecal incontinence, or occur in previously irradiated tissue (Table 43.3) [40]. Reported rates of incontinence after surgery for such "complex" anal fistulas vary from 0 to 25% for flatus, up to 26% for major fecal leakage, and as high as 63% for minor and/or passive incontinence [41]. Female gender, type of surgery, prior fistula surgery, posterior internal opening, and horizontal extension have been variables associated with postoperative incontinence. Reported fistula recurrence rates range from 0 to 30% and have been associated with a horseshoe tract, missed tracts, failure to identify the internal opening, prior surgery, and surgeon experience [41]. For distal (low) fistulas, it is generally accepted that the risk of incontinence is minimal and fistuloto-

Table 43.3 Complex versus simple fistula

Noncryptoglandular origin
Cross>30–50% of external sphincter
Anterior in females
Associated with multiple tracts
Develop in an individual with continence disturbances
Occur in previously irradiated tissue

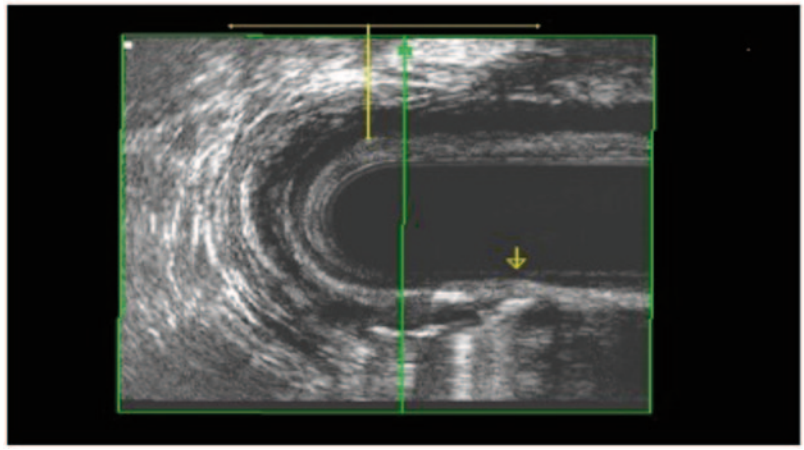

Fig. 43.3 Transsphincteric fistula with hydrogen peroxide in the tract. (Courtesy of Dr. Amy Thorsen)

my is advocated if less than one-third of the external sphincter is crossed by the fistula [42–44].

Several surgical techniques have been described to address high or complex anal fistula. The anatomy of these tracts can be defined in the operating room with fistula probes and/or with the aid of dyes or hydrogen peroxide. Alternatively, radiographic evaluation with either endoanal ultrasonography (with or without hydrogen peroxide injection) (Fig. 43.3) or magnetic resonance imaging (MRI) (Fig. 43.4) may prove helpful to identify the fistula and help quantify the amount of IAS and EAS involved by the tract and at potential risk for division [45–47].

Both draining and cutting setons may be used for high or complex fistulas. After defining the fistula tract with a probe, the surgeon may elect to use a combination of a seton placed through the tract and a partial sphincterotomy. A draining seton is used to assure complete resolution of associated abscesses and to induce fibrosis along the tract. When the inflammatory process has resolved, the seton may either be removed in hope that the fistula will go on to heal without further division of muscle or it can be removed and additional fistulotomy performed. Sometimes the draining seton is converted to a cutting seton or in the absence of significant associated abscess and inflammation, a cutting seton may be used instead of a draining seton in the first procedure. The cutting seton is gradually tightened

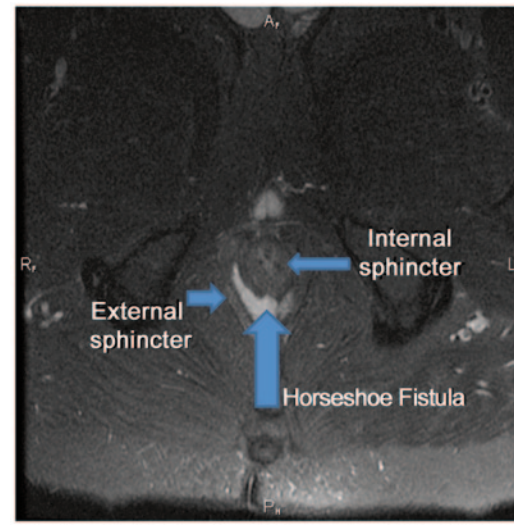

Fig. 43.4 Horseshoe fistula identified on MRI. (Courtesy of Dr. Sid Walker)

to slowly divide the remaining involved muscle in the fistula tract. This theoretically allows scar to form as the seton is slowly "walked through the sphincter," thus keeping the sphincter muscle intact and avoiding a wide gap as is noted when muscle is divided in one procedure.

Eradication of the fistula is reported to be 60–78% with recurrence rates between 2 and 9%. Although the cutting seton at one time was thought to preserve continence in comparison with direct division, reports have not confirmed

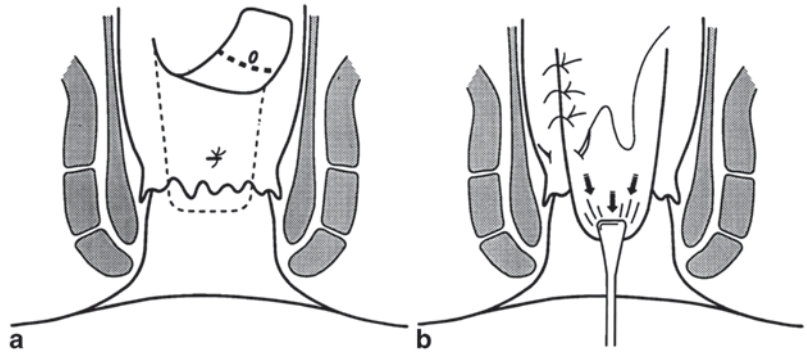

Fig. 43.5 **a** Suprasphincteric fistula. **b** Extrasphincteric fistula. (With permission from [68] © Springer)

this reputed advantage. Minor disturbance of continence occurs in 34–63 % of patients along with impaired anal manometry and postoperative deformity of the anal canal [41, 48]. Additionally, cutting setons are not well tolerated because of the discomfort associated with frequent tightening of the cutting seton. The two-stage seton fistulotomy results in similar rates of incontinence as the cutting seton with minor incontinence ranging from 54 to 66 % and major incontinence ranging from 4 to 26 % [49, 50]. Injection of fibrin glue or a collagen plug results in varying success rates ranging from 33 to 88 % with minimal associated morbidity or alteration of continence [51–53].

Endorectal advancement flaps have been used to obliterate the internal fistula opening without division of the sphincter complex in an attempt to preserve continence. Following debridement of the chronic fistula tract(s), a flap of mucosa and submucosa with or without a portion of internal sphincter muscle is mobilized beginning distal to the internal opening of the fistula. The flap is mobilized proximally increasing its width to maintain good vascularity. The proximal dissection proceeds until the mobilized flap can be advanced distally over the internal opening of the fistula and a tension-free repair of the flap to the anorectum distal to the internal opening can be achieved (Fig. 43.5). Long-term studies on advancement flaps report recurrence rates as high as 33 % in cryptoglandular disease and up to 57 % in Crohn's associated fistula. Prior attempts at repair of the fistula have been associated with increased incontinence following advancement flaps [41]. This may be due to inadvertent sphincter injury with retractors, inelastic tissue secondary to scarring, and direct injury to the internal sphincter with mobilization. Identified key steps for successful flaps include correct identification of the fistula tract and internal opening. Sepsis must be resolved and the tract should be dry and fibrotic. Draining setons should be used liberally as a first-stage procedure to ready the operative field for an advancement flap. The external opening should be enlarged to prevent premature closure of the external opening, which could lead to a postoperative track abscess which may necessitate through the repair [54].

The Ligation of the Intersphincteric Fistula Tract (LIFT) procedure is another sphincter-sparing technique that involves identification and ligation of the fistula tract in the intersphincteric groove. Success rates range from 57 to 94 % [55, 56]. Vergara-Fernandez et al. (2013) performed a review of the current LIFT literature where the primary outcomes included fistula healing rates, mean healing time, and patient satisfaction. Eighteen studies were included in the review with an *N* of 592. The mean healing rate was 74.6 %. Several risk factors for failure were identified and included obesity, smoking, multiple previous operations, and the long fistula tracts. Mean healing time was 5.5 weeks with a mean follow-up of 42.3 weeks. No *de novo* incontinence developed secondary to the LIFT procedure and patient satisfaction ranged from 72 to 100 % [57]. Currently, there is not enough evidence to assess the alleged improvement of LIFT variants.

Management

Evaluation

If anal incontinence does occur following a LIS or fistulotomy, a detailed history to assess the bowel habits including frequency of bowel movements, consistency of stools, type of incontinence (gas, liquid, solid, seepage, full bowel movement, post defecation, etc.), and severity of incontinence pre and post procedure is essential. Past history of gastrointestinal, genitourinary and neurological disorders, details of all prior anorectal procedures, medication use, and attempts to manage the incontinence should be carefully reviewed. The desire to pursue treatment of fecal incontinence depends primarily on the patient's subjective symptoms and quality of life. A number of incontinence scales are available to help objectify these symptoms including the Cleveland Clinic Florida Fecal Incontinence (CCF-FI) scale, the Fecal Incontinence Severity Index, and the Fecal Incontinence Quality of Life Scale [58].

The physical exam should include perianal and perineal inspection looking for scars (post procedure, episiotomy), unhealed wounds, persistence of a fissure or fistula, possible prolapse (full thickness, mucosal), or signs of active infection or inflammation. Digital rectal exam is performed to evaluate possible palpable sphincter defects, assess resting tone (IAS) and squeeze (EAS). It is also important to look for use of accessory muscles (buttocks), which may be used to augment squeeze and serve as a marker for decreased function. Nerve function may be assessed by evaluating the anocutaneous reflex, which is a brief contraction of the EAS when the perianal skin is lightly stroked and indicates the presence or absence of intact sensory and motor innervation [58]. Proctosigmoidoscopy is done to exclude neoplasm, evidence of ulcerative colitis or Crohn's disease, solitary rectal ulcer, or other disease states.

A detailed history and physical exam may provide enough information to formulate a conservative treatment plan with medical management. Frequency and stool consistency may play a significant role in the severity of the incontinence and incomplete emptying of the anorectum can result in seepage of mucus and small amounts of feces. Bulking agents and fiber supplements may play a significant role in reducing the episodes of incontinence and may be all that is necessary for those with mild incontinence. In individuals with diarrhea, it is important to investigate the cause of the diarrhea. The specific treatment should be geared toward the cause. Antidiarrheals that slow colonic transit and limit intestinal fluid secretion are beneficial for many. In a randomized, controlled trial, loperamide (Imodium) was found to be more effective than diphenoxylate-atropine (Lomotil) in patients with incontinence and may serve to increase sphincter tone [59]. An anal plug or cotton wick may be beneficial in those individuals with fecal soiling or seepage.

Biofeedback may be used if conservative management fails or in conjunction with conservative management. Biofeedback exercises may increase strength and endurance of the anal muscles and improve rectal sensation [58]. Success rates of biofeedback for incontinence range from 38 to 100%. A sphincter defect may limit but does not preclude the possibility of a good response.

For those individuals with persisting incontinence of unclear etiology or who fail conservative management and are possible candidates for surgery, pelvic floor testing may be beneficial to evaluate pelvic floor function and anatomy. Anal manometry is used to objectively assess anal resting and squeeze pressures as well as rectal compliance. Endoanal ultrasound and MRI are useful to detect and quantify sphincter defects. Pudendal-nerve terminal motor latency (PNTML) testing allows one to quantify nerve function.

Treatment

Injectables

For patients with passive fecal incontinence (individuals with seepage or soilage secondary to IAS damage or dysfunction) and/or low resting

anal pressures, intra-anal injectables have been promising. The mechanism of the injectable is to provide an increase in the resting tone to compensate for the failed IAS [58, 60]. Various materials have been injected to treat incontinence and include collagen, silicone, autologous fat, glutaraldehyde, carbon-coated beads, and dextranomer in hyaluronic acid gel [61]. The technique involves injection of the agent into the deep submucosa of the anal canal. Several studies have shown a reduction in fecal incontinence episodes with significant improvement of quality of life. However, long-term studies are lacking [61].

Magnetic Bowel Sphincter

The magnetic anal sphincter (Fenix, Torax Medical, Shoreview, MN) is currently experimental and not available for implantation outside of study. The sphincter is made of titanium beads with magnetic cores that are implanted around the anal sphincter muscle complex. In two separate cohort matched studies, the magnetic anal sphincter was comparable to the artificial bowel sphincter (ABS) or sacral nerve stimulator for improvement of fecal incontinence, quality of life, and resting anal pressures [62, 63].

Sacral Nerve Stimulator

The indications for sacral nerve stimulation (SNS) (Medtronic, Minneapolis, MN, USA) have expanded over the last decade after its introduction for fecal incontinence in 1995. Initially SNS was reserved for patients with an intact sphincter and impaired function [64]. However, its use has now evolved to include a wide spectrum of sphincter dysfunction. Randomized controlled trials have shown good long-term results with SNS. Mellgren et al. demonstrated, at 3 years follow-up, improvement of symptoms in 86% of the 133 patients [65]. Hull et al. reported that 89% of patients have continued reduction in fecal incontinence and 36% had a complete response to SNS at 5 years [66]. Potential complications of the SNS include lead displacement, pain, infection, and paresthesias.

Artificial Bowel Sphincter

The ABS is generally reserved for those with severe incontinence who have suffered significant loss of the sphincter muscle mass. The ABS has shown good long-term functional and qualitative results. Improvement of continence has been reported in 75% of patients as well as quality of life scores with the ABS [61]. Complications include infection (25−40%), erosion, obstructed defecation, and pain.

Diversion

For those individuals with severe fecal incontinence, who have failed all conservative and surgical options, fecal diversion is an option that may substantially restore quality of life.

In summary, LIS and fistulotomy are very effective treatments for CAF and fistula, respectively. However, care must be taken when dividing the anal sphincter complex to avoid any unnecessary issues with incontinence. Various techniques have been described for both LIS and fistulotomy with reported varying degrees of success and rates of incontinence. Preoperative studies including anal manometry, endoanal ultrasonography, and/or MRI should be considered in higher risk individuals or those individuals more prone to continence issues.

Should continence issues develop postoperatively, the individual should undergo routine history and physical exam paying particular attention to stool frequency and consistency and perianal exam. Many individuals may note significant improvement in their symptoms by simple modification of the frequency and consistency of stool with conservative methods such as fiber and/or antidiarrheals. Biofeedback may be used if conservative management fails or in conjunction with conservative management. For those individuals in whom conservative management

fails, other options to manage the incontinence are readily available.

Key Points: Strategies to Avoid the Complication of Incontinence

1. Make every effort to avoid surgery for fissure in ano by using nonoperative conservative management.
2. When surgery for fissure in ano is required to alleviate symptoms, base the extent of internal sphincterotomy on the risk of incontinence. For patients without special risk factors for incontinence, perform a limited distal partial internal sphincterotomy rather than the traditional full-thickness division of the entire internal sphincter muscle to the dentate line. Divide even less internal sphincter muscle in patients with special risk factors for incontinence, for example, individuals over 40 years of age; women, especially those with a history of vaginal delivery; anterior fissure; addition of a synchronous anorectal procedure; and underlying bowel disorders or diseases such as inflammatory bowel disease or irritable bowel syndrome.
3. Preoperative anal manometry and endoanal ultrasonography or MRI should be considered in individuals at high risk for incontinence to help delineate and define any preexisting sphincter injury and/or associated sphincter weakness.
4. Preoperative imaging including endoanal ultrasonography or MRI may be useful to define anatomy, extent of muscle involvement, and fistula tracts prior to fistula surgery.
5. If the fistula tract crosses more than one-third of the external sphincter or if a fistula is present in an individual with preexisting incontinence, consider an alternative treatment to fistulotomy such as long-term draining seton, advancement flap, or ligation of the intersphincteric tract.

Key Points: Diagnosing and/or Managing the Complication of Incontinence Either Intraoperatively or Postoperatively

1. During either the open or closed technique, intraoperative visualization and/or palpation of the IAS muscle can be used to define its length and thickness and to facilitate accurate performance of a limited, partial distal internal sphincterotomy.
2. Fistula probes, hydrogen peroxide, or methylene blue placed or injected into the fistula tract at the time of surgery may help define anatomy, distinguish simple low tracts from high complex tracts, and guide the surgeon's approach.
3. Conservative management with bulking agents, antidiarrheals, and/or biofeedback may be all that is necessary to manage some patients with postoperative incontinence.
4. For those individuals with persisting incontinence of unclear etiology or who fail conservative management and are possible candidates for surgery, pelvic floor testing may be beneficial to evaluate pelvic floor function and anatomy. Anal manometry is used to objectively assess anal resting and squeeze pressures as well as rectal compliance. Endoanal ultrasonography and MRI are useful to detect and quantify sphincter defects. Pudendal-nerve terminal motor latency (PNTML) testing allows one to quantify nerve function.
5. Injectables or implants may be beneficial in those individuals in whom conservative management fails.

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Anal Stenosis After Hemorrhoidectomy: Avoidance and Management

44

Jonathan B. Mitchem and Paul E. Wise

Introduction

Hemorrhoids are a widely prevalent disease; however, it is difficult to know the true prevalence. Reports vary from 4 to >50% depending on the data source [1]. Hemorrhoidectomy is the most effective therapy at eliminating symptoms associated with hemorrhoids in patients who fail nonoperative management [2, 3], and among patients who present with symptomatic hemorrhoids, nearly 10% undergo operative intervention [4]. Operative hemorrhoidectomy does have drawbacks, including increased complications and more pain than nonsurgical therapy [5]. Therefore, in most cases, hemorrhoidectomy is avoided until nonoperative management options have failed.

Due to the prevalence of hemorrhoidal disease and the volume of patients undergoing operative intervention for the treatment of hemorrhoids, many different techniques for excisional hemorrhoidectomy have been studied to maximize benefit and minimize complications. The two most common methods of operative intervention are the Milligan–Morgan or "open hemorrhoidectomy" [6], which is most prevalent in Europe, and the Ferguson or "closed hemorrhoidectomy" [7], which is most prevalent in the USA. Among the other methods investigated include circular mucosal resection, stapled hemorrhoidopexy, as well as the use of specialized vessel sealing devices (e.g., ultrasonic devices) or Doppler-guided hemorrhoidal arterial ligation, to name a few.

As previously mentioned, excisional hemorrhoidectomy, while a generally low-risk surgery, is not without complications. One potentially life-altering and difficult complication is that of anal stenosis. Most series report the incidence of post-hemorrhoidectomy anal stenosis as less than 5%, although many of these studies only report short-term outcomes. The incidence also varies depending on the surgical technique and definition of stenosis (Table 44.1) [8–17]. Hemorrhoidectomy is the most common cause of anal stenosis, and this risk increases with an increase in the complexity of hemorrhoidal disease [18]. In this chapter, we will discuss the workup and management of this complicated clinical issue.

Diagnosis

The evaluation and diagnosis of anal stenosis following hemorrhoidectomy starts with a thorough history and physical examination. The most common presenting symptoms are pain with defecation, constipation, narrow stool caliber, and, less commonly, bleeding [19, 20]. Fear of defecation may also be present. Often many of

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Table 44.1 Classification of anal stenosis by degree and level of stenosis

Degree of stenosis	Description
Mild	Anal canal allows insertion of a lubricated finger or medium anoscope
Moderate	Insertion of a finger or medium anoscope requires dilation
Severe	Insertion of the little finger or small anoscope requires forced dilation
Level of stenosis	*Description*
Low	>5 mm distal to the dentate line
Middle	5 mm distal to the dentate line extending to 5 mm proximal to the dentate line
High	>5 mm proximal to the dentate line

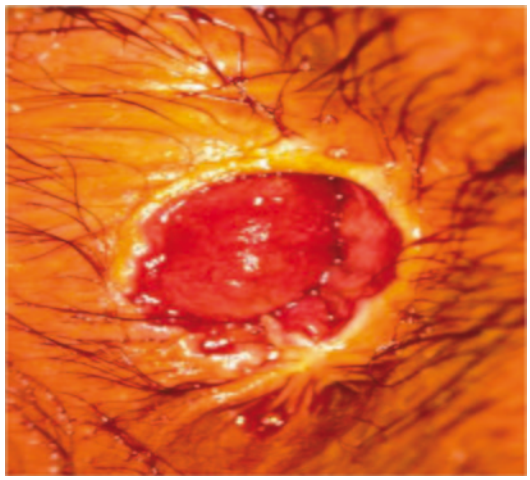

Fig. 44.1 Anal stenosis with ectropion, also known as whitehead deformity. (Courtesy of Ira J. Kodner, MD)

these symptoms overlap. Additionally, patients may present with fecal leakage or paradoxical diarrhea in the presence of obstructive symptoms or fecal overflow around impacted stool. These symptoms, combined with a history of hemorrhoidectomy, should prompt the clinician to consider the diagnosis of anal stenosis prior to examination.

Physical examination confirms the diagnosis. On visual inspection, patients may have a circular narrowing or scar-like appearance to the anal aperture (Fig. 44.1) [21]. Digital rectal examination is often difficult to perform and may be very painful, and therefore, many patients will require examination under anesthesia (EUA) to perform a complete examination. Any suspicious lesions can also be biopsied at this time to rule out other more concerning issues including neoplasia. Anoscopy as well as proctoscopy should be performed, if not previously performed or in cases where another diagnosis is being entertained. An EUA may also aid in differentiation between functional and anatomic disorders of the anal canal [21]. Functional anal stenoses are the result of impaired relaxation of the internal sphincter complex without evidence of external anal scarring. Anatomic anal stenoses are those that are the result of scarring/contracture of the anal canal structure itself. Often there are components of both functional and anatomic stenoses in each patient.

No adjunctive testing is routinely necessary beyond a thorough examination of the anal canal unless indicated to evaluate other issues or the diagnosis is in question after examination. Anal manometry and/or defecography can be utilized to rule out other pelvic floor or functional disorders causing tenesmus, constipation, and/or fecal leakage [22].

Classification of Stenosis

The severity of anal stenosis is classified as mild, moderate, or severe based on the physical examination. Stenoses are considered mild if the anal canal can be examined by a lubricated finger or a medium anoscope, moderate if insertion of a lubricated finger or medium anoscope requires forced dilation, and severe if insertion of the little finger or a small anoscope requires forced dilation. The level of stenosis is related to the distance from the dentate line. Stenoses greater than 0.5 cm distal to the dentate line are considered low; those that are between 0.5 cm distal and 0.5 proximal to the dentate line are considered middle; and those greater than 0.5 cm proximal to the

dentate line are considered high (Table 44.1)[18]. Both the level of involvement and the severity of stenosis are important when developing the plan for managing these patients.

Treatment

Prevention

The best treatment for anal stenosis after hemorrhoidectomy is a meticulous approach in the operating room during the primary operation. The risk of anal stenosis increases with the complexity and extent of the hemorrhoids treated. Surgical therapy of extensive and complicated hemorrhoids should only be approached by surgeons experienced in this operation [23]. The keys to prevention of anal stenosis after hemorrhoidectomy are meticulous submucosal dissection with avoidance of injury to the internal sphincter muscle and the preservation of sufficient intact anoderm between excision sites, generally considered at least 1 cm of intact intervening anoderm. Additionally, limiting the number of hemorrhoids excised in a given setting will also help to limit the incidence of postoperative stenosis.

Nonoperative Intervention

The cornerstone of therapy for anal stenosis from all causes is dietary modification, including a combination approach utilizing stool softeners as well as increased fiber intake and water consumption. For many patients with mild stenosis, these simple measures may alleviate the patient's symptoms. For patients not initially responsive to these measures, and those with moderate stenoses, it is reasonable to attempt a course of manual dilation in addition to the above measures. This program consists of an initial dilation in the operating room or clinic, if tolerated, followed by serial dilations at home by the patient using either a finger or a dilator (Fig. 44.2). This can be facilitated and better tolerated through the use of anesthetic jelly (e.g., lidocaine 2%). The majority of patients with mild stenosis will achieve symptom alleviation with this approach, as will many patients with moderate stenosis [14, 17, 19, 24]. Manual dilation does have some risks, such as perforation, but these risks are low [25].

Fig. 44.2 An example of pediatric dilators ranging in size from 15 to 21 mm used for dilation of anal stricture

Operative Intervention

Operative therapy is usually reserved for patients with severe stenosis or those with moderate stenosis that have failed nonoperative therapy. Many different procedures have been described to treat anal stenosis; however, there are few comparative prospective studies to guide therapy. Different patient-specific issues may lend themselves to the use of different techniques (Table 44.2).

Anatomic Versus Functional Stenoses

True functional anal stenosis refers specifically to patients that have a defect in the relaxation of the sphincter complex. These patients do not have abnormalities of the anoderm. Patients with anatomic anal stenoses have a defect in the anoderm, which is not related to relaxation of the sphincter complex. A common situation is that patients will have a combined issue, meaning impaired sphincter complex relaxation as well as structural scarring. Differentiating true functional

Table 44.2 Technique and setting of use for procedures for the treatment of anal stenosis

Technique	Setting
Lateral internal sphincterotomy	Functional stenoses
	Mild low anatomic stenoses
	Used in combination with advancement flap techniques in the treatment of some anatomic stenoses or combined stenoses
Lateral mucosal advancement flap (endorectal advancement flap)	High and some mid-anatomic stenoses
Perianal skin advancement flaps (V-Y, Y-V, Diamond, House, U-shaped flaps)	Low and some mid-anatomic stenoses

and anatomic stenosis may be apparent on physical examination; however, patients will often need further testing to ensure the appropriate diagnosis is obtained. As mentioned, patients with true functional stenoses will commonly show relaxation with the induction of anesthesia during EUA and will not have evidence of anoderm stricturing. Additionally, in the circumstance of a combined stenosis in patients with previous anorectal surgery, it is advisable to obtain preoperative anal manometry to help in guiding operative treatment. One of the most potentially devastating complications of the procedures to treat anal stenosis is loss of continence; therefore, any operation should be entered into with as much foreknowledge as possible to determine the best course of action.

Preoperative Planning

As noted, the diagnosis of anal stenosis is generally made by history and physical examination. Anoscopy, rigid proctoscopy, and colonoscopy should be used selectively on a case-by-case basis. It is recommended that patients undergo bowel preparation based on surgeon preference, although this may be difficult for patients with more severe stenoses. There are no data to support the use of preoperative antibiotic regimens, especially for more minor procedures; however, we frequently use intravenous ciprofloxacin and metronidazole or ertapenem for more extensive procedures unless there is a concern indicating usage of broader preoperative antibiotic coverage. The patient is brought to the operating room and placed in the prone jackknife position. Depending on the choice of anesthetic, patients should be intubated under general anesthetic prior to positioning. Alternatively, if local anesthetic is chosen, the patient may move over to the bed independently. The buttocks are taped apart to provide further exposure to the perianal area. The patient is then prepped and draped in the standard fashion based on surgeon preference. After the patient is sufficiently relaxed, local anesthetic is infiltrated. Local anesthetic can be considered even under general anesthesia both for better differentiation of functional stenosis and for postoperative pain relief.

Lateral Internal Sphincterotomy

For patients with primarily functional stenoses or mild mid- to low-anatomic stenoses, symptom relief may be achieved with internal sphincterotomy alone. This may be accomplished by single [24] or multiple internal anal sphincterotomies [18], to include bilateral internal anal sphincterotomy [26] in some cases. Good results have been reported with sphincterotomy in the case of mild- to moderate-low anal stenoses, as well as some mid- or high stenoses, with most patients being able to be managed in this way [18]. If the patient does not have sufficient normal anoderm, however, initial relief of symptoms may occur, but post-procedural scarring may lead to recurrent anatomic stenosis. To help diminish this issue, the wound is left open to heal by secondary intention and patients are maintained on an aggressive post-procedural regimen of stool bulking agents, laxatives, and increased hydration [20]. An important consideration when considering sphincterotomy is the possibility of postoperative fecal incontinence. This issue generally resolves with time and is worse with flatus than stool, but can be devastating if it persists. Depending on the

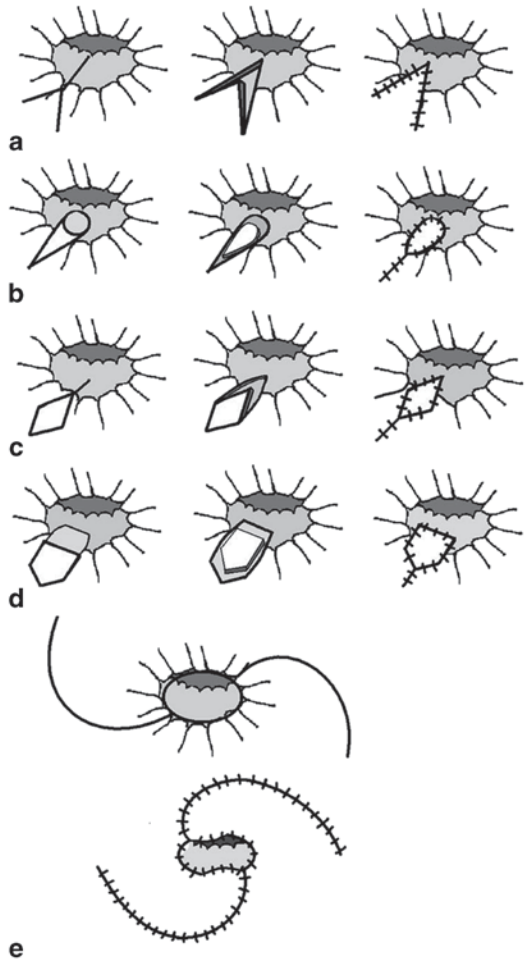

Fig. 44.3 Perianal flap techniques for anal stenosis. **a** Y-V flap. **b** V-Y flap. **c** Diamond flap. **d** House flap. **e** rotational S-flap (With permission from [40] © Springer)

individual case, it may be prudent to obtain preoperative anal manometry to determine the patients' sphincter function prior to considering this approach. It is a rare circumstance where the authors would favor this approach to stenosis after hemorrhoidectomy.

Lateral Mucosal Advancement Flap

The most common procedure used for proximal anatomic anal stenosis is a lateral mucosal or endorectal advancement flap (Fig. 44.3) [27]. This procedure is initiated by making a lateral incision in the perianal skin and transition zone such that the scar is completely divided (and a lateral internal sphincterotomy may also be performed simultaneously, if favored by the surgeon). Following scar division, the rectal mucosa is then mobilized proximally in a triangular or tongue-like formation proximally into the distant rectum in the muscular plane for 4–6 cm, ensuring that the flap can easily reach to interpose across the scar/stenosis with little to no tension. While this flap is referred to as a mucosal flap, it is vitally important to include mucosa, submucosa, and a portion of the circular muscle of the rectal wall, as flaps including only the mucosa and submucosa are prone to developing recurrent stricture due to ischemia. Additionally, the width of the flap base (proximal) should be approximately twice the width of the apex (distal) as another method to ensure adequate blood supply. The flap is then sutured to the anoderm distal to the stenosis using absorbable sutures in an interrupted, full-thickness fashion (the authors favor 3-0 vicryl, or more rarely, 3-0 chromic for smaller flaps). It is important that the mucosal flap is not fixed distal to this point, as this may lead to ectropion formation. Any portion of the excision of the stricture external to the intersphincteric groove should be left open to heal by secondary intent to avoid ectropion formation and minimize the risk of recurrent stricture. This procedure is generally well tolerated by patients in terms of postoperative pain with good long-term outcomes, and the procedure may be able to be performed with sedation and local anesthesia [21, 27, 28]. While this method is useful for proximal stenoses, perianal skin advancement flaps are better techniques for more distal anatomic stenoses.

Y-V Advancement Flap

One widely performed procedure is the Y-V advancement flap, especially for low and mid-stenoses. The Y-V advancement flap is accomplished by making a wide-based V-shaped incision with the apex just distal to the stenosis and the base of the flap laterally on the anoderm and perianal skin at least 2–3-cm wide, after which the "Y" extension is made from the apex of the "V" through the entire length of the area of stenosis (Fig. 44.3). The flap is then mobilized by dividing the deeper subcutaneous attachments

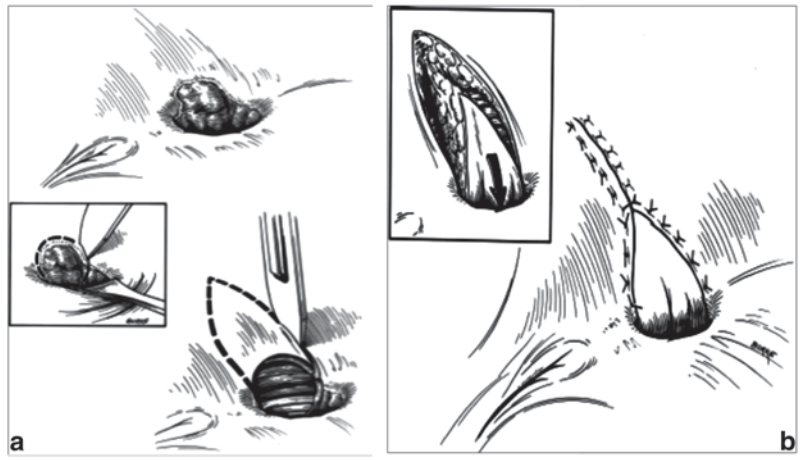

Fig. 44.4 V-Y advancement flap. **a** Excision of anal stricture and "V" incision into the perianal skin. **b** Flap mobilization including the subcutaneous fat and closure in "Y" formation

perpendicular to the skin while taking care to ensure both preservation of the subdermal blood supply and a tension-free repair, commonly requiring mobilization to the level of the underlying fascia depending on flap location. The apex of the V is then sutured to the distal corner created by the Y extension at the level of the internal-most aspect of the stenosis using interrupted longer term absorbable sutures (for example, 4-0 or 3-0 Monocryl or PDS), which creates the final "V" configuration of the repair. This technique has been described as very effective for relieving patients' symptoms [29–31]. The procedure can be performed in the posterior or lateral positions, and bilaterally, if necessary [20].

V-Y Advancement Flap

Another option for treatment of distal anal stenosis is the V-Y advancement flap (Fig. 44.3). To begin the operation, the area of stenosis is excised approximately 5 mm proximal to the dentate line (Fig. 44.4a). After excision of the stenosed segment, the V-Y advancement flap is accomplished by creating a wide V-shaped incision with the apex of the V extending into the healthy surrounding perianal skin. The base of the V should again be approximately 2–3-cm wide on the side of the stenosis, and the distal extent of the incision should be approximately two to three times the width of the base. Again, meticulous dissection is used to fully mobilize the flap while preserving the subdermal vascular plexus and ensure adequate mobilization to ensure a tension-free repair. After mobilization, the base of the V is sutured to the base of the area of excision, and the apex of the V is closed primarily to create the "Y" extension of the repair (Fig. 44.4b). It is generally felt that a 2-cm flap is adequate for a good repair [26]. While initially described for the treatment of mucosal ectropion [32], it has been applied to anal stenosis from a variety of causes with good results [33].

Diamond-Shaped Flap

To carry out the diamond flap, the scarred anoderm is incised across the stenosis laterally extending just into healthy tissue proximally (above the stenosis) and may have a slight diamond shape to facilitate flap placement (Fig. 44.3a, b and 44.5a-c). A diamond-shaped flap at least 2–3-cm wide (depending on the degree of stenosis, it may need to be wider) is then created in the surrounding perianal skin with one apex at the external end of the incision across the stenosis. Again, this flap is then fully mobilized, taking care to preserve the subdermal fat and vascular plexus. After achieving full mobilization, the flap is then sutured with interrupted full-thickness sutures to the proximal aspect of the incision across the stenosis and then the surrounding remaining

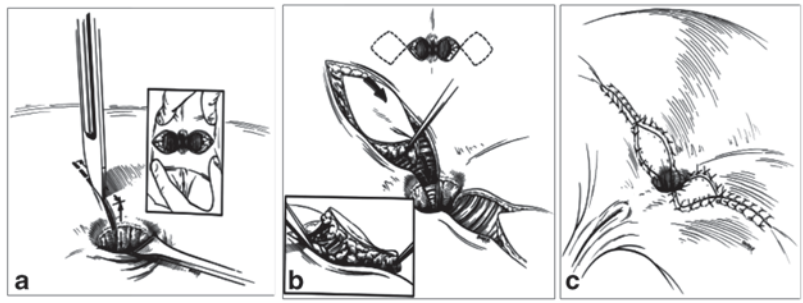

Fig. 44.5 Bilateral diamond flaps. **a** Preoperative depiction of anal stricture. **b** Incisions through the anal stricture to create the opening for flap placement. **c** Depiction of flap creation and mobilization, including the subcutaneous fat. **d** Final appearance at closure

anoderm after which the donor site is closed primarily in a linear fashion. An advantage of the procedure is that it may be used multiple times to cover multiple areas of stenosis or large defects. Results using this procedure have been reported as excellent [34], and in one study, the results were slightly better than the Y-V advancement flap [29], perhaps due to bringing a wider portion of vascularized skin into the site of the stenosis.

House Flap

The "house" flap, as originally described by Christensen et al., is another method of flap reconstruction (Fig. 44.3) [35]. It was designed to treat large areas of distal stenosis. The operation is begun by making a linear or rectangular, superficial incision in the right or left lateral position of the stenosis extending from the dentate line or most proximal edge of the stenosis through to the distal edge of the stenosis. The base (or "foundation") of the house-shaped flap is recommended to be approximately the entirety of the anal canal on the affected side (at least 2–3-cm wide), and the distal extent out onto the anoderm should be two to three times the width of the base, similar to the Y-V flap as discussed above. Transverse incisions extending laterally from the outer edge of the stenosis are made with the most lateral aspects of the anoderm incisions being brought together to form the apex of the "roof" of the house flap. The flap is then mobilized as described previously for the diamond flap, preserving the subdermal blood supply. The base/foundation of the house flap is then mobilized into the defect created in the stenosis, and the flap is sutured in place with interrupted full-thickness sutures, after which the anoderm is closed laterally at the "donor" site (similar to a V-Y closure). The house flap was designed to provide coverage for severe stenoses and can be performed multiple times in the same patient, with no single flap covering more than 25% of the stenotic area [21]. This technique has been employed with good success rates in several studies with high levels of patient satisfaction in follow-up to 26 months after repair [35–38]; although in one study there was a reported 44% rate of primary (donor site) wound separation [37], which will usually close primarily with local wound care.

U-shaped Flap

The U-shaped flap is similar to the diamond flap and has been described for use in patients with anal stenosis and mucosal ectropion [39]. This procedure is begun by incising the area of stenosis followed by making a U-shaped incision in the healthy perianal skin. The flap is then mobilized and sutured in place to cover the defect. This approach provides a larger distal extent of the flap to potentially avoid the concern for possible tip ischemia associated with V-Y flap advancement.

Postoperative Care

Patients undergoing limited procedures, such as sphincterotomy, can generally be handled on an outpatient basis. When a more extensive operation

is undertaken involving flap reconstruction, these patients are generally admitted at least overnight to the hospital to ensure adequate pain control. While some of these patients were admitted for 3–4 days in the past and kept NPO for the first 2 days of hospitalization, followed by subsequent initiation of a high-fiber diet, laxatives, and mineral oil to avoid constipation, there are no data to support this approach. Instead, most patients are immediately advanced to a high-fiber diet and stool softeners with or without laxatives. Patients are provided adequate analgesia in the form of oral pain medications, sitz baths, or showers are used for comfort as well as to clean after bowel function, and the patients are instructed to otherwise keep the area clean and dry. Prolonged sitting and strenuous activities are discouraged for the first 2 weeks postoperatively. It is not routine practice to use closed drainage unless a large flap is created, and this should be removed at the surgeon's discretion, usually when the output is less than 5–10 cc/day. Routine use of topical and/or oral antibiotics is not indicated postoperatively unless infection occurs. Short-term postoperative complications are similar to other perineal and anal operations and include urinary retention and local infection. Significant bleeding is rare. Flap ischemia may occur and is usually managed with local wound care, although operative debridement may rarely be needed. Long-term complications include ectropion formation, leakage/incontinence, and/or recurrence of stenosis. These complications are relatively infrequent, if the appropriate surgical approach is chosen and performed by experienced surgeons.

Summary

Anal stenosis is a rare complication of hemorrhoidectomy and can generally be avoided by performing meticulous dissection in the submucosal plane, avoiding injury to the underlying muscle, and ensuring adequate normal intervening anoderm during the index operation. Most patients with anal stenosis can be managed nonoperatively using a combination of increased dietary fiber, hydration, and stool softeners; however, it is important to confirm that there is not a more concerning underlying process, such as anal or rectal neoplasia. It is uncommon for patients with mild stenosis to require operative intervention, but in patients with mild to moderate stenosis in whom non-operative methods fail, a trial of serial dilations commonly provides resolution. In patients with nonresponsive moderate stenosis or severe stenosis, there are a multitude of options for intervention including sphincterotomy and various methods of flap anoplasty. Surgical therapy should be guided by location and the ability to create a tensionless flap and preserve integrity of flap blood supply. After surgical intervention, patients should be maintained on high-fiber diet and stool softeners, as well as being provided adequate analgesia, as these will help to prevent postoperative complications and lead to good outcomes and resolution of symptoms in the vast majority of patients.

Key Points: Managing Complications

1. Managing anal stenosis after hemorrhoidectomy starts with the index operation. To avoid this complication:
   a. Employ techniques of meticulous dissection in the submucosal plane, avoiding injury to the internal sphincter muscle.
   b. Ensure adequate intervening normal anoderm between excisions, generally considered ~ 1 cm.
   c. When possible, limit the number of sites of hemorrhoid excision at each intervention.
   d. Complex hemorrhoidal disease should be managed by surgeons experienced in the treatment of perianal conditions.
2. Anal stenosis can be due to a functional defect in the internal sphincter complex, anatomic strictures of the anal canal, or a combination of both. Each of these issues may be managed slightly differently, so it is important to arrive at the appropriate diagnosis preoperatively.
3. The diagnosis of anal stenosis is primarily one based on history and physical examination; however, adjunctive assessments may be necessary in the appropriate clinical setting.

4. The majority of patients with mild and moderate stenosis can be managed nonoperatively.
5. There are a number of techniques used to treat this condition operatively, and the approach to each patient should be individualized based on severity of stenosis, location, and patient symptoms.
6. Postoperatively, patients should be provided adequate analgesia and maintained on a regimen of high-fiber intake, increased fluids, and stool softeners.
7. Complications are rare when the techniques are performed as described; however, complications may include the following:
   a. The most common immediate postoperative complication is flap ischemia/necrosis, which can generally be managed with local wound care.
   b. Long-term complications can include ectropion, leakage/incontinence, and recurrent stricture. These complications are best treated preventatively by adherence to surgical principles during the index operation.

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Part V
Other Considerations

Delivering Bad News: Conversations with My Surgeon

45

Murray F. Brennan

Introduction

Almost all successful human interrelationships succeed because of shared and understood expectations whether between spouses, parents and children, employee and employer, business partners, or doctor and patient. If expectations are understood by both participants, then much of the rancor and future potential conflict can be avoided or ameliorated.

No better example of this is seen than between surgeon and patient prior to the performance of a major surgical procedure. Much of the difficulty and angst encountered in delivering "bad news" occurs because of the failure to anticipate a poor outcome because of either unrealistic expectations of the patient, his or her family, or the failure of the surgeon to convey the potential for less than a perfect outcome. No surgical procedure can ever be perfect and there are situations when unanticipated problems do occur. The ability to minimize the unanticipated is foremost in making delivery of bad news tolerable and less likely to engender anger.

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Informed Consent

Informed consent is intended to convey just that, "informed" consent. It is your devoir. The importance is underappreciated by the surgeon who delegates consent to a junior member of the team. We need be cognizant that informed consent is often offered at a time when the patient is most vulnerable, and often obtained at a time when patient receptivity is at a minimum. Presentation of a diagnosis of cancer of the pancreas or the anticipation of a pancreatic cancer is accompanied by mind numbing shock and rarely delivered in a situation where calm and considered "informed consent" can be obtained. Legal requirements of informed consent are often vague, poorly understood, or interpreted by patient and surgeon alike [1]. When one anticipates that some form of complication minor or major occurs in up to 50% of patients undergoing pancreaticoduodenectomy, one realizes how infrequently such potential events are described. Conversely, the willingness to emphasize complexity of any procedure and the potential of some complication occurring is essential to future rapport. This can be simplistically conveyed when talking about the duration of hospital stay. The mention of the anticipated postoperative stay, that is the statistical median, should always be tempered by "should a complication occur hospital stay will be prolonged."

Hospital readmission is not uncommon and should not be feared but anticipated. With the current emphasis on early discharge, the patient should be informed of the likelihood of readmis-

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sion. Currently 25% of complications of major procedures occur post initial discharge, and the majority of those will require readmission [2].

The personal investment of the responsible surgeon's time in obtaining his or her own informed consent is an excellent investment in the long-term surgeon–patient relationship. The inclusion of the family in this discussion is crucial. No greater potential for misunderstanding occurs than when conversations with the family either do not occur or occur in the absence of the patient, such that subsequent interpretation is seen differently by either side. A simple hand-drawn diagram outlining the planned procedure can often convey a sense of intimacy that is well appreciated.

Of additional importance for all major procedures is that all members of the team are "on the same side." This is of most help, if one has a personal nurse or assistant who is familiar with your approach to procedures and can reinforce and explain, always being consistent. As a junior faculty member this may not be possible as variable support staff is available at the time of the initial visit. This means even greater importance of the participation of the primary surgeon. If you are unaware of the approach of your support staff to patients, your personal involvement must increase.

The simple offer of a willingness to discuss things further between the time of initial visit and consent and the planned procedure can do much to allay concern and defray the potential for misunderstanding. This offer sets the awareness that the surgeon and members of his team are available and willing to address concerns of the patient and family both pre- and postoperatively.

Empathetic informed consent should rarely, if ever, be obtained with either surgeon or patient standing. The simple effort of sitting beside or in front of the patient as the consent is carefully considered conveys an air of understanding and empathy. The perception of being rushed to "sign here" is not worth the few minutes it may potentially save.

Other situations can be anticipated at the time of consent and the family and patient prepared for eventualities unrelated to the complications or outcome. The simple suggestion that the procedure "normally takes 4 h" can be conveyed with the understanding that if the procedure is particularly difficult it will take longer. Conversely, a very short procedure will anticipate a very different outcome; usually in cancer surgery it will mean that the tumor cannot be removed. The patient and the family are then clearly prepared; should they learn that only an hour has passed and the surgeon is coming to speak with them. This is an important strategy when diagnostic laparoscopy precedes an intended complicated procedure. The setting of expectations cannot be overemphasized.

The potential for having to deliver bad news has begun at the initial patient encounter and at the time of informed consent.

The Family Does Not Want the Patient to be Fully Informed

The false belief that by not mentioning the word cancer the patient will be reassured or the family's guilt assuaged should be confronted. For example, you come to see a patient. The family is hovering outside the room and begins with, "You know, doctor, he does not know he has cancer" and more concerning, "We do not want him told." The truth is rarely that. The family does not want to discuss the frightening diagnosis, and rather than being reassured, the patient is often more terrified than justified. The situation has to be confronted with empathy and directness but absolute truthfulness.

Telling the truth does not need to be presented as a crucifixion. There are many strategies. From the simple as in my case, "Do you not think the patient knows the name of this hospital?" Or "Do you not think he knows what kind of surgeon I am?" Although seemingly more arrogant, "Do you trust your father?" followed by, "Will he be able to trust you if he learns that you have not been honest with him?" Or perhaps even more superficially arrogant, "Do you think your mother/father is intelligent?" followed immediately by, "Of course, you do. Do you not think he/she deserves the respect of his family?" There are

many ways to address this issue. The importance is that avoidance of reality will only lead to difficulties in subsequent encounters.

Perioperative Death

In major operations, the potential for intraoperative or perioperative death should always be mentioned. The concept of "is there a risk of you dying?" can always be presented in the context of "of the last 100 patients undergoing this operation in our institution two did not survive the first 30 days." This emphasizes the potential seriousness of the procedure without drama or inappropriate terror.

Intraoperative death is far less frequent today than it was 20 years ago. It is a rare situation where an intraoperative complication cannot be successfully managed to have the patient leave the operating room and be received in the post-surgery and anesthesia care unit. In that situation, the family can prepare at the bedside or nearby for an anticipated demise. Certainly, in a situation where a major intraoperative disaster occurs, the ability of one of the surgical team communicating to the family that difficulties have been encountered, and that they can anticipate the surgeon responsible speaking with them but not until the problem is addressed, is most helpful. This reinforces the importance of continued communication between surgical team and the patient's family. The awareness of the patient and the family that there will be a nurse who will communicate with the family as to progress of an operative procedure provides an excellent resource. If the patient is aware that communication is available, then a wise surgeon encountering difficulty or even awareness that the procedure will be prolonged can have that communicated to the family. When serious life-threatening intraoperative problems occur, the ability to forewarn the family leads to a gradual anticipation of a potentially lethal event.

All of these scenarios are such that the delivery of bad news can be anticipated and planned for. The suggestion that the family be moved to a private consulting room ahead of the surgeon's arrival provides similar anticipatory understanding.

When an Intraoperative Death Does Occur

When an intraoperative death occurs, it is essential that the surgeon responsible assumes that responsibility and discusses it with the family. The preparation of the family by giving them awareness that problems have been encountered is helpful. The invitation for the family to move to a private consulting room forewarns them of the gravity of the situation. It can be helpful to have the nurse who is dealing with the family accompany the surgeon to the family, but it should not be several members of the operating team who confront the family. This is the primary surgeon's responsibility. This conversation does need to take place in a quiet environment with everyone sitting and composed. The initiation of the conversation can be difficult. Most often, the patient will be able to be resuscitated to where they will reach the recovery room. In that situation, the conversation can begin with, "Unfortunately, things have not gone well, and we have encountered a problem that is not solvable." This can be followed by the actual description of the circumstances and must, if the anticipated outcome is demise, include a comment to the effect that, "We do not expect Mr. X to survive." Such comments can always be tempered by a caveat as to the seriousness of the situation, the anticipation of permanent morbidity or organ failure if initial recovery does occur. Again, in the absence of absolute demise everything should be done to set the scene for the anticipated outcome. It is often most valuable once the anger and angst is tempered to suggest that you, the responsible surgeon, are going once again to see the patient and then will return to bring the family or the most closely associated members of the family to the bedside to reinforce the anticipated outcome.

Discussion of Unresectability or Metastatic Disease that Precludes Resection

Much of this can be anticipated if one characterizes the potential duration of the intended procedure. The simple approach of preemptively defining that "finding of disease spread outside of the primary site will mean that I cannot and should not proceed to remove the tumor. This will mean a much shorter procedure." Often this concept is not understood and so any ability to explain prior to the procedure that an operation that fails to remove the entire visible tumor does not help the patient is a preemptive strike that improves understanding.

Discussion of a Postoperative Complication

The defined willingness to let the patient and his or her family understand when you will make rounds each day is most valuable. It can preclude much anxiety and many unnecessary phone calls. If you are organized and your staff and office support understand that on each nonoperative day you will make rounds at a specified time, the family can be encouraged to be present and efficient communication of information readily delivered. If you are concerned about the progress that the patient is making, that should be conveyed prior to the identification of a defined complication. The willingness to convey that you are concerned that the patient is not recovering as fast as one had hoped often sets the stage for understanding of any potential situation particularly for other invasive procedures such as interventional radiology. It is far better to convey that you are concerned and have the patient improve the next day than to be happily reassuring the patient and the family that everything is fine only to have a major complication occur and appear to be completely unanticipated by the surgical team. Genuine concern equates with empathetic care.

Discussion of the Unanticipated Major Postoperative Complication

Often the scenario occurs outside of the normal working day and is precipitated by some untoward event that results in the need for resuscitation or intubation and the direct admission to the intensive care unit. On all occasions, the family understands the seriousness of being transferred from the floor to the Intensive Care Unit (ICU). The ability of the primary responsible surgeon to convey that information is important but not always possible. Most importantly, once such an event occurs and the patient is in the ICU, a formal meeting with the family as early as is possible is crucial. This needs to be led by the responsible surgeon, requires the responsible intensivist and his or her staff to be present so as to ensure that only one definable message is identified. Nothing creates greater anxiety and potential for a subsequent lawsuit than for the communication to be poor or for communication from junior members of the staff to be in sharp contradistinction to that provided by the senior staff. It is essential in the absence of the family to discuss with the responsible intensivist and his or her staff just what you anticipate and what you will convey to the family. There should be no attempt to hide the realities of the situation, but everyone will perform better if given an awareness of what is and is not the issue. In institutions where the intensive care unit is not controlled by surgeons, this can be a complicating matter not readily understood by those not intimately involved with major unanticipated and catastrophic postoperative complications. The attributions of hemodynamic, respiratory or renal failure, to pulmonary embolus, cardiac ischemia or drug toxicity, following a major intraabdominal procedure, should always be questioned. Much more likely is that the instability is a sign of an underlying intraabdominal event. Resolution of organ failure will be difficult or impossible if the underlying cause is not addressed. How many times have you seen the first manifestation of an anastomotic leak, be an arrhythmia, hypoxia, or decreased renal output!

Discussion of Operative Findings

Every patient and their family deserve a clear enunciation of the findings and clear description of what was performed. The extent to which this is provided will vary from patient to patient and provides an opportunity to set the stage for what can be anticipated at the time of the pathology report. If tumor was left behind, there is no advantage to pretend that the scenario was better than it really was. "The surgeon said he got it all," should never be implied if known to be untrue, or if positive residual even microscopic disease is anticipated. Even if complete resection has been obtained but discontiguous disease was identified and the risk of subsequent recurrence is known to be high, that too should be conveyed, not in fatalistic terms but in realistic terms as to what the consequences are. Such discussions are often held better at the bedside on day 1 or 2 predicated by, "Let me tell you what we found at the time of operation." If that can be done with the family present and with the senior resident or fellow helping to care for the patient, then no confusion should occur. Currently many operative reports are synoptic; they define the "bare facts" and may not convey the complexities seen in a verbose descriptive report. Verbal communication of the operative findings thereby assumes greater importance.

The Need for Reoperation

Return of the postoperative patient to the operating room, no matter how appropriate, is perceived as a failure of the first procedure. We should accept that as correct, not that anything was done with malicious intent, but to think everything would always proceed satisfactorily on the first occasion is not realistic. If there is any thought at the time of leaving the operating room that a future operation or reoperation is anticipated, that should be conveyed to the patient, and the family immediately. It is invariably better to convey the possibility of a further procedure being required than the converse. Today reoperation is less common than in the past because of the availability of sophisticated imaging and the ability of interventional radiologists to address issues that previously required a return to the operating room. On occasions, an interventional radiological procedure does not solve the problem. It is far better to forewarn the patient that they are going for an interventional radiology (IR) procedure with an understanding that if that should not be successful then further operation will be contemplated.

When major IR procedures are performed, having a member of the surgical team, known by the patient, accompany the patient to the imaging suite is great reassurance. The appearance of the senior surgeon at the time of such procedure to convey the intent of the intervention to the interventionist colleague is most valuable. That the family sees the surgeon entering the IR suite is both reassuring and emphasizes the care intended. A similar explanation by the surgeon (not the most junior IR staff) of the findings and consequences of a procedure can do much to retain patient and family confidence.

A frank and honest appraisal of the need for reoperation will be appreciated and understood. If there is uncertainty as to the operative findings, then that should be conveyed. The communication that you care for and are worried about the patient and are taking them back to the operating room because of your concern that some problem has occurred related to the procedure you performed but not necessarily caused is far better than trying to explain subsequently why nothing was found and why you took the patient to the operating room.

Complications that Occur in your Absence from the Hospital

This is a most challenging event. We all have demands placed on us by commitments to other professional societies and our families that necessitate at least sometime where we are not directly seeing the patient on a daily basis or being directly involved in their care. Preparation for your absence should be discussed freely. The patient should know before they agree to an operation if you are not going to be there in the days follow-

ing the procedure, even to the extent that you can offer to reschedule if there is sufficient patient or family concern as to consequences of your absence. The informed patient or family may have already established your future absence with your staff. For patients to discover that subsequent to the procedure is perceived as deliberate obfuscation.

Judicious decisions as to the nature of operations that you would do when you anticipate being away from the institution for any length of time following them should always be made. It is not appropriate to do a high-risk procedure which becomes prolonged when you have an evening flight. Such behavior only engenders enmity and should a complication occur, is an almost certain prescription for a lawsuit.

Complications do occur in your absence, and the patient should be made aware prior to your leaving just exactly who is covering you, who can be anticipated to see them on a daily basis, and be made aware that you will continue to be in communication. Whenever possible, making rounds prior to your departure and introducing the patient to your colleague is a sensitive and important anticipatory event. The somewhat light hearted, "If I was sick, Dr. X is who I would have care for me," is valuable. A simple note in the medical record the morning of your departure, describing the anticipated progress and formally identifying the senior surgeon covering you, is essential. With modern communication, it is very simple to be sure that you are completely in touch with your patients. A phone call from you to the patient or the family from a remote site to say that you are aware of what is taking place and reinforcing your agreement with the manner with which the complication is being managed can defer both anxiety and unhappiness.

Withdrawal of Life-Sustaining Measures

It is a frightening thought that 8% of Medicare patients in the United States undergo an operation in their last week of life and 18% in the last month of life [3]! The classic role of the surgeon in discussions of withdrawal of active intervention is often being supplanted by the fact that the patient is in the intensive care unit and can be maintained on life support, even when that may not be in the patient's best interest and may have no possible hope of ever being reversed. The involvement of the primary surgeon in these decisions should be mandatory. No one should know the patient better than the person who first made the diagnosis, brought them to the operation, and performed the initial procedure. The willingness of surgeons to assume this role is progressively diminished. This, I believe, is a great retrograde step. The patient trusted you enough to place his or her life in your hands; you should be strong and willing enough to assume the responsibility when therapeutic measures are futile. The religious and ethnic mores of each patient have to be considered in such discussion. As has been reiterated, preparation for this event is the way in which it is made easier. An awareness of the facts that confront the patient, that is, the likelihood of the patient ever leaving the hospital, can be readily described in general, although statistically precise terms for the individual family member may be difficult. The patients are often not participants in this discussion, being intubated, ventilated, and sedated. The presence of an advance directive is helpful, and the identification of the primary spokesperson for the family is crucial. Failure to appreciate that there is one dominant person within the family who is making the decisions can be a critical factor in developing this trust. Bad outcome and poor communication are the two events that summate to the accusation of malpractice. Good communication, preparation, and anticipation even in the presence of a bad outcome is valuable both for the comfort of the family and avoidance of accusations of malpractice.

Discussing the Pathology Report

Today the pathology report is often not back before the patient leaves the hospital. The first postoperative visit then becomes a seminal event, and time should be placed such that that visit is not

rushed. If anything, the first postoperative visit will be longer than any subsequent follow-up visit, not just a "post op check." If the pathology report is available before the patient leaves the hospital, it should be discussed at that time. The patient will have ultimate access to the pathology report, and those that feel there have been any attempt to confuse or minimize the findings will readily be challenged. A brief note in the record of when and what was described to the patient as to the pathologic findings is helpful when patients and families complain, "they were never informed," enabling you to point out the date it was provided.

In either event, such discussion should be held in a calm and controlled environment. If it is the patient's room, then the surgeon must not be standing hovering over the supine patient like the sword of Damocles. Preferably the patient and surgeon are seated. The same applies in the outpatient department. Direct eye-to-eye contact is important, and on occasions, if the results have ominous findings, gentle but physical contact is often reassuring. Most patients or their families will have requested or subsequently request a copy of the pathology report. They should be encouraged if there is any confusion either at that time or subsequently to return to discuss the findings. The pathological report that is read and well interpreted can avoid subsequent confusion and denial.

Discussion of Long-term Survival Prospect

One of the more difficult things in the management of patients, particularly the patient with cancer, is the discussion of long-term survival. Sadly, much of our information is not precise and not patient specific. Staging systems vary widely and prognosis within stage is extraordinarily variable [4]. Nevertheless, precise scoring systems, and increasingly nomograms, can give realistic statistical predictions for the individual patient [5].

Absolute precision is never possible. There is the patient anticipated to die in weeks to months who lives years, and the patient, one would anticipate to live for years, having an early or even very late recurrence from their original tumor.

Delivering bad news, that is following an operation in which unresectable metastatic disease was encountered, is highly dependent on the availability of alternate treatment and more importantly, the likelihood that that alternate treatment will benefit. Data from prospective randomized trials allow us to say with some confidence that one can or cannot be anticipated to benefit. Unfortunately, we all predict that the advantages of additional treatment or of surgical operations are better than they really are. Physicians want to promise their patients that the outcome will be better than the knowledge base would suggest. This, when taken to extremes, results in the unrealistic expectations of the patient and, progressively, dissatisfaction by the family.

The sadly neglected approach is the approach where available adjuvant therapy is statistically shown to improve survival, but that survival benefit is extraordinarily small, but we convey that that benefit is of more clinical significance than is justified. With large often industry-supported clinical trials, small benefits to 5-year survival from 90 to 92% are often expressed as a 20% benefit. Physicians rarely point out that in this situation 100 patients have to be treated for two to benefit. No one discusses that should we treat there is a statistical benefit, but there are at least 49 chances out of 50 that there will be no benefit, mainly because the patient was never going to recur. The judgment in that situation should be taken based on the side effects of the treatment being offered. There is no treatment that is without side effects. This approach is essentially ignored by all physicians. We invariably and appropriately want to make the intervention that "will make a difference." We do not want to face the fact that there is a silent majority in any situation where untreated survival is greater than 50% who cannot possibly benefit from the treatment and can only be harmed. Such thinking requires a radical change in how we present outcome information.

But what if the patient does have terminal and essentially untreatable disease, or at least disease

not treatable with any meaningful response? The most important issue is not to say, "I cannot help you, please go away." The thing to say is, "Further operations will not help you, but I will take care of you." It is equally inappropriate to absolve your responsibility for this by saying, "You need to see the medical oncologist for treatment." Making unrealistic expectations for the patient and asking your colleague to deliver such unrealistic expectations are unprofessional, unkind, and should be avoided at any cost.

What if there truly is no effective treatment. How do you answer the question, "How long will I live?" This is not a situation where we could anticipate and prepare the patient; one has to give a realistic estimation. It should always be commenced with, "I will help take care of you; there are many things we can do." If a patient becomes relentless, then you have to give some realistic expectations. You will know from statistical outcomes and can use the obvious disclaimer of, "I do not know, as every patient is different," but a helpful approach, if forced into a situation, is to describe, "I cannot say for certainty in your case but similar patients with the problem that you have, have lived weeks, months or years." This is almost always satisfactory. The optimistic patient will fasten onto the years as being many, and the pessimistic patient will focus on the weeks as a week or two.

Management of the Difficult Family

We all encounter families who can be "difficult." (Think of your own!). Much can be done to defray this. Much of the difficulty revolves around the internal dynamics between patient and family. This cannot be something that you are completely aware of, and you should tread warily in this minefield. The key to the management of the difficult family is consistency. They need to have a solid understanding of the initial expectations with no false promises and no unrealistic plans for miracles, and this should be consistently reinforced. No matter how you feel, getting angry does not solve anything. The moment that you are angry this is demonstrated and confirms for the family that it is not they that are a difficult family, it is you who are a difficult surgeon. Regular but not too frequent meetings are important. They should be at defined times, controlled in length, and require constant repetition of the facts of the matter not the incriminations of the various professional care providers.

Delivery of "bad news" is a part of surgical life; it needs to be embraced as part of caring for another human being. Much can be anticipated and much can be shared. It is all part of the privilege of caring.

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Index

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