The SAGES University Masters Program Series

Editor-in-Chief: Brian Jacob

The SAGES Manual of Acute Care Surgery

David Renton
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Editors
David Renton
Division of General Surgery
The Ohio State University
Columbus, OH
USA

Robert Lim
Tripler Army Medical Center
Surgery
Honolulu, HI
USA

Alberto S. Gallo
Baptist Health Louisville
Louisville, KY
USA

Prashant Sinha
NYU Langone
Hospital – Brooklyn
NYU Langone Health
New York, NY
USA

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Preface

Acute care surgery has changed a great deal in the past decade. While the nature of surgical emergencies is not different, the approaches taken by the surgeon to correct them has evolved to include different treatment options, including minimally invasive techniques, endoscopic options, and new medical therapies. The experts at SAGES have pooled their knowledge and have created this manual to describe the most up-to-date treatment options for the emergent surgical patient. This manual will cover subjects such as minimally invasive surgery in the trauma setting, surgical emergencies in the bariatric patient, and treatment of emergencies in pregnant, cirrhotic, and anticoagulated patients. We hope that our collective knowledge will help educate surgeons to bring the optimum care to the patients that they are called to see in their emergency rooms.

Columbus, OH, USA David Renton
Honolulu, HI, USA Robert Lim
Louisville, KY, USA Alberto S. Gallo
New York, NY, USA Prashant Sinha

Contents

Contributors

Nawar A. Alkhamesi, MD, PhD, FRCS Department of Surgery, Schulich School of Medicine and Dentistry, Western University and University Hospital, London Health Sciences Centre, London, ON, Canada

Alexi Bloom, MD Department of Surgery, Houston Methodist Hospital, Houston, TX, USA

Matthew Bloom, MD, MSEE, FACS Department of Surgery, Division of Trauma and Acute Care Surgery, Cedars-Sinai Medical Center, Los Angeles, CA, USA

Kenneth Bogenberger, MD General Surgery, Tripler Army Medical Center, Honolulu, HI, USA

Daniel J. Bonville, DO Acute Care Surgery & Surgical Critical Care, Houston Methodist Hospital, Houston, TX, USA

Department of Surgery, Houston Methodist Specialty Physician Group, Houston, TX, USA

Elliott Brill, MD Stanford University School of Medicine, Stanford, CA, USA

Department of Surgery, Boston University School of Medicine, Boston, MA, USA

Department of General Surgery, Kaiser Permanente, Santa Clara, CA, USA

Courtney Collins, MD Department of Surgery, The Ohio State University Wexler Medical Center, Columbus, OH, USA

Christos Colovos, MD, PhD Department of Surgery, Division of Acute Care Surgery, University of Vermont Larner College of Medicine, Burlington, VT, USA

Robert Conrad, MD General Surgery, Tripler Army Medical Center, Honolulu, HI, USA

Michael W. Cripps, MD Department of Surgery, University of Texas Southwestern Medical Center, Dallas, TX, USA

Paul Deramo, MD Department of Surgery, Methodist Dallas Medical Center, Dallas, TX, USA

Alberto S. Gallo, MD, FACS Baptist Surgical Associates, Baptist Health Louisville, Louisville, KY, USA

Suzanne Gillern, MD Department of Surgery, Tripler Army Medical Center, Honolulu, HI, USA

Weidun Alan Guo, MD Department of Surgery, Jacobs School of Medicine and Biomedical Sciences, University at Buffalo, Buffalo, NY, USA

Elizabeth C. Hamilton, MD Department of Surgery, University of Texas Southwestern Medical Center, Dallas, TX, USA

Sara A. Hennessy, MD, FACS Department of Surgery, University of Texas Southwestern Medical Center, Dallas, TX, USA

Brian P. Jacob, MD, FACS Department of Surgery, Mount Sinai Health System, New York, NY, USA

Daniel B. Jones, MD, MS, FACS Office of Technology and Innovation, Minimally Invasive Surgical Services, Bariatric Program, Beth Israel Deaconess Medical Center, Boston, MA, USA

Harvard Medical School, Boston, MA, USA

Brent D. Matthews, MD Department of Surgery, Carolinas Medical Center, Atrium Health, Charlotte, NC, USA

Laura Mazer, MD, MS Department of General Surgery, Stanford University Hospital and Clinics, Stanford, CA, USA

Jennifer A. Minneman, MD Department of Surgery, University of Washington, Seattle, WA, USA

Bradley J. Needleman, MD Center for Minimally Invasive Surgery, The Ohio State University, Wexner Medical Center, Columbus, OH, USA

Brant K. Oelschlager, MD Division of General Surgery, University of Washington, Seattle, WA, USA

Jin Sol Oh, MD Department of Surgery, University of Washington, Seattle, WA, USA

Christopher Pearcy, MD Department of Surgery, Methodist Dallas Medical Center, Dallas, TX, USA

Caroline E. Reinke, MD, MSHP Department of Surgery, Carolinas Medical Center, Atrium Health, Charlotte, NC, USA

H. Alejandro Rodriguez, MD Department of Surgery, University of Washington, Seattle, WA, USA

Jarrett R. Santorelli, MD Department of Surgery, Jacobs School of Medicine and Biomedical Sciences, University at Buffalo, Buffalo, NY, USA

Linda Schultz Society of Gastrointestinal and Endoscopic Surgeons, Boston, MA, USA

Steven D. Schwaitzberg, MD, FACS Department of Surgery, University of Buffalo, Jacobs School of Medicine, Buffalo, NY, USA

Biomedical Sciences, The State University of New York, Buffalo, NY, USA

Nathalie Sela, MD, MSc Department of Surgery, Schulich School of Medicine and Dentistry, Western University and University Hospital, London Health Sciences Centre, London, ON, Canada

Prashant Sinha, MD NYU Langone Hospital – Brooklyn, NYU Langone Health, New York, NY, USA

David P. Sonntag, MD Department of Interventional Radiology, St. Luke's Health System, Boise, ID, USA

Motokazu Sugimoto, MD Department of Hepatobiliary and Pancreatic Surgery, National Cancer Center Hospital East, Kashiwa, Chiba, Japan

Luis R. Taveras, MD Department of Surgery, University of Texas Southwestern Medical Center, Dallas, TX, USA

Michael Timoney, MD NYU Langone Hospital – Brooklyn, NYU Langone Health, New York, NY, USA

L. William Traverso, MD Center for Pancreatic and Liver Disease, St. Luke's Health System, Boise, ID, USA

Michael S. Truitt, MD, FACS Department of Surgery, Methodist Dallas Medical Center, Dallas, TX, USA

Holly B. Weis, MD Department of Surgery, University of Texas Southwestern Medical Center, Dallas, TX, USA

Joshua J. Weis, MD Department of Surgery, University of Texas Southwestern Medical Center, Dallas, TX, USA

Chapter 1
SAGES University MASTERS Program: Acute Care Pathway

Daniel B. Jones, Linda Schultz, and Brian P. Jacob

The Masters Program organizes educational materials along clinical pathways into discrete blocks of content which could be accessed by a surgeon attending the SAGES annual meeting or by logging into the online SAGES University (Fig. 1.1) [1]. The SAGES Masters Program currently has eight pathways including acute care, biliary, bariatrics, colon, foregut, hernia, flexible endoscopy, and robotic surgery (Fig. 1.2). Each path-

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Adopted from Jones DB, Stefanidis D, Korndorffer JR, Dimick JB, Jacob BP, Schultz L, Scott DJ. SAGES University Masters Program: a structured curriculum for deliberate, lifelong learning. Surg Endosc. 2017;31(8):3061–71.

D. B. Jones (✉)
Office of Technology and Innovation, Minimally Invasive Surgical Services, Bariatric Program, Beth Israel Deaconess Medical Center, Boston, MA, USA

Harvard Medical School, Boston, MA, USA
e-mail: djones@bidmc.harvard.edu

L. Schultz
Society of Gastrointestinal and Endoscopic Surgeons, Boston, MA, USA

B. P. Jacob
Department of Surgery, Mount Sinai Health System, New York, NY, USA

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FIGURE 1.1 MASTERS Program logo

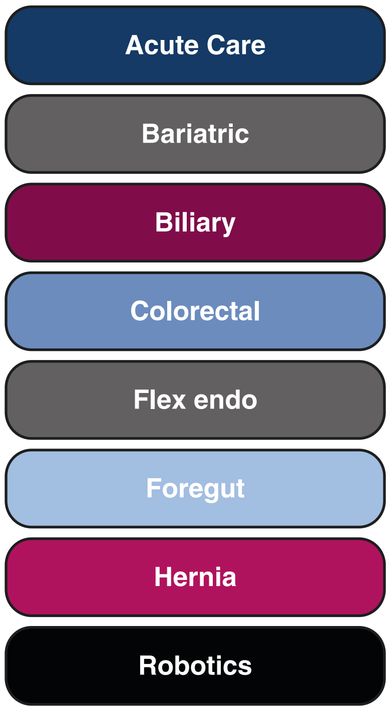

FIGURE 1.2 MASTER Program Clinical Pathways

way is divided into three levels of targeted performance: competency, proficiency, and mastery (Fig. 1.3). The levels originate from the Dreyfus model of skill acquisition [2], which has five stages: novice, advanced beginner, competency, proficiency, and expertise. The SAGES MASTERS Program is based on the three more advanced stages of skill acquisition: compe-

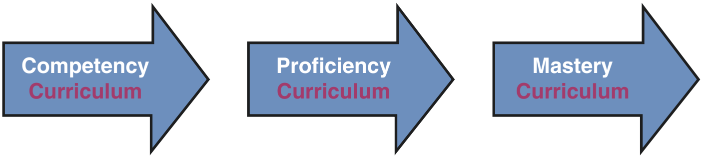

FIGURE 1.3 MASTERS Program Progression

tency, proficiency, and expertise. Competency is defined as what a graduating general surgery chief resident or Minimally Invasive Surgery (MIS) fellow should be able to achieve; proficiency is what a surgeon approximately 3 years out from training should be able to accomplish; and mastery is what more experienced surgeons should be able to accomplish after several years in practice. Mastery is applicable to SAGES surgeons seeking an in-depth knowledge in a pathway, including the following areas of controversy, outcomes, best practice, and ability to mentor colleagues. Over time, with the utilization of coaching and participation in SAGES courses, this level should be obtainable by the majority of SAGES members. This edition of the *SAGES Manual of Acute Care Surgery* aligns with the current version of the new SAGES University MASTERS Program Acute Care Surgery pathway (Table 1.1).

Acute Care Surgery Curriculum

The key elements of the Acute Care Surgery curriculum include core lectures for the pathway, which provide a 45-minute general overview including basic anatomy, physiology, diagnostic work-up, and surgical management. As of 2018, all lecture content of the annual SAGES meetings are labeled as follows: basic (100), intermediate (200), and advanced (300). This allows attendees to choose lectures that best fit their educational needs. Coding the content additionally facilitates online retrieval of specific educational material, with varying degrees of surgical complexity, ranging from introductory to revisional surgery.

Table 1.1 Acute Care Surgery curriculum

Curriculum elements	*Competency*
Anchoring procedure – competency	2
CORE LECTURE	1
CORE MCE 70%	1
Annual meeting content	6
Guidelines	1
SACME hours	6
Sentinel articles	2
Social media	2
SAGES top 21 video	1
FLS	12
PEARLS	1
Credits	*35*
Curriculum elements	*Proficiency*
Anchoring procedure – proficiency	2
CORE LECTURE	1
CORE MCE 70%	1
Annual meeting content	5
FUSE	12
Outcomes database enrollment	2
SA CME hours (ASMBS electives, SAGES or SAGES-endorsed)	6
Sentinel articles	2
Social media	2
SAGES top 21 video	1
PEARLS	1

(continued)

Table 1.1 (continued)

Safe Chole	3
Safe Chole six steps sign-off	1
Cholangiogram interpretation modules	1
Credits	*40*
Curriculum elements	*Mastery*
Anchoring procedure – mastery	2
CORE LECTURE	1
CORE MCE 70%	1
Annual meeting content	6
FES	9
Fundamentals of surgical coaching	4
Outcomes database reporting	2
SA CME credits (ASMBS electives, SAGES or SAGES-endorsed)	6
Sentinel articles	2
Serving as video assessment reviewer and providing feedback (FSC)	4
SMART enhanced recovery	1
Social media	7
Credits	*45*

SAGES identified the need to develop targeted, complex content for its mastery level curriculum. The idea was that these 25-minute lectures would be focused on specific topics. It assumes that the attendee already has a good understanding of diseases and management from attending/watching competency and proficiency level lectures. Ideally, in order to supplement a chosen topic, the mastery lectures would also identify key prerequisite articles from *Surgical Endoscopy* and other journals, in addition to SAGES University videos.

Many of these lectures will be forthcoming at future SAGES annual meetings.

The MASTERS Program has a self-assessment, multiple-choice exam for each module to guide learner progression throughout the curriculum. Questions are submitted by core lecture speakers and SAGES annual meeting faculty. The goal of the questions is to use assessment for learning, with the assessment being criterion-referenced with the percent correct set at 80%. Learners will be able to review incorrect answers, review educational content, and retake the examination until a passing score is obtained.

The MASTERS Program Acute Care Surgery curriculum taps much of the of SAGES existing educational products including FLS, FUSE, SMART, Top 21 videos, and Pearls (Fig. 1.4). The Curriculum Task Force has placed the aforementioned modules along a continuum of the curriculum pathway. For example, FLS, in general, occurs during the Competency Curriculum, whereas the Fundamental Use of Surgical Energy (FUSE) is usually required during the Proficiency Curriculum. The Fundamentals of Laparoscopic Surgery (FLS) is a multiple-choice exam and a skills assessment conducted on a video box trainer. Tasks include peg transfer, cutting, intracorporeal and extracorporeal suturing, and knot tying. Since 2010, FLS has been required of all US general surgery residents seeking to sit for the American Board of Surgery qualifying examinations. The Fundamentals of Endoscopic Surgery (FES) assesses endoscopic knowledge and technical skills in a simulator. FUSE teaches about the safe use of energy devices in the operating room and is avail-

Figure 1.4 SAGES Educational Content: FLS, FUSE, SMART able at FUSE.didactic.org. After learners complete the self-paced modules, they may take the certifying examination.

The SAGES Surgical Multimodal Accelerated Recovery Trajectory (SMART) Initiative combines minimally invasive surgical techniques with enhanced recovery pathways (ERPs) for perioperative care, with the goal of improving outcomes and patient satisfaction. Educational materials include a website with best practices, sample pathways, patient literature, and other resources such as videos, FAQs, and an implementation timeline. The materials assist surgeons and their surgical team with implementation of an ERP.

Top 21 videos are edited videos of the most commonly performed MIS operations and basic endoscopy. Cases are straightforward with quality video and clear anatomy.

Pearls are step-by-step video clips of ten operations. The authors show different variations for each step. Before viewing, the learner should have a fundamental understanding of the operation.

SAGES Guidelines provide evidence-based recommendations for surgeons and are developed by the SAGES Guidelines Committee following the Health and Medicine Division of the National Academies of Sciences, Engineering, and Medicine standards (formerly the Institute of Medicine) for guideline development [3]. Each clinical practice guideline has been systematically researched, reviewed, and revised by the SAGES Guidelines Committee and an appropriate multidisciplinary team. The strength of the provided recommendations is determined based on the quality of the available literature using the GRADE methodology [4]. SAGES Guidelines cover a wide range of topics relevant to the practice of SAGES surgeon members and are updated on a regular basis. Since the developed guidelines provide an appraisal of the available literature, their inclusion in the MASTERS Program was deemed necessary by the group.

The Curriculum Task Force identified the need to select required readings for the MASTERS Program based on key articles for the various curriculum procedures. Summaries of each of these articles follow the American College of Surgeons (ACS) Selected Readings format.

Facebook™ Groups

While there are many great platforms available to permit online collaboration by user-generated content, Facebook™ offers a unique, highly developed mobile platform that is ideal for global professional collaboration and daily continuing surgical education (Fig. 1.5). The Facebook groups allow for video assessment, feedback, and coaching as a tool to improve practice.

Based on the anchoring procedures determined via group consensus (Table 1.2), participants in the MASTERS Program will submit video clips on closed Facebook groups, with other participants and/or SAGES members providing qualitative feedback. For example, for the Acute Care Curriculum, surgeons would submit the critical views during a laparoscopic appendectomy. Using crowdsourcing, other surgeons would comment and provide feedback.

Figure 1.5 Acute Care Facebook group

FIGURE 1.5 (continued)

Table 1.2 Anchoring procedures for Acute Care Surgery pathway

Anchoring procedure	Level
Lap appendectomy	Competency
Lap cholecystectomy for severe cholecystitis	Proficiency
Lap management of perforation	Mastery

Eight unique vetted membership-only closed Facebook groups were created for the MASTERS Program, including a group for bariatrics, hernia, colorectal, biliary, acute care, flexible endoscopy, robotics, and foregut. The Acute Care Surgery Facebook group is independent of the other groups and will be populated only by physicians, mostly surgeons or surgeons-in-training interested in Acute Care surgery.

The group provides an international platform for surgeons and healthcare providers interested in optimizing outcomes in a surgical specialty to collaborate, share, discuss, and post photos, videos, and anything related to a chosen specialty. By embracing social media as a collaborative forum, we can more effectively and transparently obtain immediate global feedback that potentially can improve patient outcomes, as well as the quality of care we provide, all while transforming the way a society's members interact.

For the first two levels of the MASTERS Program, Competency and Proficiency, participants will be required to post videos of the anchoring procedures and will receive qualitative feedback from other participants. However, for the mastery level, participants will submit a video to be evaluated by an expert panel. A standardized video assessment tool, depending on the specific procedure, will be used. A benchmark will also be utilized to determine when the participant has achieved the mastery level for that procedure.

Once the participant has achieved mastery level, she/he will participate as a coach by providing feedback to participants in the first two levels. MASTERS Program participants will therefore need to learn the fundamental principles of surgical coaching. The key activities of coaching include goal setting, active listening, powerful inquiry, and constructive feedback [5, 6]. Importantly, peer coaching is much different than traditional education, where there is an expert and a learner. Peer coaching is a “co-learning” model where the coach is facilitating the development of the coached by using inquiry (i.e., open-ended questions) in a noncompetitive manner.

Surgical coaching skills are a crucial part of the MASTERS curriculum. At the 2017 SAGES Annual Meeting, a post-graduate course on coaching skills was developed and video recorded. The goal is to develop a “coaching culture” within the SAGES MASTERS Program, wherein both participants and coaches are committed to lifelong learning and development.

The need for a more structured approach to the education of practicing surgeons as accomplished by the SAGES MASTERS Program is well recognized [7]. Since performance feedback usually stops after training completion and current approaches to MOC are suboptimal, the need for peer coaching has recently received increased attention in surgery [5, 6]. SAGES has recognized this need and its MASTERS Program embraces social media for surgical education to help provide a free, mobile, and easy to use platform to surgeons globally. Access to the MASTERS Program groups enables surgeons at all levels to partake in the MASTERS Program curriculum and obtain feedback from peers, mentors, and experts. By creating surgeon-only private groups dedicated to this project, SAGES can now offer surgeons posting in these groups the ability to discuss preoperative, intraoperative, and postoperative issues with other SAGES colleagues and mentors. In addition, the platform permits transparent and responsive dialogue about technique, continuing the theme of deliberate, lifelong learning.

To accommodate the needs of this program, SAGES University is upgrading its web-based features. A new learning management system (LMS) will track progression and make access to SAGES University simple. Features of the new IT infrastructure will provide the ability to access a video or lecture on-demand in relation to content, level of difficulty, and author. Once enrolled in the MASTERS Program, the LMS will track lectures, educational products, MCE and other completed requirements. Participants will be able to see where they stand in relation to module completion and SAGES will alert learners to relevant content they may be interested in pursuing. Until such time that the new LMS is up and running, it is hoped that the SAGES Manual will help guide learners through the Masters Program Curriculum.

Conclusions

The SAGES MASTERS Program ACUTE CARE SURGERY PATHWAY facilitates deliberate, focused post-graduate teaching and learning. The MASTERS Program certifies completion of the curriculum but is NOT meant to certify competency, proficiency, or mastery of surgeons. The MASTERS Program embraces the concept of lifelong learning after fellowship and its curriculum is organized from basic principles to more complex content. The MASTERS Program is an innovative, voluntary curriculum that supports MOC and deliberate, lifelong learning.

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Chapter 2
Appendicitis

Joshua J. Weis and Elizabeth C. Hamilton

Introduction

Appendectomy is the most common emergent abdominal operation performed. Over 300,000 appendectomies are performed each year in the United States alone. The lifetime risk of appendicitis is estimated to be about 9% for males and 7% for females [1]. In 2017, appendectomy is most commonly performed laparoscopically. When compared with open surgery, laparoscopic intervention is associated with fewer wound infections, earlier discharge from the hospital, and earlier return to normal activities [2]. Appendectomy is the gold standard for treatment of acute appendicitis. Modern management strategies, however, also include initial or definitive medical management with intravenous antibiotics, percutaneous drainage by interventional radiology, and possible interval appendectomy.

Indications

Assuming surgeon comfort and experience with laparoscopy, laparoscopic appendectomy should be considered in patients who either present with signs and symptoms of acute appendicitis or have radiologic evidence of inflammation in the region of

J. J. Weis · E. C. Hamilton (✉)
Department of Surgery, University of Texas Southwestern Medical Center, Dallas, TX, USA
e-mail: Elizabeth.hamilton@utsouthwestern.edu

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the appendix. The most common presentation of acute appendicitis is a history of periumbilical pain migrating to the right lower quadrant, associated with nausea and/or anorexia. Physical exam findings classically include fever and right lower quadrant rebound tenderness. Laboratory findings of leukocytosis with a left shift support the diagnosis. Importantly, many patients do not have classic symptoms, and their complaints may be vague and include only right flank or pelvic pain, especially in cases of delayed presentation or a retrocecal appendix.

The differential diagnosis of acute appendicitis is broad and includes the following: regional adenitis, enteritis/ileitis, inflammatory bowel disease such as Crohn's or ulcerative colitis, epiploic appendagitis, cecal or sigmoid diverticulitis, perforated ulcer disease, Meckel's diverticulitis, pancreatitis, cholecystitis, incarcerated hernia, and urinary tract infection. Additional diagnoses in females include ectopic pregnancy, torsion of the ovary, hemorrhagic ovarian cyst, pelvic inflammatory disease, and pneumonia.

There is ongoing debate in the literature regarding the appropriate use of imaging in the diagnosis of acute appendicitis. CT scan is often performed in the emergency room before surgical consultation is obtained. A contrast-enhanced CT scan of the abdomen and pelvis showing a rim-enhancing appendix over 6 mm with surrounding inflammation in a patient with clinical concern for appendicitis is diagnostic. Ultrasound is an alternative imaging modality. However, the sensitivity and specificity of ultrasound vary significantly based on operator skill and the body habitus of the patient. Ultrasound is generally considered the preferred modality for children and pregnant patients [3]. MRI may be preferred in pregnant patients if ultrasound is indeterminate, but emergent MRI imaging is not available in all centers. Some data suggest that experienced clinicians can reliably diagnose appendicitis in young men without advanced imaging, and many clinicians feel comfortable omitting imaging in this population if signs and symptoms are classic [4, 5]. Ultimately, the choice of imaging depends on surgeon comfort level with the diagnosis and available resources at the institution.

Contraindications

Laparoscopic appendectomy will be safe for the vast majority of patients encountered. However, an open approach via a McBurney or Rocky-Davis incision may be preferred in patients with extensive adhesions from prior surgery or patients who will not tolerate insufflation due to medical co-morbidities. Patients with severe co-morbidities or those taking therapeutic anticoagulation may be appropriate candidates for a trial of medical management with IV antibiotics. Patients presenting in a delayed fashion with diffuse contamination may benefit from an open procedure to improve washout of the peritoneal cavity. Patients presenting with septic shock from perforation and abscess need rapid source control. Urgent image-guided drainage under local anesthesia may be helpful if this technique is available. However, sepsis should not be treated as a contraindication to immediate surgery via an open or laparoscopic approach, as long as these patients receive appropriate IV fluid resuscitation and intravenous antibiotics prior to general anesthesia.

Patient Preparation and Positioning

Open appendectomy technique has been described extensively elsewhere. Laparoscopic appendectomy should be considered for the initial surgical approach and is described here.

1. All women of child-bearing age should have a pregnancy test.
2. All patients should receive preoperative intravenous antibiotics to cover gram-negative and anaerobic organisms. Antibiotics are often started in the emergency room. Redosing antibiotics within 30 minutes prior to incision may be considered.
3. Lower extremity sequential compression devices should be placed for DVT prophylaxis.

4. The patient should be asked to urinate immediately before the operation. Alternatively, a Foley catheter should be placed to decompress the bladder. This will improve laparoscopic access to the pelvis and right lower quadrant and is particularly important if a suprapubic trocar is used.
5. The patient should be padded and strapped appropriately to facilitate steep Trendelenburg and left-side-down positioning.
6. If possible, tucking the patient's left arm can assist the surgeon in their positioning at the shoulder of the patient, with the assistant on the same side to their left.
7. As depicted in Fig. 2.1, video monitors may be placed at the foot of the bed, on the right side of the patient, or in both locations. The laparoscopic tower may be at the foot of the bed or lateral to the patient's upper body on the right or left side of the patient. The surgeon and assistant stand on the left side of the patient.

Abdominal Entry and Trocar Placement

1. An open or Veress needle technique may be used to gain entrance into the abdominal cavity using standard laparoscopic safety principles. Trocar placement is depicted in Fig. 2.2. The initial trocar is generally placed at the umbilicus. In these patients, the surgeon should be cognizant that the major vascular structures are only 2–3 cm away from the umbilicus with the patient in the supine position. The trocar can be 5 mm or 12 mm depending on the preferred location for introducing a stapler. Palmer's point (left upper quadrant subcostal) should be considered as an alternative entry point in patients with suspected dense adhesions from previous surgery.
2. Most surgeons use three trocars to triangulate on the right lower quadrant. The size and the position of the trocars vary based on surgeon preference, but the following principles should be kept in mind. 5 mm trocars are adequate for most energy devices, dissecting instruments, and a 5 mm

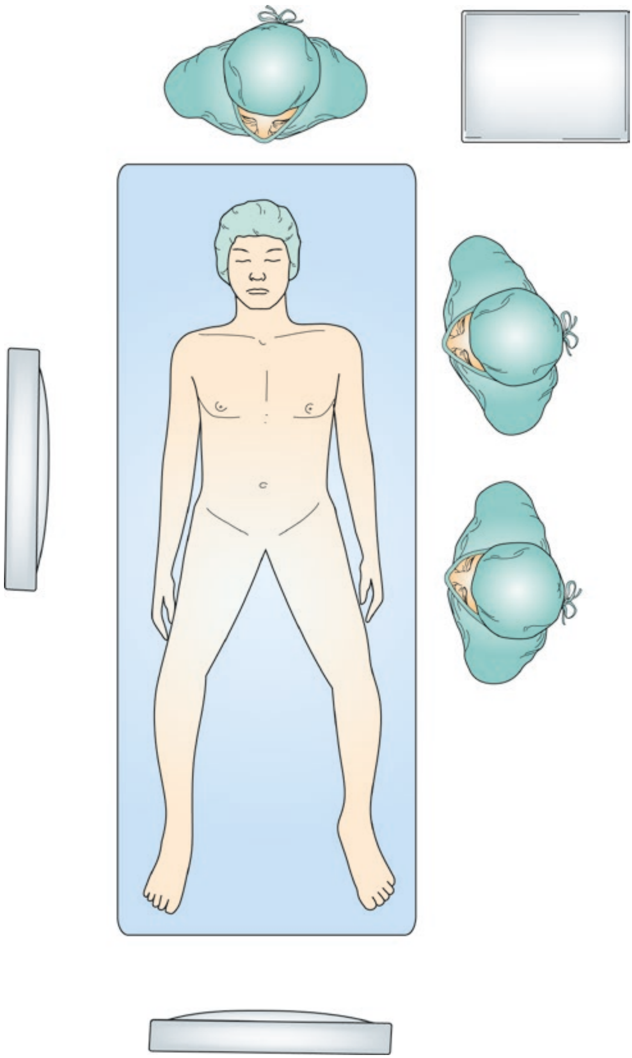

FIGURE 2.1 Recommended room setup for laparoscopic appendectomy – the surgeon and assistant both stand on the patient's left side. Left arm can be tucked. Monitors should be placed at the foot of the bed and to the patient's right side. (Illustration by D. Henriquez)

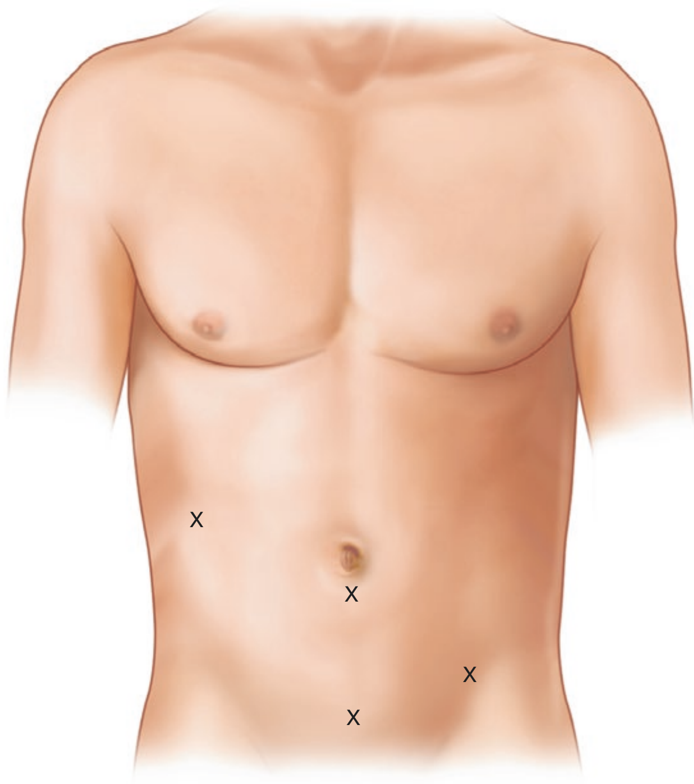

FIGURE 2.2 Possible trocar placements for laparoscopic appendectomy – standard placement is umbilical, suprapubic, and left lower quadrant. Alternative/optional port can be placed in the right lower quadrant for an assistant to retract. (Illustration by D. Henriquez)

camera. However, to remove the appendix, at least one 11 mm trocar will be needed to accommodate a specimen retrieval bag. Also, most laparoscopic staplers require a 12 mm trocar. As such, one 12 mm trocar and two 5 mm trocars are typically used.

3. Initial gross evaluation of the abdomen using diagnostic laparoscopy may be helpful to identify unexpected findings and alter trocar placement at that time if needed. We pre-

fer a 5 mm angled laparoscope, since it works well through any trocar and can be moved to any other site later when a stapler or specimen retrieval bag is introduced.

4. The patient should be positioned in the Trendelenburg position and rotated toward the left.
5. Two additional trocars should be placed under direct visualization, commonly in the left lower quadrant and in the suprapubic position cephalad to the level of the bladder. The trocars can be two 5 mm trocars if the periumbilical port was a Hasson (12 mm), or a 5 mm and an 11/12 mm trocar depending on the method the surgeon plans to use for stump closure (Fig. 2.2).
6. Alternative trocar placement options are also shown.

Operative Steps

1. After examining the abdomen for other pathologies, the initial step in the operation is to identify the appendix (Fig. 2.3). This is sometimes very easy but is often more difficult than it sounds. Adherence to basic principles minimizes potential difficulties. Positioning the bed in steep Trendelenburg position with the right side elevated as well can facilitate removing surrounding structures from the right lower quadrant. First, the omentum and the small bowel should be swept cephalad to expose the right lower quadrant. Next, the cecum and the terminal ileum should be identified. The appendix is always found where the taenia meet at the base of the cecum lateral to the ileocecal valve (Fig. 2.3). If the cecum can be seen clearly, but the appendix cannot, a retrocecal appendix should be suspected. In this case, the cecum must be mobilized off of the retroperitoneum by taking down the White Line of Toldt and rolling the cecum medially to expose the posterior cecal wall and appendix.
2. Once the appendix is identified, care must be taken to avoid grasping it in such a way that the appendix ruptures. Atraumatic instruments such as a Babcock or Spring graspers may be helpful. If perforation occurs, it should be contained in the area and aspirated out completely before

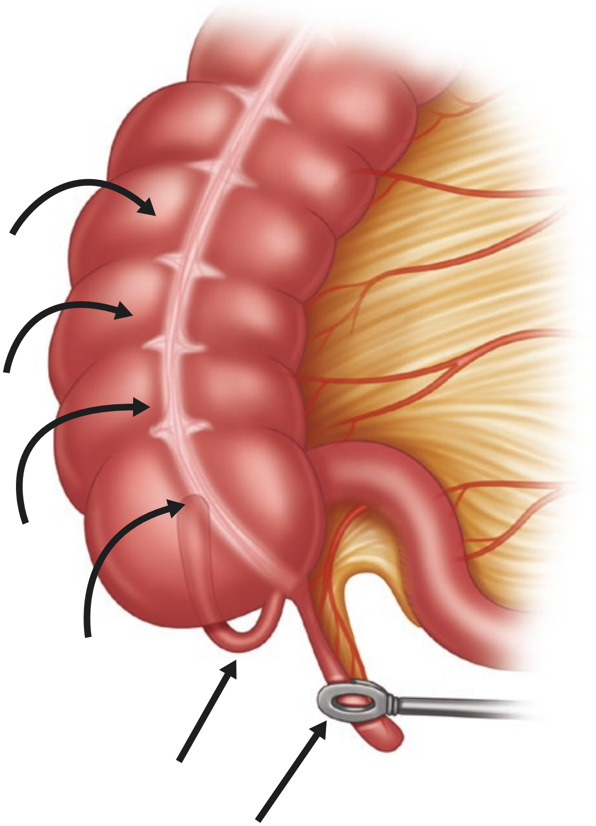

FIGURE 2.3 Identification of the appendix – the appendix is always located at the base of the cecum. If the appendix is not clearly visualized, a retrocecal location should be suspected and the cecum should be mobilized from right to left (curved arrows) to expose the appendix. (Illustration by D. Henriquez)

irrigation is used. Alternatively, the mesoappendix may be grasped to provide traction without directly grabbing the inflamed appendix.

3. Adhesions between the appendix and surrounding structures such as the terminal ileum, the omentum, the liga-

ment of Treves, and the peritoneum should be taken down with care. Adhesions can often be taken down bluntly with graspers or a Kittner. In some cases, energy devices such as hook monopolar energy, an ultrasonic dissector like the Harmonic scalpel, or an advanced bipolar device like the Ligasure are most efficient and most hemostatic.

4. Dissection must be continued until the entire appendix is visualized entering the wider cecal wall, taking care to ligate the appendix flush with the cecum (Fig. 2.4) and not to leave an unrecognized appendiceal stump that could lead to later presentation with stump appendicitis.
5. Once the base of the appendix is clearly exposed where it enters the cecum, a decision must be made on how to divide both the base of the appendix and the mesoappendix containing the appendiceal artery. A laparoscopic stapling device or an Endoloop may be used to ligate the appendix. A hemaclip, a vascular stapling device, or an energy source may be used to ligate and divide the appendiceal artery within the mesoappendix. A window can be created between the appendix and the mesoappendix bluntly with Maryland forceps, taking special care not to poke the tips of the dissecting instrument into the base of the cecum.
6. If a stapler is to be used, the base of the appendix and the mesoappendix are each controlled with a separate staple firing (Fig. 2.4). Taking each structure separately allows the use of different staple heights, ensures good apposition of staples, and may minimize bleeding and stump leaks. Before firing the stapler, verification of the positions of the cecum and terminal ileum is necessary to ensure that neither structure is inadvertently grasped by the stapler. A blue load of a linear laparoscopic stapler (open staple height 3.5 mm) is used to ligate and divide the base of the appendix, and a white load (open staple height 2.5 mm) is used for the mesoappendix. The structures can be divided in either order.

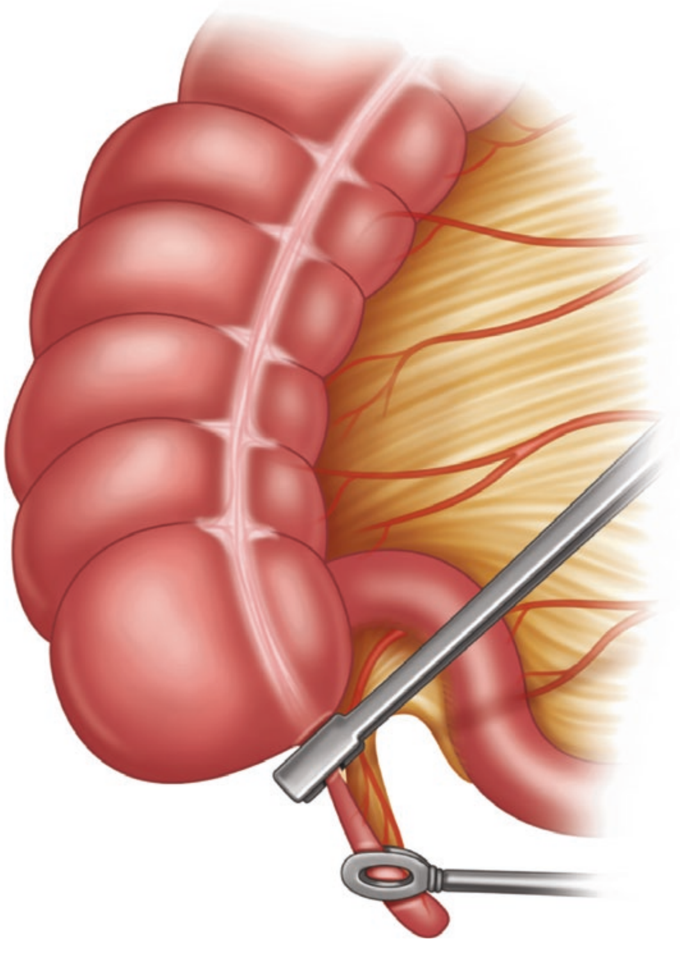

FIGURE 2.4 Division of the appendix – staplers should be applied to divide the appendix flush with the base of the cecum. (Illustration by D. Henriquez)

7. If the choice is made not to use a stapler, the mesoappendix may be dissected off the appendix from tip to base using an energy device (ultrasonic or bipolar vessel sealer) that both obtains hemostasis and divides tissue. Caution must be used when approaching the base of the appendix such that the tips of the energy device do not injure the cecum or terminal ileum. With the mesoappendix divided, the appendiceal base can be divided between two PDS endoloops as a cost-efficient alternative to stapling.
8. Regardless of the strategy for dividing the base of the appendix and the mesoappendix, careful inspection of both is essential to ensure the absence of leakage or bleeding.
9. The appendix should be placed in a specimen retrieval bag and removed via the largest port site under direct visualization.
10. A suction irrigator device may be used if there is contamination. All visible contamination should be quickly evacuated with suction. Wide irrigation is NOT recommended as it may spread otherwise localized contamination widely throughout the peritoneal cavity.
11. In situations where there is identification of perforation, care should be taken to remove any visualized fecalith and to evacuate all contamination from the abdomen and pelvis. If the surgeon does not feel this can be done, conversion to an open procedure should be considered.
12. Once the appendix has been removed, fascia in trocar sites larger than 5 mm should be closed with a 0-vicryl suture.
13. Local anesthetic may be injected if not done so already, and the skin can be closed with 4–0 absorbable monofilament suture in a subcuticular fashion.
14. As in all surgery, conversion to an open procedure should not be considered a failure or complication but rather a next step in the appropriate surgical care of the patient.

Postoperative Care

Complications

Postoperative complications from laparoscopic appendectomy are infrequent but include bleeding, usually from the appendiceal artery or trocar sites. A falling hematocrit or hemodynamic instability are indications for re-exploration that can be done laparoscopically. Evacuation of a large hematoma decreases the risk of abscess and often lessens postoperative pain for the patient. A non-disposable 10 mm suction aspirator is helpful in cases of intraperitoneal bleeding with clot that needs to be evacuated.

Trocar site cellulitis or abscess is rare and usually can be treated with oral antibiotics plus or minus bedside incision and drainage. Postoperative abdominopelvic abscess or phlegmon is rare in cases of uncomplicated appendicitis but can occur in 25–30% of patients with perforated appendicitis. Patients usually present 5–14 days postoperatively with pain, fever, and bowel dysfunction. These deep-space infections can usually be managed with some combination of percutaneous drainage, intravenous antibiotics, and bowel rest. Leaking of the staple line is infrequent and can generally be managed similarly to an abscess. However, clinical toxicity warrants abscess drainage and/or conversion to ileocecectomy with or without diverting ileostomy.

Bowel injury from trocar placement is possible, and there should be a higher suspicion of this in the presence of adhesions. Inspection of the entire operative field and placement of trocars only under direct visualization can aid in the prompt detection and repair of such injuries to decrease patient morbidity. Conversion to a larger incision or open operation may be needed.

Pathology

Pathology reports should be checked on every patient undergoing appendectomy. Occasionally, a carcinoid tumor of the appendix will be detected. If the margin is clear, the associated lymph nodes are negative, and the size of the carcinoid is less than 2 cm, no further surgery is needed. For carcinoids over 2 cm in size or with a positive lymph node (removed incidentally) or positive margin, right hemicolectomy is considered an appropriate next step.

Less commonly, other masses will be found on the appendix, including mucoceles, mucinous-producing adenomas, or adenocarcinomas of the appendix. If encountered intraoperatively, frozen section and conversion to laparoscopic versus open right hemicolectomy should be considered. Patients with adenocarcinomas diagnosed on final pathology should be treated according to the same algorithm as a patient diagnosed with right-sided colon cancer on colonoscopy.

Special Management Considerations

Uncomplicated Appendicitis

As stated before, data suggest that medical management of acute appendicitis may be appropriate in some circumstances and is an option that should be discussed with patients during the process of gaining informed consent. Patients with strong opposition to surgery and non-toxic patients presenting with right lower quadrant abdominal pain and radiologic evidence of uncomplicated appendicitis without appendiceal obstruction may be started on intravenous antibiotics in lieu of initial surgery [6]. Patients are usually admitted to the hospital and placed on intravenous antibiotics until their pain is resolved and their white blood cell count and temperature are within normal limits. At that time, patients are changed to oral antibiotics and may be discharged home to complete a 10–14-day course of oral antibiotics. Access to good follow-up and warnings about recurrent symptoms are crucial.

During medical management, approximately 25–30% of patients cross over to the surgical pathway during the initial 48 hours of observation. Radiologic predictors of success for the medical management of acute appendicitis include an appendix less than 10 mm and the absence of a fecalith within the appendiceal lumen. Short-term success rates as high as 70–80% are reported. It is estimated that approximately 15–40% of patients will return in the first year with recurrent symptoms of acute appendicitis and need to go to surgery.

Complicated Appendicitis

In a non-toxic patient, preoperative identification of a large phlegmon or abscess is a relative contraindication to immediate surgery. These patients may be managed with admission, intravenous antibiotics, and serial abdominal exams to monitor for worsening symptoms or changes in vital signs [7]. Image-guided percutaneous drainage is an appropriate additional step in draining discrete, accessible, large fluid collections concerning for abscess. The drain should be left in place until output is minimal and symptoms have resolved. Repeat CT imaging is not always needed prior to drain removal.

Unsuspected finding of phlegmon or abscess at the time of surgery may make identification and removal of the appendix difficult. Placement of the patient in the left lateral decubitus position may help mobilize the cecum and small bowel away from the right lower quadrant. Placement of additional port sites may also help with visualization. With careful dissection, experienced laparoscopists can still identify and remove the appendix in many of these cases. However, if a surgeon feels he or she cannot proceed safely, at a minimum, he or she should proceed with aspiration of all visible contamination or purulent fluid followed by washout and drain placement. Identification and isolation of the appendix is almost always possible with conversion to an open operation via a lower midline or McBurney's incision. The appendix is usually distinctly palpable in the area of concern. Regardless of which of the above strategies is used, the patient should be admitted postoperatively for a minimum of 24 hours of continued intravenous antibiotics and observation. For patients who undergo washout and drain placement without appendectomy, an interval appendectomy should be considered.

Toxic or septic-appearing patients are best managed via laparoscopy or laparotomy to promptly achieve source control. Phlegmon or significant inflammation in the periappendiceal area can lead to a more difficult surgery, including the need for ileocecectomy. Counseling of patients with suspected complicated appendicitis should include the possibility of bowel resection and in the rare case, ostomy.

If the appendix is perforated at the base, limited ileocecectomy or removal of a sliver of cecum may be necessary to get the stump closed. Intracorporeal suture of the os of the appendix can also be performed. Routine drainage of the stump or appendiceal bed in the absence of discrete abscess is not recommended.

If the surgeon feels he or she cannot visualize the entire appendix, encounters uncontrolled bleeding, notes dense adhesions, or cannot accomplish optimal evacuation of contamination, consideration of conversion to open procedure should take place.

Interval Appendectomy

After presentation with complicated appendicitis, interval appendectomy has traditionally been recommended about 6 weeks after resolution of symptoms to prevent recurrent disease [1]. More recently, however, it is thought that the chance of recurrence is low (below 15%), can be handled with low morbidity, and may in fact not be needed in select groups [8, 9]. Especially in patients over the age of 50, care should be taken to make sure the patient is current on colonoscopy to minimize the chance of missing a malignancy as the source of appendicitis. There should also be discussion about the fact that, occasionally, malignancy of the appendix is present that may not be detected on colonoscopy and therefore missed if appendectomy is not performed [10].

Appendicitis in Pregnancy

Pregnant patients with right lower quadrant pain offer a special diagnostic challenge. Multiple studies have shown that appendicitis in pregnancy, especially complicated appendicitis, can lead to adverse maternal and fetal outcomes. Compared to controls, pregnant women with appendicitis have significantly higher rates of preterm delivery, abruption, and infectious complications. The majority of these complications occur in women with complicated appendicitis, so early diagnosis and treatment are critical to achieving good outcomes [11].

Round ligament pain is in the differential diagnosis but right lower quadrant or suprapubic abdominal pain is acute appendicitis until proven otherwise. Ultrasound and MRI are first line imaging modalities to be used in the pregnant patient to avoid radiation exposure. CT scan can also be used after the first trimester and with careful discussion with the obstetrician and patient. Once the patient is diagnosed with appendicitis, surgery should be recommended immediately. Compared to surgical therapy, conservative therapy with antibiotics and observation has been shown to result in higher rates of severe maternal complications including peritonitis and septic shock [12].

There is evidence to support the safe use of laparoscopic appendectomy in pregnant patients. Benefits may include less pain, fewer wound infections, shorter LOS, and shorter OR times [13]. There is also low-grade evidence to suggest that fetal loss may be more frequent with a laparoscopic versus an open approach to appendectomy and careful informed consent should be obtained before surgery [14].

In the operating room, the patient should be positioned in the left lateral decubitus position to avoid compression on the vena cava. Pneumoperitoneum should be limited to about 10–12 mmHg. Trocar placement may have to be modified cephalad to avoid the gravid uterus. An open Hasson technique is usually recommended but a Veress needle can be used based on surgeon comfort. During dissection, extreme care should be taken to avoid contact with the gravid uterus as this is thought to increase the risk of preterm labor.

The Normal-Appearing Appendix

Occasionally, during appendectomy, the appendix will appear normal, necessitating evaluation of other possible etiologies of the patient's pain. This should include inspection of the right colon for possible diverticuli, evaluation of the tube and ovary in the female patient, and running the small bowel to rule out Meckel's diverticulum. It is considered appropriate to remove the patient's appendix if the indication for surgery is right lower quadrant abdominal pain, as the continued presence of the organ could lead to further diagnostic confusion. In addition, approximately 30% of normal-appearing appendices will show some pathology [15].

Incidental appendectomy is no longer recommended on a routine basis; however, as newer information suggests, the appendix plays a part in housing important lymphoid tissue and colonic flora.

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Chapter 3 Cholecystectomy

Laura Mazer and Elliott Brill

Gallbladder disease is the most common cause of gastrointestinal-related hospital admission in the United States, [1] impacting 10–15% of the adult population and resulting in over 750,000 cholecystectomies performed every year [2]. Evaluation and treatment of gallstone disease is one of the most common clinical problems facing the acute care surgeon, and an understanding of gallbladder pathology and operative technique is essential. This chapter will cover the common indications for cholecystectomy, with a review of preoperative imaging modalities, intraoperative technique, and postoperative complications.

L. Mazer
Department of General Surgery, Stanford University Hospital and Clinics, Stanford, CA, USA

E. Brill (✉)
Stanford University School of Medicine, Stanford, CA, USA

Department of Surgery, Boston University School of Medicine, Boston, MA, USA

Department of General Surgery, Kaiser Permanente, Santa Clara, CA, USA

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Indications for Cholecystectomy

By far the most common indication for laparoscopic cholecystectomy is gallstone disease. The spectrum of gallstone disease ranges from asymptomatic cholelithiasis to complications such as gallstone pancreatitis and choledocholithiasis (Fig. 3.1).

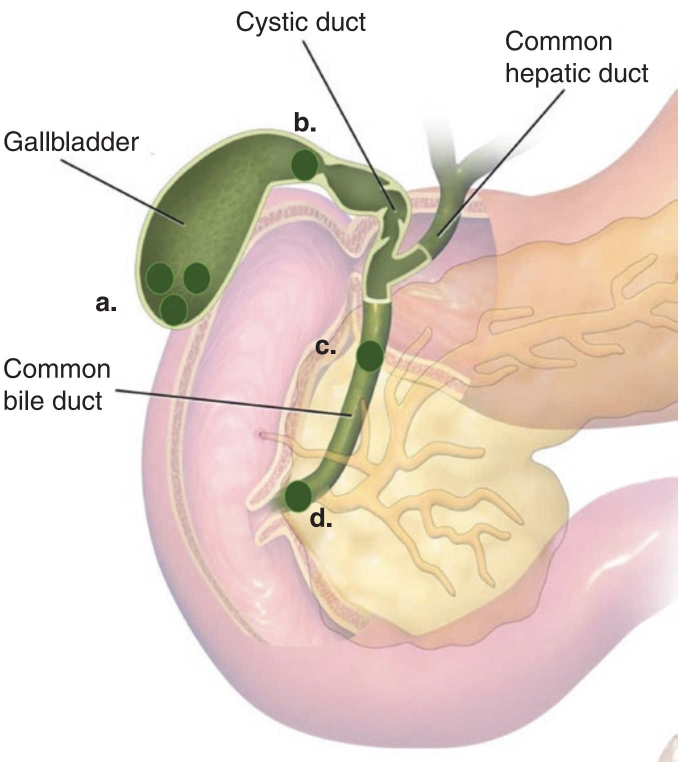

FIGURE 3.1 Spectrum of gallstone disease. (**a**) Cholelithiasis, stones within the gallbladder; (**b**) cholecystitis, gallstone obstructing the cystic duct leading to inflammation; (**c**) choledocholithiasis, gallstone obstructing the common bile duct leading to upstream biliary stasis; (**d**) gallstone pancreatitis. (*Image adapted by the authors from "Gallbladder" by Bruce Blaus, available under a creative commons attribution share alike license from https://commons.wikimedia.org/wiki/File:Gallbladder_(organ).png*)

Asymptomatic cholelithiasis represents the majority of gallstone disease. Only approximately 20% of patients with gallstones develop symptoms, and only about 5% will develop the more severe pathology of cholangitis or pancreatitis [3]. As the majority of gallstones are discovered incidentally, cholecystectomy is not indicated for asymptomatic cholelithiasis [4]. Traditionally, cholecystectomy was recommended for diabetics with asymptomatic cholelithiasis, as cholecystitis was thought to be more serious in this patient population with worse infectious sequelae and more rapid disease progression [5]. More recent evidence, however, shows that the natural history of gallstones in diabetics is actually more benign than previously thought, and that there is no clear benefit to prophylactic cholecystectomy in diabetic patients with asymptomatic gallstones [6].

Biliary colic or *symptomatic cholelithiasis* refers to pain elicited from transient obstruction of the cystic duct. Typically, patients present with postprandial pain in the epigastrium or the right upper quadrant that may radiate to the back. Biliary colic patients usually have normal laboratory tests and no evidence of secondary inflammation on imaging. Typically, this pain lasts for a few hours, but it can be as brief as a few minutes or as long as 12 hours. Biliary colic is a well-accepted indication for cholecystectomy, although the ideal timing is still in debate. In general, patients with biliary colic are referred for elective outpatient surgery, which can take months to schedule. There is a risk of developing further complications during the waiting period, raising the question of the urgency with which these patients should undergo cholecystectomy [4]. A Cochrane review found only one trial addressing this question, comparing immediate (within 24 hours) to elective (mean wait 4.2 months) cholecystectomy for biliary colic. In the delayed group, 22% of patients developed a complication of gallstones while waiting, and the length of stay and operative time in the early group were significantly shorter [7].

Biliary dyskinesia is defined as the symptoms of biliary colic in the absence of gallstones and can present a diagnostic challenge. Biliary dyskinesia is often a diagnosis of exclusion, after a prolonged workup. Patients will typically have a history consistent with biliary colic but imaging studies will be negative. Hepatobiliary scintigraphy (HIDA) can help with the diagnosis by evaluating gallbladder function. A normal ejection fraction is approximately 40–74%; between 35% and 40% is usually chosen as a diagnostic cutoff for dyskinesia [8]. Although treatment remains controversial, there are numerous trials showing that up to 90% of patients with a positive HIDA study for biliary dyskinesia will have long-term symptom resolution of symptoms after cholecystectomy [8, 9]. Gallbladder dysfunction in the absence of stones has been considered an indication for cholecystectomy as early as the 1920s, by Allen Oldfather Whipple [10]. Cholecystectomy is indicated for this pathology, but patients should be counseled about the risk of continued symptoms after surgery.

Acute cholecystitis is an acute inflammation of the gallbladder due to obstruction of the cystic duct, typically due to a gallstone impacted in Hartmann's pouch, the gallbladder neck, or the cystic duct itself. The diagnostic criteria for acute cholecystitis include physical exam, laboratory, and imaging findings and are summarized in the 2018 Tokyo Guidelines (Table 3.1) [11]. In general, acute cholecystitis should be treated with early operation, although timing ultimately depends on the severity of the inflammation (Table 3.2). As the disease progresses from mild to severe, the operation is riskier, and the likelihood of complications or conversion to an open procedure increases. Laparoscopic cholecystectomy should be performed within 96 hours of symptom onset; beyond that period, initial nonoperative management with antibiotics and delayed cholecystectomy is preferred [11]. Severe cholecystitis in an unstable patient is treated with percutaneous cholecystostomy tube and antibiotics, with eventual cholecystectomy weeks or months later [11].

Gallstone pancreatitis and *choledocholithiasis* are the most serious common complications of gallstone disease. Patients with asymptomatic cholelithiasis have an annual risk of 1–2% for developing these conditions [12]. Gallstone pancreatitis is diagnosed in patients with upper abdominal pain, serum amylase, or lipase more than three times the upper limit of

Table 3.1 2018 Tokyo guidelines for diagnosis of acute cholecystitis [11]

A. Local signs of inflammation	1. Murphy's sign 2. RUQ mass/pain/tenderness
B. Systemic signs of inflammation	1. Fever 2. Elevated CRP 3. Elevated WBC
C. Imaging findings	1. Imaging findings characteristic of acute cholecystitis
Suspected diagnosis: one item in A + one item in B *Definite diagnosis: one item in A + one item in B + C*	

Table 3.2 2018 Tokyo guidelines for severity grading of acute cholecystitis [11]

Grade I (mild)	Grade II (moderate)	Grade III (severe)
Does not meet criteria of Grades II or III; acute cholecystitis in a healthy patient with no organ dysfunction	*Any of the following:* 1. WBC >18,000/mm^3 2. Palpable, tender RUQ mass 3. Duration of symptoms >72 hours 4. Marked local inflammation[a]	*Any of the following:* 1. Hypotension requiring pressor support 2. Altered mental status 3. PaO2/FiO2 <300 4. Renal dysfunction 5. Hepatic dysfunction 6. Platelet count <100,000/mm^3

[a]Defined as gangrenous cholecystitis, pericholecystic abscess, hepatic abscess, biliary peritonitis, or emphysematous cholecystitis

normal and imaging signs of gallstones [4]. After a first episode, up to 33% of patients will develop recurrent pancreatitis while awaiting surgery, and delay carries no benefit in terms of operative complications when comparing same-admission versus interval cholecystectomy [13]. To avoid recurrent episodes of pancreatitis, patients with mild to moderate acute pancreatitis should undergo laparoscopic cholecystectomy during the index hospital admission. There are no trials looking specifically at severe acute pancreatitis, and the ideal length of time to wait before operating on these patients is not well established [14].

Choledocholithiasis is the most common cause of nonmalignant biliary obstruction [15]. In uncomplicated cases, these patients typically present with biliary colic type symptoms, including right upper quadrant pain and tenderness. Liver function tests are elevated, specifically bilirubin and alkaline phosphatase, and imaging studies may show a stone in the common bile duct and intra- and extrahepatic biliary dilation. Patients with a strong suspicion of having uncomplicated choledocholithiasis should undergo ERCP for removal of any common bile duct stones, followed by an elective cholecystectomy. If the clinical picture is not clear, magnetic resonance cholangiopancreatography (MRCP) is a noninvasive option that can help diagnose common bile duct (CBD) stones. If positive, the patient would then undergo an ERCP; if negative and suspicion remains high, perhaps an ERCP can still be considered or laparoscopic cholecystectomy with intraoperative cholangiogram [16].

Obstruction of the common bile duct and biliary stasis can lead to bacterial infection of the biliary tree, or *acute cholangitis.* Classically, cholangitis presents with Charcot's Triad (right upper quadrant pain, jaundice, and fever) or, as the symptoms progress, Reynold's Pentad (the addition of hypotension and altered mental status). On history and physical, acute cholangitis should be suspected in patients with jaundice and evidence of severe sepsis. It is vital that these patients are started on broad-spectrum antibiotics as soon as possible. Acute cholangitis patients can decompensate quickly, and early antibiotic administration and biliary decompression are vital in ensuring a good outcome.

ERCP with sphincterotomy and stone extraction with or without a biliary stent is the treatment of choice for achieving biliary drainage in acute cholangitis. However, if ERCP is not technically feasible (patient has had a previous Roux-en-y gastric bypass) or decompression fails, biliary drainage can be attempted by percutaneous transhepatic cholangiography or open surgical decompression. Once these patients recover from their sepsis, cholecystectomy in the elective setting is recommended to prevent a recurrence.

Gallbladder cancer is a rare malignancy that usually presents at a late and unresectable stage with an overall 5-year survival of less than 5% [17]. Preoperatively, suspected gallbladder cancer will generally be referred to a hepatobiliary surgeon, but the majority of these cancers are discovered incidentally. 70–90% of patients with gallbladder cancer have gallstones, and gallbladder cancer is found incidentally after 0.5–1% of elective cholecystectomies [17]. For the acute care surgeon, it is important to know what preoperative findings should raise a suspicion for cancer, and what to do if cancer is suspected intraoperatively. Preoperative findings that should prompt consideration of cancer include a mass in the gallbladder, focal or diffuse wall thickening without other evidence of inflammation, or an intraluminal polypoid mass [18]. Bile spillage during cholecystectomy for cancer can cause diffuse carcinomatosis, and most patients with gallbladder cancer require more extensive resection than simple cholecystectomy [17]. If cancer is suspected preoperatively, patients should be treated with antibiotics and referred to a tertiary center for evaluation. Intraoperatively, the main goal is to avoid bile spillage that would worsen oncologic outcomes. If there is high intraoperative suspicion for cancer and the case can be safely aborted, it is reasonable to close and defer cholecystectomy until the complete evaluation for cancer can be performed.

Prophylactic cholecystectomy is a controversial topic, and indications continue to evolve. Some surgeons advocate for prophylactic cholecystectomy for all patients undergoing *bariatric surgery*. Obesity is a risk factor for gallstone formation, due to increased hepatic secretion of cholesterol, but a rapid weight loss is also a cause of new gallstone formation [1]. While 34% of bariatric surgery patients have gallstone disease prior to surgery, 21% develop de novo stone disease within the first postoperative year [19]. Despite this high incidence of postoperative disease, concomitant cholecystectomy during bariatric surgery does add time to the case and may increase complications. The role of routine prophylactic cholecystectomy in this population remains controversial [4].

Porcelain gallbladder refers to a calcified gallbladder wall, historically considered an indication for prophylactic resection due to a high risk of cancer. Recent series, however, indicate that the risk of cancer has been overstated, and prophylactic cholecystectomy is currently not recommended [17]. Other potential indications for prophylactic cholecystectomy include *sickle cell disease*, *transplantation,* and *immunocompromised state,* due to high rates of gallstone disease and associated cholecystitis requiring emergent surgery [20].

Preoperative Workup

The patient evaluation begins with the history and physical findings, some of which have been described above. Classically, patients report right upper quadrant pain, with possible fever, nausea, emesis, and anorexia. A good history should include any prior episodes, dietary triggers, and risk factors (the classic constellation of fat, female, fertile, and forty). In general, the pain of biliary colic will go away within 12 hours; after that time, these symptoms are more consistent with acute cholecystitis. Physical exam findings can include rebound, guarding, and Murphy's sign (placing the hand below the right costal margin at the midclavicular line, a positive sign is an inspiratory halt as the tender gallbladder comes down and hits the examiner's fingers). Differential diagnosis includes hepatitis, appendicitis, colitis, pancreatitis, or gastroesophageal reflux.

Laboratory studies should include a full chemistry panel and complete blood count. Leukocytosis has a 63% sensitivity and 57% specificity for the diagnosis of cholecystitis; the white blood count should be normal in biliary colic [15]. Choledocholithiasis is suggested by an elevation in alkaline phosphatase (>120 U/L) and total bilirubin (>2 mg/dL), and an elevated amylase or lipase implies gallstone pancreatitis. A significant elevation in aspartate and alanine transaminase (AST, ALT) with a near-normal bilirubin should prompt a workup for primary hepatic problems.

Key imaging findings are summarized in Table 3.3. The initial imaging modality of choice for suspected gallbladder

Table 3.3 Summary of common imaging modalities for preoperative evaluation prior to cholecystectomy

Modality	Key findings	Indications
Ultrasound	Presence of stones/sludge Wall thickening Pericholecystic fluid Size of CBD[a] Presence of CBD stones	Initial imaging test of choice for all gallbladder disease
CT scan	Presence of stones (not as well imaged as on ultrasound) Distension Wall thickening Pericholecystic fluid Fat stranding Intra/extrahepatic biliary dilation	A good first test if the diagnosis is unclear; evaluates a broader initial differential list
HIDA	Visualization of the gallbladder Biliary to bowel transit time Degree of gallbladder contraction	Diagnostic uncertainty after ultrasound Suspected biliary dyskinesia
MRCP	Presence of CBD stones When combined with MRI, can identify all key findings listed above for CT	Suspected CBD stone, noninvasive option to confirm diagnosis prior to ERCP
ERCP	Direct visualization of CBD Presence of stones Appearance of the ampulla Presence of pus Ability to cannulate ampulla and perform sphincterotomy	CBD stone

[a]Common bile duct

pathology is the right upper quadrant ultrasound. Ultrasound is readily available, noninvasive, and inexpensive, with a high sensitivity for gallbladder stones and biliary dilation [21]. A normal common bile duct diameter is 4–5 mm, although this tends to increase by approximately 1 mm per decade after age 50. An enlarged CBD, (whether or not stones are actually seen on ultrasound), should prompt consideration of choledocholithiasis, in combination with the classic clinical features and laboratory abnormalities. Typical findings of cholecystitis on ultrasound include gallstones or sludge, a thickened wall, and pericholecystic fluid. More rare findings include a striated gallbladder wall, indicating gangrenous cholecystitis, or gas in the gallbladder lumen or wall secondary to emphysematous cholecystitis from gas- forming bacteria [21].

It is not uncommon for patients in the emergency room to be evaluated with computed tomography (CT) prior to ultrasound, especially if they present with a less typical history and physical exam. Typical findings on CT scan include the presence of stones, wall thickening, pericholecystic fluid, and gallbladder distension. Because CT scan is less sensitive and specific for stone disease than ultrasound, surgeons will often be asked to evaluate patients with gallbladder distension and wall thickening but without other findings. Distension and wall thickening are relatively nonspecific and also occur in the setting of hypoalbuminemia, large volume fluid resuscitation, ascites, hepatitis, or unrelated inflammatory processes [22]. If the diagnosis is uncertain, a confirmatory ultrasound can help distinguish between secondary distension and a primary gallbladder problem. In a patient with significant diagnostic uncertainty, a HIDA scan can help conclusively establish a diagnosis of cholecystitis. Typically, the HIDA tracer is taken up first by the hepatic parenchyma, then within 30 minutes by the biliary tree. In a normal patient, the tracer should appear in the bowel within 60 minutes. Nonvisualization of the gallbladder (passage of contrast directly from liver to the small bowel) implies an obstructed cystic duct and is diagnostic of cholecystitis [21, 23]. If the gallbladder is visualized, the study is negative for cholecystitis.

Suspicion of common bile duct stones can be evaluated with either magnetic resonance cholangiopancreatography (MRCP) or endoscopic retrograde cholangiopancreatography (ERCP). MRCP is noninvasive, provides no radiation, is safe in pregnancy, and is highly sensitive for common duct stones. It does not, however, have the therapeutic potential of ERCP and can ultimately delay treatment. ERCP remains the gold standard for diagnosis and treatment of common bile duct stones, allowing direct visualization of the common duct, evaluation for pus and stones, and treatment by removing the acute obstruction and preventing subsequent episodes with a sphincterotomy.

Surgical Management

Preoperative Setup

Prior to induction, patients should be placed supine on the operating room table with sequential compression devices for prevention of deep vein thrombosis; chemoprophylaxis is not indicated for laparoscopic cholecystectomy [24]. Preoperative antibiotics should be administered within an hour of incision, or in patients with cholecystitis who are already on antibiotics, on their regular dosing schedule. Patient and room setup is shown in Fig. 3.2. The right arm may be tucked, the primary surgeon stands on the patient's left and the assistant on the right. For teaching institutions, the resident will usually stand on the patient's left side to perform the dissection while the attending surgeon retracts. The laparoscopic cholecystectomy is an important educational case, allowing trainees to progress from a one-handed to a two-handed laparoscopic surgeon. Early in training, the attending can utilize both lateral ports for retraction while the trainee holds camera and dissects through the epigastric port. As the resident gains experience, he or she can begin to use the medial retraction port left-handed while dissecting through the epigastric port. This leaves the attending surgeon operating the camera and the lateral retraction port. For improved ergonomics, the attending can place one grasper

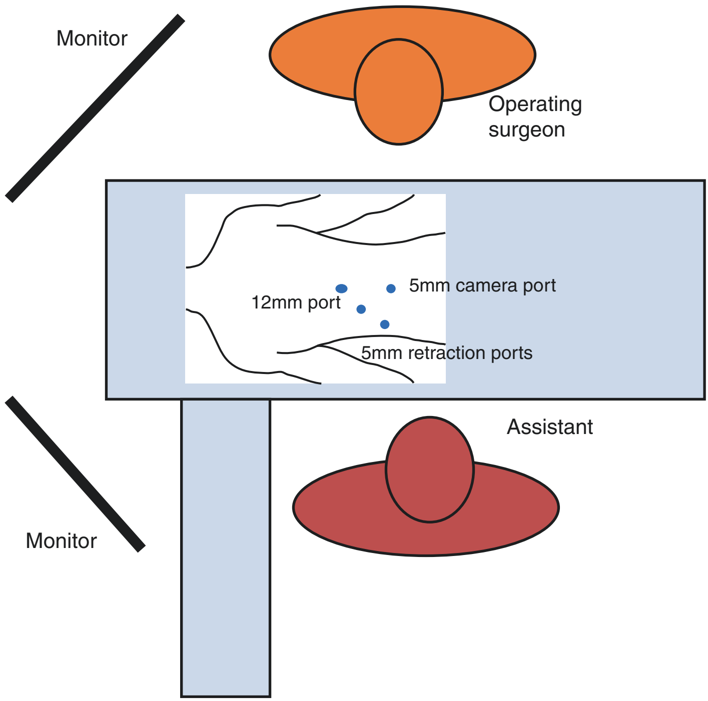

FIGURE 3.2 Room setup for typical laparoscopic cholecystectomy

on the fundus of the gallbladder, retract cephalad, and use a nonpenetrating towel clamp to secure the retractor in place. This allows the attending to come to the right side of the table to drive camera and easily trade the second retraction hand back and forth with the resident as needed for intraoperative teaching.

Intraoperative Technique: The Six-Step Cholecystectomy

1. Abdominal access and port placement

The first port is placed at the umbilicus using either the Veress or Hasson technique. As most studies do not show a difference in outcomes between these alternative access techniques, this is mostly dependent on surgeon preference [25]. The remaining ports are shown in Fig. 3.2: two 5 mm retraction ports along the right costal margin, one at the anterior axillary line and other at the midclavicular line a little more than two fingers breadth below the ribs. The working port is placed in the epigastric area, with the trocar entering the abdomen just to the right of the falciform ligament. Some surgeons favor placing the 12 mm extraction port in the umbilicus, while others place the 12 mm port in the epigastric area. Placing the larger port at the umbilicus is a more cosmetic option that may improve postoperative pain, [26] although it carries a potentially higher surgical site infection and port site hernia rate [27]. There is insufficient data to recommend either technique conclusively, and so the location of the extraction port can be determined by patient and surgeon preference [28].

2. Gallbladder retraction (Fig. 3.3)

The gallbladder is initially grasped at the fundus with a locking grasper and retracted cephalad. The second grasper is placed at the infundibulum through the medial retraction port; this is handled either by the assisting surgeon on the patient's right or by the operating surgeon working two

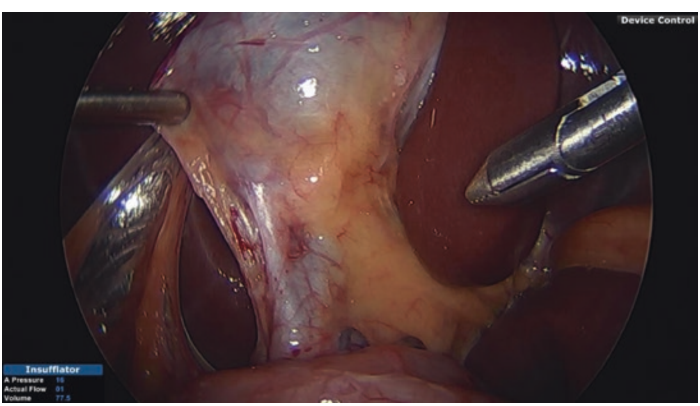

FIGURE 3.3 Gallbladder retraction

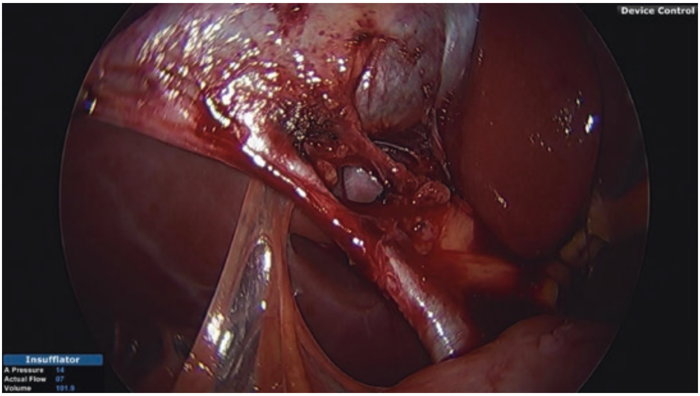

FIGURE 3.4 Critical view of safety

handed. Strong lateral retraction is essential to opening the triangle of Calot and pulling the cystic duct away from the common hepatic duct.

3. Critical view of safety (Fig. 3.4)

First described by Strasberg in 1992, the critical view of safety (CVS) was proposed as a technique to avoid bile duct injuries during laparoscopic cholecystectomy. Identification of the CVS reduces bile duct injuries and should be considered standard of care, and many centers are now encouraging or requiring intraoperative photos to document that an adequate critical view was obtained [29]. The CVS requires three things: complete clearance of the triangle of Calot or cystohepatic triangle bordered by the cystic duct, the common hepatic duct, and the liver edge (Fig. 3.5), separation of the lowest part of the gallbladder from the cystic plate, and identification of two and only two structures entering the gallbladder, the cystic duct and the cystic artery, which courses within the triangle of Calot.

4. Division of the cystic duct and cystic artery (Fig. 3.6)

The cystic duct and artery can now be taken. The structures should be doubly ligated proximally and single ligated distally, and divided sharply.

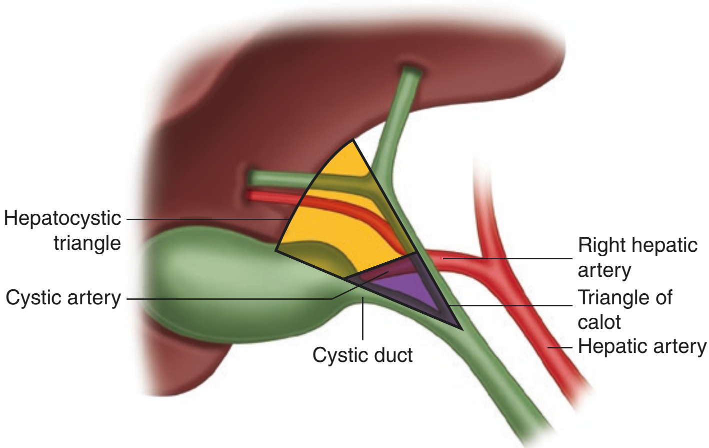

FIGURE 3.5 Triangle of Calot and hepatocystic triangle. Boundaries of the triangle of Calot: the cystic artery superiorly, common hepatic duct medially, and cystic duct laterally; and the larger hepatocystic triangle: inferior edge of the liver, common hepatic artery, and the cystic duct. The cystic artery runs through the middle of the *hepatocystic triangle*. These two terms are often confused, even in textbooks

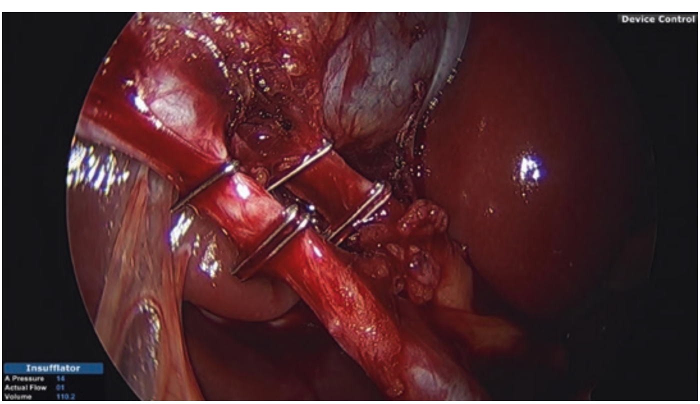

FIGURE 3.6 Clipping the cystic duct and artery

5. Dissection of the gallbladder off the liver

The gallbladder is then removed from the cystic plate with electrosurgical energy, taking care to avoid rupturing the gallbladder and spilling bile and stones. If stones do spill, every effort must be made to find and remove them, to avoid a post-cholecystectomy abscess. In addition, the spillage of alkalinizing bile can result in peritonitis, so every effort should be made to copiously irrigate until the aspirate is clear. Equally important, care should be taken not to use surgical energy too deeply into the liver, to avoid injuring a superficial hepatic vein or bile duct.

6. Removal of the specimen and closure

Finally, the specimen is placed into a retrieval bag and removed through the 12 mm port. Frequently, with large gallstones or an inflamed gallbladder, the specimen is too large to easily pull through the port site. Options include enlarging the fascia by bluntly using a large Kelley clamp to spread the fascial hole; bringing the bag partially outside the skin and using an empty ring clamp to morcellate the gallbladder and remove it in pieces; or incising the fascia sharply and creating a larger incision. If bile spills in the wound, it should be irrigated to prevent infection. All port sites are then infiltrated with a long-acting local anesthetic. The 12 mm port fascia is closed with an absorbable 0 suture. Skin is approximated with an absorbable subcuticular suture, and covered with adhesive strips or skin glue.

The Difficult Cholecystectomy: Conversion to Open, Subtotal, and Top-Down

An acutely inflamed gallbladder can present significant difficulty, and there are situations when the six-step cholecystectomy described above is not possible, or when patient anatomy or degree of inflammation precludes adequate visualization of the CVS. There are several intraoperative strategies for managing the difficult gallbladder.

Top-down or *fundus-first cholecystectomy* is a strategy for patients in whom the triangle of Calot cannot be safely visualized. By starting in a place of relative safety and proceeding in the manner of an open operation, the fundus-first method aims to prevent a bile duct injury in an acutely inflamed and obscured field. More dissection around the critical structures can be performed after orientation has been established from the top down. For adequate retraction while dissecting from the fundus, an additional 5 mm port for a liver retractor is sometimes necessary [30].

Decompression should be considered for any gallbladder that is too tense or stone-filled to retract sufficiently. For a tense, bile-filled gallbladder, a Veress needle can be introduced to draw off enough fluid so that the gallbladder becomes flaccid enough to grasp. A cholecystostomy can also be made with electrosurgical energy and the bile aspirated. If the gallbladder is too impacted with stones, it is also possible to incise a part of the wall, carefully remove some of the stones from the lumen, and use suture to close the hole. The emptied gallbladder can now be grasped to provide retraction [31]. Care should be taken to avoid any spillage of stones into the abdomen.

Subtotal or *partial cholecystectomy* is a well-established option for a difficult gallbladder, by leaving behind a portion of the organ when the critical view of safety cannot be achieved [32]. Strasberg et al. have suggested a new terminology for these procedures [33]. He prefers *subtotal* over *partial* to describe an operation in which the majority of the gallbladder is removed, but some remnant is left behind. He further classifies these procedures into *fenestrating* (the infundibulum is left open, and no gallbladder remnant is recreated) and *reconstituting* (the remaining infundibulum is oversewn or closed) [33]. If the cystic duct is occluded in cholecystitis, a fenestrating procedure will not result in a bile leak, and is less likely to result in recurrent cholecystitis in the remnant gallbladder. In either procedure, the back wall of the gallbladder may be left on the liver bed and should be extensively treated with monopolar energy in coagulation mode.

Intraoperative cholangiogram (IOC) can always be performed when the anatomy is in question, if there is suspicion of a common duct stone, or when there is concern that a bile duct injury has occurred during the dissection. Routine intraoperative cholangiogram has not been shown to reduce the rate of common bile duct injuries, but it does increase the likelihood that injuries are identified at the time of initial operation [34]. IOC begins with obtaining the CVS. With the infundibulum of the gallbladder retracted, a small hole is made in the distal cystic duct. A 5 French ureteral stent or other similar sized cholangiocatheter can then be inserted into the duct and secured with an Olsen clamp or with a separate clip. A diluted 1:1 solution of contrast solution and saline can then be injected to illuminate the biliary tree. Filling of the duodenum without evidence of common bile duct filling defects, and filling of the right and left hepatic ducts should be visualized during IOC.

An alternative or adjunct to IOC is *indocyanine green (ICG) fluorescence cholangiogrpahy*. The intravenous injection of ICG provides the advantage of outlining the biliary tree anatomy prior to dissecting the triangle of Calot. It also avoids the radiation exposure associated with IOC. Studies comparing radiographic IOC to fluorescence ICG in regard to sensitivity of outlining the biliary tree and preventing or reducing common bile duct injuries are yet to be completed. This technique is not able to visualize stones in the common duct, so if this is suspected, traditional IOC should be performed. If ICG is to be utilized, it should be given 45–60 minutes before the commencement of the operation to give the chemical time to be excreted into the biliary system.

Conversion to open is an option in any difficult case. The most important focus in a cholecystectomy is safe removal of the gallbladder and avoidance of bile duct injuries; if that cannot be safely accomplished laparoscopically, an open operation is justified.

Postoperative Care

Most laparoscopic cholecystectomies are performed as an outpatient procedure and require little specific postoperative management. Patients can generally resume a regular diet and be discharged the same day.

Complications

Common bile duct injury is the most dreaded complication after cholecystectomy, and rates remain higher with laparoscopic than open operations. There are numerous schemas to classify types of bile duct injury. The Stewart-Way classification divides bile duct injuries by the cause of injury, most commonly misperception of one structure for another, and the resulting damage [35]. The classes of injury are summarized in Table 3.4. Class I–III are either partial or full thickness injuries to the common hepatic or common bile duct. If these injuries are recognized intraoperatively, there should be a very low threshold for wide drainage and transfer to a tertiary care center for reconstruction. Class IV injuries involve a right hepatic or right sectoral duct. These injuries should be initially managed nonoperatively, as they will often result in

Table 3.4 Stewart-Way classification of bile duct injury [35]

Class I	*Mechanism:* CBD mistaken for cystic duct, but recognized *Result:* Incision into CBD without loss of duct
Class II	*Mechanism:* unintended clips or cautery onto the bile duct, usually to control bleeding while working too deeply in the triangle of Calot *Result:* Lateral damage to hepatic duct
Class III	*Mechanism:* Misperception, transecting the CBD early thinking it is the CD, and the CHD unknowingly while taking the GB off the liver *Result:* Transection and excision of a length of duct that includes the CD-CBD junction
Class IV	*Mechanism:* Misidentification of RHD as CD or from lateral RHD injury during dissection deep in the triangle of Calot *Result:* Injury or transection of the RHD or a right sectoral duct

an atrophy-hypertrophy complex in the liver and eventual normal hepatic function [36].

Other complications include postoperative bleed, intraabdominal abscess (either acutely from infection or delayed from retained stones), cystic duct leak, or duct of Luschka leak. Many of these can be managed nonoperatively, or with percutaneous drainage. Retained common bile duct stones after cholecystectomy can typically be managed with ERCP, sphincterotomy, and stone retrieval. All of these complications individually occur in less than 0.5% of patients, but given the frequency of laparoscopic cholecystectomy, acute care surgeons will likely see most of these complications at least once during their careers.

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Chapter 4
Foregut and Hindgut Perforations

Prashant Sinha and Michael Timoney

Perforations

Intestinal perforations occur throughout the gastrointestinal (GI) tract as a consequence of a variety of mechanisms. This chapter is organized from foregut to hindgut and presents updated and context specific management of these emergencies. Topics covered include evidence-based guidance, judgment-guided adjustments to treatment strategies, and an overarching imperative to achieve source control with aggressive management of sepsis; biology of inflammation still plays a major role in approach and outcome. Fortunately, the surgeon's tool set has significantly expanded in three areas: new minimally invasive and percutaneous devices and tools, improvements in broad spectrum antibiotics and sepsis management and an increasing collaborative, team-based approach to care. Even with these advances, the surgeon remains at the center of good care delivery and care coordination; the

P. Sinha (✉) · M. Timoney
NYU Langone Hospital – Brooklyn, NYU Langone Health, New York, NY, USA
e-mail: Prashant.Sinha@nyulangone.org

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overwhelming body of literature referenced here and elsewhere recognizes the importance of the surgical team as the safest place for patients presenting with intestinal perforation.

Current Management of Foregut Perforations (Upper GI Tract)

The management of upper gastrointestinal perforation is undergoing a rapid shift away from traditional surgical modalities toward less invasive techniques that include endoscopy and percutaneous drainage. However, the basic tenets remain the same: source control, drainage, and antibiotics, with early diagnosis and treatment conferring improved outcome. Traditional surgical approaches still maintain an important role. Several authors suggest that, more than optimal timing of intervention, treatment of some upper GI perforations in a tertiary center by a team of experienced experts, using evolving nonsurgical treatments results in the best outcomes [1, 2].

This chapter details traditional modalities of treatment as well as rapidly evolving techniques that are decreasing morbidity and improving survival in the patient with upper GI perforation.

Esophageal Perforation

Esophageal perforation is a surgical emergency that is associated with a historical mortality as high as 80% [1]. Diagnosis and characterization of the perforation and initiation of treatment within 24 hours was considered the standard time frame in which primary repair could be performed and was associated with improved morbidity and survival [3]. Early diagnosis and early treatment still directly affect outcome; however, early diagnosis is often difficult to make as patients often present late after the onset of the injury and the symptoms of foregut perforation may mimic other disease entities.

Increasingly, nonsurgical and hybrid options have evolved (especially in the setting of delayed diagnosis) and, with them, so have concomitant improvements in morbidity and mortality.

In 1979 Cameron described the criteria needed to selectively treat esophageal rupture nonoperatively. These included disruption that is contained in the mediastinum, drainage of the cavity back into the esophagus, minimal symptoms, and minimal signs of clinical sepsis. A trial of nothing by mouth (NPO), broad-spectrum antibiotics, parenteral nutrition, serial imaging, and eventual administration of a clear liquid diet [4]. Thus began the exploration of less invasive measures to treat these injuries in order to avoid the high mortality associated with surgical management.

Clinical Presentation and Workup of Esophageal Perforation

The clinical manifestations of esophageal rupture are nonspecific and include chest pain, epigastric pain, fever, tachypnea, dysphagia, and subcutaneous emphysema. These signs and symptoms can mimic other disease states such as pneumonia, myocardial infarction, perforated peptic ulcer, aortic dissection, and pneumothorax, thus, leading to diagnosis delays. However, these symptoms in proximity to esophageal instrumentation must prompt a workup and treatment for perforation.

The most common etiology of esophageal perforation in the West is iatrogenic at 59%. This usually occurs in the setting of endoscopic treatment of stricture or achalasia as well as in other endoscopies such as sclerotherapy and variceal ligation. Fifteen percent of cases result from barogenic esophageal rupture (Boerhaave syndrome), with foreign body ingestion, trauma, caustic ingestion, and operative injury making up the remainder of benign perforation [5].

The diagnostic workup of esophageal perforation must identify the injury, its location, the extent of contamination, and spread beyond the mediastinum into the chest or abdominal cavity. Chest X-ray is a good initial screening tool and may demonstrate pneumomediastinum, subcutaneous emphysema, new pleural effusion, or, in cases of low rupture, free air under the diaphragm. Contrast esophagography remains an excellent tool to locate the lesion and quantify extent of contamination. A water-soluble contrast is used in the initial study, followed by the more sensitive barium contrast if the initial study is negative. Unlike a CT scan, a dynamic esophagram may be helpful in demonstrating the rate and direction of contamination through the perforation [6]. CT scan demonstrates the extent of mediastinal contamination, secondary abscess formation, and is useful in guiding drainage procedures [7]. It may be the definitive study if esophagography cannot be performed and it is a sensitive adjunct when esophagography is equivocal [5]. CT scan has become the defacto standard evaluation for known or suspected upper GI perforation due to its improved sensitivity in detection of leaks, its high reproducibility, low latency for upper GI evaluation, and low interobserver variability when compared with esophagrams.

Finally, flexible esophagoscopy is a sensitive and specific diagnostic and therapeutic tool for identification of traumatic injury [8]. Operator skill is very important in avoiding further injury, and an imaging study should precede endoscopy in order to allow for appropriateness and therapeutic planning. Most diagnostic endoscopy and all therapeutic endoscopy are now done with carbon dioxide to reduce patient discomfort, air dissection injury, thermal injury, and retained pneumomediastinum.

Resuscitation and treatment of sepsis remain the mainstays of early management of esophageal perforation. Early use of computed tomographic (CT) scan and endoscopy to identify the location and the extent of the injury as well as to gauge the extent of mediastinal and/or pleural contamination is essential in the assessment of the patient and help to guide therapy. The factors that determine the treatment course are the hemodynamic stability of the patient, extent of contamination, and characteristics of the perforation (size, location, mucosal viability, and presence of secondary pathology) [2]. The following sections will review specific injury patterns, standard operative approaches, and a review of evolving interventional techniques.

Anatomical Considerations of Esophageal Perforation

The esophagus takes a curvilinear course through the chest. It curves to the left just below its origin at the lower border of the cricoid cartilage (at the level of the sixth cervical vertebra) and returns to the midline at the level of fifth thoracic vertebra. It curves again to the left as it crosses the descending thoracic aorta and penetrates the diaphragm to form the cardiac orifice of the stomach at the 11th thoracic vertebra. The anatomical site of esophageal injury has implications for how the perforation manifests itself and for how it may be managed.

The areas of highest likelihood of perforation in the normal esophagus are at the three areas of anatomic narrowing: the region of the cricopharyngeus, the impingement of the arch of the aorta and the left main stem bronchus, and the distal esophagus at the gastroesophageal junction [5].

Cervical Perforation

The morbidity and mortality of injury to the cervical esophagus is generally favorable. This is in part because these injuries are more readily apparent and more quickly diagnosed. Just as important is the fact that contamination at the level of the cervical esophagus remains contained and spreads slowly to the mediastinum. The mechanism for perforation of the cervical esophagus is usually iatrogenic trauma or penetrating trauma. Immediate visualization and recognition of an injury after instrumentation or symptomatology in proximity to instrumentation prompts earlier recognition and management than thoracic perforation.

Esophageal perforation associated with anterior cervical spine surgery is a complication that occurs at an incidence of 0.2–1.52%. These perforations can occur as a result of direct surgical iatrogenic injury or, more commonly, in a delayed manner from hardware injury related to screw and plate migration or chronic erosion of the esophagus over the hardware. ([9]) The patient with cervical esophageal perforation manifests symptoms of cervical pain and dysphagia, dysphonia, and bloody regurgitation. Subcutaneous emphysema is usually seen on physical exam and on X-ray [5, 10]. Along with the management of sepsis, an early challenge in these and other perforations is airway management. Anesthesiologists with difficult airway equipment, and a surgeon prepared to perform a tracheostomy are key to safety. Early intubation in the presence of spreading subcutaneous emphysema is warranted.

Traditional management of cervical esophageal perforation is operative. Proponents of the operative approach point to the low operative morbidity of cervical exploration and the relatively easy access to the injury allowing definitive repair. The cervical esophagus is approached via an incision along the medial border of the left sternocleidomastoid muscle. A cervical collar incision can be used if bilateral cervical exploration is planned. The esophagus is exposed and examined circumferentially to identify all injuries. Intraoperative endoscopy can be used help identify the perforation. A primary repair with absorbable suture can be performed. Buttressing with a muscle flap improves the success of the repair. Sternocleidomastoid is the most common flap but a variety of others may be used [9]. After repair, endoscopic insufflation of air should be performed to assess for leak. Methylene blue administration can also be instilled to help identify leak or small perforations [11].

An increasing body of literature is demonstrating the benefits of nonoperative management of cervical esophageal injury especially in the setting of iatrogenic injury [5]. Authors point to lower morbidity compared with traditional surgical techniques. Observation with antibiotics and nothing by mouth may be successful in patients presenting within 24 hours, without any oral intake after the injury and without signs of sepsis [12]. Alternate strategies include immediate endoscopic intervention with immediate recognition of iatrogenic injury during endoscopy to the cervical esophagus. The placement of fully covered self-expandable metallic stents with removal on day three and discharge on day 4 on soft diet is described [13, 14]. Transcervical drainage is an alternate method to convert a small perforation into a "spit" fistula, diverting saliva from the pharynx and upper esophagus to the skin. This method involves an adequate sized drain directed percutaneously into the perforation, using laryngoscopy or endoscopy, to allow a tract to form over several weeks followed by drain removal, and with alternative enteral access. Endoscopic clipping may also be performed; however, it has not been well described in this region.

Mid and Distal Esophageal Perforation

In 1949, Barrett first described the successful operative management of a patient with spontaneous esophageal rupture after vomiting. Heretofore, most patients were diagnosed postmortem, and none who were diagnosed antemortem survived their treatment. Early diagnosis was made and primary repair and drainage followed. Postoperative management took months [15]. Management recommendations did not change significantly in the decades that followed. For example, in a 1980 series of 47 patients with esophageal perforation, Skinner, Little, and DeMeester recommended early primary repair, with some combination of resection, diversion, feeding access, and reconstruction as therapy when primary repair could not be achieved. Their 30-day mortality was 21% [16].

Traditional operative approaches to injury of the mid and distal esophageal carry high morbidity and mortality that are often associated with the sepsis that ensues with the injury. Operative approach depends upon mechanism of injury, patient stability, suitability of the esophagus for repair, and the presence of other pathology. Primary repair is performed in single or double layers, and many authors advise reinforcement with a flap (pericardial fat, pleura, intercostal, diaphragm, stomach, or omentum) [2]. Management of perforated malignancy after instrumentation may include resection with diversion (cervical esophagostomy) and later interposition reconstruction in the setting of nondisseminated cancer. Free perforation after dilation of a benign stricture may be treated by primary repair (which may include reinforcement with a flap) and a concomitant myotomy. A free perforation that occurs in the absence of obstruction may be primarily repaired (with possible flap) if timed early. Operative therapy is more likely to be of benefit for larger iatrogenic injuries and for Boerhaave syndrome. Options in early free spontaneous rupture include primary repair with reinforcement flap and feeding jejunostomy. Operative management of later presentations of spontaneous rupture with severe mediastinal contamination may include T-tube placement and controlled fistula, especially in the setting of instability. However, this approach carries a high mortality [17]. Resection, diversion, and feeding jejunostomy can be performed in the stable patient with nonviable esophagus [2, 7].

Contained perforation of the esophagus may be treated conservatively (NPO, antibiotics, gastric decompression, drainage, and close observation) as long as the tenants established by Cameron remain in place.

In patients with minimal contamination and who are hemodynamically stable, thoracoscopic and laparoscopic approaches may be considered in the setting of Boerhaave syndrome. [18–20] Minimally invasive surgical treatment of perforation in the setting of dilation for achalasia is increasingly accepted and offers the advantage of definitive repair and treatment of the achalasia. Authors describe a traditional laparoscopic approach with definition of the injury using methylene blue, suture closure of the injury, contralateral myotomy, and a Dor or Toupet fundoplication [21, 22]. In other early presentations of mid to distal esophageal rupture, surgeons comfortable with minimally invasive tools may assess the tissue conditions for repair versus drainage alone with less incision related morbidity. Sepsis may not be an absolute contraindication to a minimal access approach, rather, the surgeon should achieve source control, and coverage or wide drainage without causing physiologic harm from insufflation or prolonged anesthesia.

Endoscopy offers the benefit of internal assessment and immediate closure/coverage of the internal defect in order to stop ongoing contamination. A few methods are described including clips, covered stents, transmural pigtail stents, polyglycolic acid sheets, and a negative pressure sponge attached to a nasogastric tube [23–27]. Each of these methods requires careful assessment of systemic parameters for patient stability—sepsis occurs from the existing contamination of the sterile space and less so from persistent enteric communication. Mediastinal drainage should be minimal or be addressed in parallel before an endoscopic treatment. Mediastinal drains are important for drainage and to help create a controlled fistula. Transmural pigtail stents create a controlled fistula directly while clips, polyglycolic sheets, and covered stents attempt to achieve closure. Occasionally, the mediastinal space will form a contained abscess cavity that can be coaxed into internal drainage. The negative pressure NG tube concept attempts to control the local enteric fluids and create tissue coaptation simultaneously and may help promote this idea of internalization of mediastinal drainage [28]. A coordinated surgical and therapeutic endoscopy team is required for these more advanced techniques, and the members should review all cases in order to create a continuous learning environment for best outcomes and to prevent failures from escalating into severe sepsis. No single endoscopic approach can be recommended at this time, nor are all modalities equally available due to the hospital supply chain or cost.

Gastric Perforation

Causes of gastric perforation include iatrogenic injury, peptic ulcer, and malignancy. Patients experiencing gastric perforation most frequently exhibit acute onset of abdominal pain with evidence of free air on abdominal X-ray. The traditional management goals of surgical treatment of gastric perforation are management of sepsis, closure of the perforation, and definitive operation to decrease the possibility of recurrence and/or complications from the ulcer. Mortality is reported to be between 10% and 40% [29].

Spontaneous perforation of gastric cancer is a rare but serious event that can result in free perforation or bleeding. Clinical manifestations of a perforated gastric cancer are usually not different than gastric perforation for benign disease. Cancer should be considered with spontaneous gastric perforation, especially in the elderly. Peri-ulcer biopsy should be performed in spontaneous gastric perforation to identify malignancy. Outcomes of emergency surgery in the setting of perforated gastric cancer are generally poor and are correlated with stage of disease and completeness of resection, with early stage disease and complete resection resulting in good survival [29–31]. For appropriate oncological candidates, a two-stage procedure (immediate control of sepsis with later definitive treatment of cancer) may be considered in order to confirm the diagnosis and to allow for the patient to recuperate from the physiological effects of the initial peritonitis [32].

Endoscopic mucosal resection and endoscopic submucosal dissection are increasingly popular modalities in the management of early gastric cancer. However, these techniques may result in iatrogenic perforation at a rate of 0.5–4%. Frequently, these perforations are recognized early and may be treated with traditional surgical approaches. However, there is an increasing body of literature that demonstrates that these injuries may be treated endosopically with clipping, stenting or negative pressure sponges [33, 34]. Minami describes direct closure with clips for small injuries and, for larger injuries, endoscopic omental patching using clips with a success rate of 98.3% in 115 patients with these injuries. The newer over-the-scope clips have improved the ability to achieve closure of larger perforations, and have improved the ability to achieve full thickness bites resulting a more durable closure. These larger clips have been employed for iatrogenic injuries resulting from inadvertent full thickness endoscopic dissection or scope trauma in the acute setting and for fistula closure in the non-acute setting [35].

Perforated Marginal Ulcers and Bariatric Leaks

Ulcer formation at the gastro-jejunal anastomosis, or marginal ulcer (MU), occurs at a rate of 0.6–16% [36–40]. These ulcers can result after partial gastrectomy for gastric cancer and peptic ulcer disease and, more commonly today, after Roux-en-Y gastric bypass for morbid obesity. A prospective study by Coblijn described a rate of perforation of 1.1% of patients followed after gastric bypass [41]. These ulcers tend to occur late after surgery and their etiology is not entirely clear. Factors that are commonly thought to contribute to the formation of these ulcers are a larger-sized gastric pouch which produce more acid, nonabsorbable suture material, anastomotic tension, gastro-gastric fistula, diabetes, smoking, corticosteroid use, and the use of nonsteroidal anti-inflammatory drugs. The role of *H. pylori* is unclear in the formation of MUs [40, 41]. Acute leaks after gastric bypass and sleeve gastrectomy occur as reported in the literature between 0.1% and 8% and has decreased with greater understanding to roughly 1% or less. With the exception of larger bougie sizes (40Fr or larger), avoiding excessive narrowing at the incisura, and preventing stapling of the esophageal wall there are no other well studied adjuncts to prevent leaks. Leaks, however, occur at various time points and require different approaches based on acuity. Early operative intervention is helpful in acute leaks, with repair possible in the first several postoperative days. Most leaks, however, require drainage, source control, time, and nutritional support.

Symptoms associated with later onset bariatric leaks and perforated MUs are severe abdominal pain, nausea, vomiting, fever, chills, and sustained tachycardia. Free air may be demonstrated on upright chest X-ray or on CT scan. Initial management of the patient consists of close monitoring, resuscitation, management of sepsis, acid suppression, and nutritional support. Surgical treatment should be undertaken to gain sepsis source control by containing the perforation and washing out any ascites and wide drainage. A small perforation may be treated with a sutured omentoplasty, but larger perforations may require revision of the gastro-jejunostomy, a conversion of a sleeve to a bypass, or a bypass to an esophagojejunostomy. Laparoscopic treatment is associated a shorter operating time and shorter patient length of stay [42, 43]. A remnant gastrostomy or feeding jejunostomy should be performed for enteric nutritional support.

Whether acute or chronic, endoscopic modalities provide an important adjunct to source control. In the acute setting, large over scope clips can close a defect, and can be covered with a stent to allow oral intake to bypass the affected area. In chronic settings, a covered stent is most commonly used to reduce or prevent ongoing contamination. Endoscopy may also be used to lavage and clean abscess cavities to accelerate the healing process, and may also allow placement of pigtail drains to allow internal drainage of a chronic cavity. Chronic perforations/fistulas may take a month or more before healing is complete [44]. An additional benefit of stenting is the ability to transition to an oral diet earlier.

Long-term treatment includes avoiding modifiable risk factors such as smoking, NSAID use, and steroid use [45]. Some authors have concluded that high dose PPI therapy has helped to resolve MUs and prevent recurrence and sucralfate may be a helpful adjunct [46, 47]. Nine percent to 32% of MUs will not resolve with conservative therapy and, in the long term, may require revisional surgery to reduce the size of the gastric pouch, resolve a gastro-gastric fistula, or reduce tension [48, 49].

Peptic Ulcer Disease

With improved medical management of peptic ulcer disease (PUD), hospitalizations for the disease have trended down significantly. From 1993 to 2006, surgical management of bleeding PUD increasingly became supplanted by endoscopic methods and transcatheter embolization. During the same time period, the percentage of patients undergoing peptic ulcer surgery (oversewing of ulcer, gastrectomy, or vagotomy) decreased from 13.1% to 9.7% [50]. Pharmacological treatment to inhibit acid production (H2 antagonists and proton pump inhibitors) is eliminating the need for acid-reducing surgery. Also, the ease of diagnosis, treatment, and eradication of *H. pylori* infection have resulted in significant improvement in ulcer treatment.

Perforated peptic ulcer (PPU) is a frequent emergency condition worldwide with associated mortality up to 30% [51]. The epidemiology of PUD varies according to region, reflecting socioeconomic variations in fundamental disease treatment [7]. Patients with PPU often present with severe, sudden-onset epigastric pain, which can become generalized. Acid exposure results in peritonitis "board-like rigidity." Obesity, immunosuppression, and chronic steroid use, may blunt the classic clinical picture. Initial imaging may include upright chest X-ray, which reveals the pathognomonic free air under the diaphragm. CT may be used when X-ray is nondiagnostic.

Early resuscitation and surgery remains the mainstay of treatment. However, observation and a trial of nonoperative treatment with IV antibiotics, NPO, nasogastric tube, anti-acid medication (proton pump inhibitor), and contrast imaging study to confirm a sealed leak may be considered in a subset of stable patients with minimal symptoms [52, 53]. Nonoperative treatment should be approached with caution as there exists a direct relationship between mortality and time to surgical treatment.

In 1937 Roscoe Graham first described the technique of omental patching to treat perforated duodenal ulcer. Laparotomy with oversewing of the perforation with the "Graham patch" has remained the mainstay of treatment since then. Laparoscopic repair of perforated duodenal ulcer was first described in 1990 by Mouret [54]. Increasingly, laparoscopic variations of the Graham patch have been described.

Multiple reviews have compared outcomes of open versus laparoscopic repairs of PPU and have found similar outcomes with trends toward longer operative times, decreased post-op pain, and earlier recovery in the laparoscopic groups [55–58]. Laparoscopy should be reserved for the patient who is physiologically capable of undergoing abdominal insufflation. Questions remain regarding the role of peritoneal lavage with evacuation of the effluent versus simple evacuation of ascites without lavage. Proponents of lavage site the dilution of bacterial load and the ability to visualize the drainage in the deep spaces of the peritoneal cavity. Opponents cite the potential dissemination of an otherwise localized contamination that can lead to distant abscess formation. Siu et al. performed a series of 54 repairs of perforated duodenal ulcers during which they performed "thorough peritoneal lavage" with subsequent aspiration of the fluid with no significant difference in intra-abdominal collection compared to the matched open group [59]. Others have shown similar outcomes [58, 60]. The use of generous irrigation in this setting does add time to surgery and its benefit has not been definitively proven.

Limited studies have described endoscopic treatment of perforated peptic ulcers. Bergrström published a small series of cases treated with covered self-expandable metal stents. However, this should be reserved as second-line treatment for those who fail more traditional surgical omentoplasty or for whom medical comorbidities or surgical barriers preclude the usual surgical treatment [61]. Finally, Bingener has described a small series of laparoscopically assisted Natural Orifice Transluminal Endoscopic Surgical (NOTES) approaches to management of perforated duodenal ulcers. The endoscope was used to grasp an omental patch through the perforation and endoscopic clips were used to affix the omentum to the mucosa. Laparoscopic guidance was used to aid the endoscopist and at times to help perform omental dissection. This remains an experimental technique whose benefit remains to be proven [62, 63].

Management of Endoscopic/ERCP-Related Injuries

The rate of iatrogenic injury to the duodenum is about 1% [64]. Traditional management of traumatic duodenal injury is surgical. Some of these injuries may be managed medically but the mortality is high [21, 65]. An increasing body of literature supports endoscopic management of acute iatrogenic duodenal perforations from Endoscopic Retrograde Cholangiopancreatography (ERCP). A selective management scheme can be used depending on the characteristics of the ERCP-related injury. The major complication rate of ERCP is about 10% and perforation occurs at a rate of about 1%. Death related to these perforations occurs at a rate of about 16–18% [64, 66]. The injury may be recognized during the ERCP procedure either by direct visualization or by a limited contrast study during the procedure. Post-procedurally, the injury may be recognized by air under the diagram on chest X-ray, or it may be recognized by upper GI series or by CT. Physical findings may be masked by the retroperitoneal nature of some of these injuries. Larger intra-abdominal injuries will present with immediate peritonitis. Late diagnosis may be made when the patient develops signs of sepsis [67]. CT should be performed in any case where a perforation is suspected in order to diagnose the perforation and to determine the size of injury and associated fluid collection [68].

Stapfer proposed a classification for ERCP-related duodenal injuries. Type I injuries are lateral or medial wall perforations caused by the endoscope. These tend to be large and remote from the ampulla, and require immediate surgery. Type II injuries are located in the peri-ampulla region. Type III injuries represent distal bile duct injuries related to wire or basket instrumentation and are often small. Type II and III are typically retroperitoneal injuries related to sphincterotomy or guide wire placement and are less likely to require surgery but should be closely monitored for persistent contrast extravasation and worsening clinical signs that warrant surgery. Consideration should be made for biliary drainage in

Type II and III injuries, as well as for the use of broad-spectrum antibiotics and nasogastric drainage [68]. A type IV injury represents retroperitoneal air related to the use of compressed air and is not a true perforation that requires surgical intervention [67]. Choice of surgical treatment depends on timing, size, and location of the injury and may include primary repair for smaller early injuries, gastro-jejunostomy with pyloric exclusion, or duodeno-antrecomy with reconstruction [69].

Increasingly, advanced endoscopic techniques are being utilized to treat type I injuries that would have traditionally been treated with open surgery. Several small series have shown the benefit of endoscopic techniques, including fibrin glue, endoscopic loops, and clipping. Clipping may be performed with through-the-scope clips for smaller injuries, whereas injuries larger than 10 mm or 12 mm may require over-the-scope clips. The iatrogenic injury must be immediately recognized and treated in order to avoid open repair [70–74]. Treatment may include aspiration of duodenal contents through the hole prior to closure [75]. Once the injury is closed, these patients should be closely monitored and immediate failure of endoscopic management or signs of worsening peritonitis warrant operative intervention [76]. Similar to esophageal perforations, endoluminal negative pressure therapy may be used for treatment of this injury. A vacuum sponge attached to a nasogastric tube is placed with endoscopic guidance in proximity to the injury. The GI secretions are directed intraluminally while the negative pressure sponge helps close and heal the injury [77].

Colonic Perforation

Colonic perforations occur more frequently in the modern era than foregut perforations due to improvements in medical therapies for hyperacidity, the impaired mucosal barrier, and *H. pylori* infections. Perforations in the colon also occur from iatrogenic causes, inflammatory diseases, obstruction, and cancer; however, the treatment approach is highly influenced by the very different physiology and anatomy of the hindgut. We will review the various types of perforations and approaches, leaving the broader treatment of diverticular disease and inflammatory bowel disease to their own chapters.

Overview

Perforations from iatrogenic causes are most commonly from therapeutic endoscopy and surgery. The incidence of colonic perforations from endoscopy is about 1 per 1000 cases; lower for diagnostic cases than therapeutic. In a 2015 NSQIP study, the overall colorectal anastomotic leak rate was 3.8% [78]. In a separate study for only cancer operations [79], the leak rate was higher at 8.7%, and influenced by obesity, total serum protein, anticoagulant use, male sex, number of hospital beds, and intraoperative complication. The remainder of perforations in the colon is dominantly diverticulitis and locally advanced colon cancer followed by a collection of conditions including inflammatory bowel disease, pseudo-obstruction, volvulus, and complications of some biologic agents.

The overall management of diverticulitis and inflammatory bowel disease are covered in separate sections; however, perforation may be a common acute presentation for either and is covered here. Importantly, the number of hospital admissions for diverticulitis has increased by 26% [80], and is the most common of gastrointestinal admitting diagnoses when diverticular bleeding is included. Fortunately, most diverticulitis admitted to the hospital does not need urgent surgery, and maneuvers including drainage, bowel rest, and antibiotics tend to work for the majority. Still, about 15–20% require surgical intervention in the index hospitalization [81].

Complicated colon cancer whether locally invasive, obstructed, or perforated occurs as the initial diagnosis in a small percentage of patients; approximately 9% of cases performed in the past 2 years at our institution were emergent and 3% of malignant cases were done emergently (unpublished data). Perforated colorectal cancer may masquerade as diverticulitis and is associated with worsened morbidity and mortality relative to elective procedures and higher recurrence rate. Fortunately, long-term outcomes may not be affected by perforation, but rather by perioperative sepsis, comorbid conditions, and advanced tumor stage [82, 83]. The most common sites of perforation tend to be at the tumor; perforations proximal to the tumor and uncontained perforations had worse outcomes. Perforations due to biological agents occur at low frequency but pose specific risks beyond the perforation. Bevacizumab, a VEGF-A inhibitor, is the best studied, posing a 1.1% risk of bowel perforation [84], but other chemotherapy and biologic agents significantly modify immune, marrow, and wound healing response making surgical recovery challenging. Patients with stage 4 colorectal cancer on chemotherapy have a low but real risk of perforation and obstruction. At one center the longitudinal risk was found to be about 10%. Finally, in the postoperative period, colorectal anastomoses have an overall leak rate of 3% but rectal anastomoses performed in the lower third portion have a significantly higher rate of leakage.

Some other common patterns of perforations include foreign body and stercoral perforations. Foreign body insertions may perforate near or below the rectosigmoid junction, sometimes allowing for less invasive treatments. Stercoral perforations occur most commonly at the rectosigmoid junction and less commonly in the rectum, but may cause proximal dilation and perforation in the right colon. Perforations in inflammatory bowel disease (IBD) compromise a small but complex group requiring an understanding of immunological, physiological, and anatomical processes. Extra care is required for colonoscopy in the hospitalized cohort of IBD patients as the risk of perforation is almost twice that of non-IBD patients, particularly when a dilation is performed [85].

Principles in Managing Colonic Perforation

Colonic perforations pose a series of challenges significantly more complex than that of the upper GI tract. High bacterial burden and comparatively reduced vascular supply create a negative synergy for healing. Consequently, the management of sepsis, blood supply, and immune modification and sound nutritional management form the basis of surgical strategy rather than a specific set of tools. Colon anatomy is not uniform throughout its course, and various segments introduce specific challenges; understanding these anatomical constraints in the context of perforation will help inform safe conduct.

Anatomic Constraints

Factors that are causative or contributory to perforation in the colon are listed below and include strategies for their management.

Blood supply: The colon is supplied by three main vessels, but with significant variability. Watershed areas occur between the distributions of the ileocolic artery, the middle colic artery and the inferior mesenteric artery. Cases of segmental ischemia occur in left and descending segments more than right or transverse, and much less in the rectum [86]. The rectum is spared as it receives supply from both internal iliac arteries. Small bowel and the right colon have somewhat increased redundancy of blood supply that arises from the superior mesenteric artery; however, the more distal inferior mesenteric artery supplies the distal half of the colon suffers from increased atherosclerosis and lower pressures. In the management of perforations, resection and anastomosis can be considered acutely, but particular care should be taken to preserve the marginal arcades particularly in the left colon, otherwise a segmental resection may be necessary in order to maintain a healthy blood supply, even if unaffected colon is ultimately sacrificed. Under conditions of shock or sepsis, local vascular autoregulation leaves the colon at higher risk for ischemia than other organs.

Wall thickness: The right colon, particularly the cecum is compliant and less muscular as it is responsible for receiving a large volume of liquid material from the ileum relatively quickly. Its thin wall leaves it prone to a larger degree of distention from distal mechanical or pseudo-obstruction, and consequently perforation. Relatively larger amount of fecal contamination can emanate from right colonic perforations than left resulting in potentially worse peritonitis. From the endoscopists viewpoint, the cecum is more prone to perforation from simple polypectomy, and a much more challenging region for the submucosal dissection of larger adenomas.

Extraperitoneal relationships: The extraperitoneal space contains the distal upper rectum and the entire mid and low rectum and mesenteric vessels. It is not unusual to have stercoral or iatrogenic perforations that occur outside of the peritoneal cavity, and we see perforations of diverticula in the colon into the fat of the mesentery and into the retroperitoneal space. These relatively contained spaces prevent rapid dissemination of pus or fecal material, are relatively well vascularized, and can be drained with percutaneous techniques. Cross-sectional imaging will often reveal air infiltrating through this space as the only clue of extra-peritoneal perforation.

Management Principles

Diagnosis of colonic perforations are most commonly suspected on the presenting history and physical examination. Laboratory testing generally is of secondary value but may indicate coexistent anemia, acute kidney injury, and electrolyte abnormalities that require correction. Given the variety of causes of colonic perforation, it is important to assess for specific causes. A history of colonoscopy, therapeutic or screening may suggest iatrogenic injury or an undiagnosed malignancy. Bleeding and constipation may suggest diverticular disease. A history of anal instrumentation, should also be assessed for an otherwise atypical presentation. Constipation and overflow diarrheal incontinence may suggest stercoral obstruction in the elderly. A history of major non-colonic surgery, particularly cardiac or abdominal aneurysm repair may unmask an ischemic etiology. Patients undergoing therapy for malignancy should have a review of any related surgical history and all chemotherapeutic agents used. Imaging is more often than not an important part of the diagnostic work up; a CT scan with intravenous and oral contrast will in most circumstances provide the best information. In ambiguous cases, a period of observation with abdominal examination will reveal localized or generalized peritonitis in evolution.

Imaging: In most cases, a CT scan will provide the most information when clinically acceptable; however, other modalities can and should be used as alternatives and adjuncts. Free air under the diaphragm on chest X-ray, particularly with significant abdominal exam findings and/or sepsis, is sufficient to warrant operative intervention without adding unnecessary time. In the absence of sepsis or peritonitis; however, more sensitive imaging may help direct less invasive therapeutic modalities or even to recommend non-procedural interventions. Anastomotic leaks, for example, tend to occur after a period of time and not dramatically. CT scans outperformed contrast enemas in detecting anastomotic leaks in colorectal surgery [87]. One well-conducted study demonstrated, however, that free air on chest X-ray after postoperative day three should not be present [88]. In stercoral perforations, the obstructing stool ball may prevent significant contamination and may only allow a small amount of localized free air if any. Subtle findings of bowel wall discontinuity, pericolonic inflammatory changes, and small extraluminal gas are increasingly diagnosed on CT scans and help make the diagnosis of stercoral perforation. A gastrografin enema or flexible endoscopy may confirm suspicious findings [89]. Finally, suspected perforation at the time of colonoscopy can be imaged with contrast injection and fluoroscopic evaluation at the time if the equipment is available; this type of evaluation will only demonstrate gross perforation and not subtle findings best noted on CT.

Laboratory Evaluation

No specific laboratory test has demonstrated value in predicting colonic perforation or anastomotic leaks. An individual's immune response to localized or generalized peritonitis varies highly and may not readily be distinguishable from the postsurgical stress response. Procalcitonin level measured on the third or fifth postoperative date has good negative predictive value for anastomotic leak following elective colon surgery. A multicenter study demonstrated negative predictive values for procalcitonin less than 2.7 and 2.3 ng/ml of 96.9% and 98.3% on postoperative days 3 and 5, respectively [90].

Source Control of Peritoneal Contamination

Early source control is the single most important aspect of colonic perforation management. In the treatment algorithms for diverticulitis, both purulent and feculent peritonitis require aggressive measures; a large perforation allowing feculent contamination requires immediate operative source control. Generally, this is done most expeditiously with open lavage but may be done with laparoscopic techniques if the host response allows, and if the contamination can be readily removed with laparoscopic tools. Purulence is more amenable to minimally invasive tools such as laparoscopy and percutaneous drainage; however, delayed conversion to feculent drainage can occur. A peritoneal drain is unlikely to control feculent drainage in comparison to thinner upper gastrointestinal fluids. In order to achieve good initial source control all gross contamination must be removed; a process that requires patience and perseverance in the face of four quadrant contamination. Both dilutional large-volume lavage and suction-only strategies can be employed effectively, by removing most if not all bacterial contamination as the end goal. Wide lavage requires wide suctioning of the lavage fluid, and a drain may be used to continue postoperative removal of any lavage-diluted contamination. Choosing not to lavage requires a careful and methodical search for all areas that may be hiding contamination, and may be best used in localized contamination.

Antibiotic strategies depend on the host response, but are usually adjunctive in the face of colonic perforation. There are notable exceptions when the perforation is localized and contained. For diverticular intramural abscesses less than 4 cm in diameter, primary antibiotic therapy may work without percutaneous or surgical source control. Larger abscess sizes may respond albeit with higher operative conversion rates up to 25% [91]. Irrespective of the nonoperative strategy, drain or antibiotics, a 20% failure rate is still reported [92]. Antibiotics should be targeted based on cultures so that a beneficial balance between treatment failure and overtreatment can be achieved. When the host exhibits signs of sepsis, however, broad-spectrum antibiotics initiated within the hour with aggressive fluid resuscitation guided by lactate clearance is the best strategy; de-escalation to culture-based antibiotics occurs once sepsis is resolved. The Surviving Sepsis campaign 1-hour bundle requires the following elements: obtain blood cultures, initiate broad spectrum antibiotics, rapidly administer intravenous fluids at 30 ml/kg, check lactate and repeat if greater than 2 mmol/L, and start vasopressors immediately or during resuscitation to maintain an mean arterial pressure (MAP) of ≥65 mm Hg [93].

Perforation Management

Surgical source control strategy includes removal of existing contamination but also the prevention of further contamination. Judgment is required when deciding on how to repair the perforation. Techniques include nonoperative management with bowel rest and antibiotics and/or a drain, suture repair, endoscopic clipping, diversion, segmental resection with diversion, segmental resection with anastomosis, segmental resection with anastomosis, and proximal diversion. To date, no well-defined objective criteria exist to direct this decision-making process but specific contexts do have guiding evidence. The least controversial choice historically is diversion in the face of gross or severe fecal contamination, favoring the Hartmann's procedure rather than a primary anastomosis with proximal diversion [94, 95]. The most commonly encountered colonic perforation, an anastomotic leak in the lower colon or rectum, has commonly required a diversion. Only pinpoint holes detected early and without overt sepsis are likely to seal with antibiotics alone; even in these situations, the addition of a proximal diversion will add security to the healing process. The difficulty in this approach is the variability in host response to small leaks, often causing delays before diagnosis. When an anastomosis breaks down however, and sepsis sets in, diversion and resection are the only modalities that will produce a rapid resolution. The use of large endoscopic clips for small leaks holds promise as a useful adjunct or primary therapy, and is described below. It is worth mentioning that in the setting of penetrating trauma, greater than 4 units of packed red blood cell transfusions, severe fecal contamination and single antibiotic prophylaxis were significantly associated with abdominal complications [96]. Interestingly, in this trauma study, the use of diversion versus anastomosis did not influence outcomes. This evidence has supported the possibility of repair without diversion in penetrating colonic injuries when patients are taken to the OR early.

In the situation of a known perforation recognized during a well prepped colonoscopy, a laparoscopic or open repair and washout offers a good result without requiring a diversion. A large or irregular tear is best managed with a local resection and anastomosis, but most small endoscopic perforations only require a two-layer suture repair. Delayed recognition of perforation requires assessment of the host response and degree of contamination and may require significantly more surgery and longer hospitalization. A controversial topic is the effectiveness of endoscopic closure of perforation using clips. Literature cites many examples of endoscopic closure; however, failure of clipping may delay definitive treatment and should be done with careful patient selection [97–100]. Effective endoscopic tools include standard clips, large over-scope clips, and covered stents. Unlike upper GI perforations, VAC sponges, transluminal drains, and endoscopic suturing have not been widely described; ease of use within the long tortuous colon is one factor, and formed stool is the other.

A multidisciplinary approach with surgeons, radiologists, and gastroenterologists actively involved in this decision-making process allows for the best institution-specific outcomes. At our institution, suspected or clipped perforations are managed by a surgical admission, with a strong preference for early (laparoscopic) surgical intervention in colonic perforations while a multimodal approach is preferred for iatrogenic upper GI perforations. Very low colonic perforations tend to respond better to clipping than more proximal areas, particularly because of the demands of navigating the flexures and the thin wall of the right colon create difficult conditions for reliable clipping. A discussion between our surgeons and gastroenterologists includes a detailed review of any endoscopic findings in addition to traditional imaging and surgical concerns. Our team has found that in the chronic or diverted setting, particularly when the perforation is small and sepsis is not present, persistent perforations leading to abscess and/or fistula may respond well to over-the-scope clipping. Other authors, in selected series have also reported high success rates into the 80% range with these larger clips [101]. Left-sided anastomotic leaks are most commonly described, but high splenic flexure leaks have also been closed with this approach. Covered colonic stents migrate and are not commonly useful in the management of a colonic perforation unless the perforation occurs at or near the site of a stricture [102].

Conclusion

Perforations in the gastrointestinal tract present unique challenges based on their acuity and location. The most important concepts converge on the importance of early source control and management of sepsis. The expansion of minimally invasive tools and techniques has allowed patients to recover faster with less surgical stress; however, these tools do not create a substitute for good judgment. The management of these complex perforations should move into a multidisciplinary framework where anatomy and physiology create contextual guidance for a team of experts to select the best combinations of tools to improve patient outcomes. The team approach to managing these complex perforations will help ensure patient safety while identifying the best treatment modalities to efficiently recover the patient, and avoid therapies that are not likely to be effective through continuous learning and improvement.

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Chapter 5
Small Bowel Obstruction

Christos Colovos and Matthew Bloom

Introduction

Though the adage of "never let the sun set on a small bowel obstruction" had historically obligated surgeons to operate without delay, in current practice a trial of nonoperative management is performed in the majority of patients who present with adhesive small bowel disease. This chapter reviews the clinical presentation of small bowel obstructions (SBOs) and their workup, their operative vs. nonoperative management including the role of a Gastrografin challenge, and technical points of open and laparoscopic surgical approaches.

C. Colovos
Department of Surgery, Division of Acute Care Surgery, University of Vermont Larner College of Medicine, Burlington, VT, USA

M. Bloom (✉)
Department of Surgery, Division of Trauma and Acute Care Surgery, Cedars-Sinai Medical Center, Los Angeles, CA, USA
e-mail: Matthew.Bloom@cshs.org

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Epidemiology and History

SBOs are responsible for nearly 15% of the patients with abdominal pain who present to the emergency room, ~15% of surgical admissions, more than 300,000 yearly operations, and healthcare costs in excess of USD2.3 billion in the Unites States annually [1–4]. The surgical management of SBO was first described in the third and fourth centuries by Praxagoras who is attributed with having created an enterocutaneous fistula in order to relieve a bowel obstruction [5]. But until the advent of modern surgical and anesthetic techniques, the management of bowel obstruction was primarily nonoperative, including the external reduction of hernias, the ingestion of heavy metals, the use of laxatives, as well as the application of leeches to remove toxic agents [5]. It was Treves' work in the late 1800s that first described the etiologies of mechanical obstruction and the use of proximal intestinal decompression to treat SBO symptoms which has laid the foundation for current management [6]. In the 1930s, Wangensteen performed additional studies that validated the use of gastrointestinal intubation, determined that the distention found in both obstruction and ileus was due to swallowed air, and described the need for adequate fluid resuscitation of the patient [7].

Simultaneously, as the era of modern anesthesia and surgery developed, the primary cause of SBOs shifted from naturally occurring hernias and masses to intra-abdominal adhesions caused by prior abdominal surgery. Current practice makes this distinction between adhesive disease and other causes of SBO, as it directly dictates management. In the industrialized world, adhesive disease accounts for most of the cases of SBO and may be initially managed without reoperation. Other common causes of bowel obstruction (Table 5.1) should be understood and include malignant obstructions, incarcerated/strangulated hernias, anatomical consequences of bariatric weight-reduction surgery, and inflammatory conditions such as Crohn's disease. These conditions may require an aggressive surgical or medical approach, instead of a more conservative management.

Table 5.1 Differential diagnosis of small bowel obstruction by mechanism of obstruction

Mechanism	**Etiology**	
		Prior operation
	Adhesions	**Congenital**
Extraluminal	Hernias	Abdominal/groin hernia
		Internal hernias
	Neoplastic	Carcinomatosis
		Extrinsic compression by extraintestinal neoplasm
	Abscesses/fluid collections	Secondary to diverticulitis, appendicitis, pancreatitis, etc.
	Congenital	Malrotation, duplication cysts, atresia
	Inflammatory/ infectious	Inflammatory bowel disease
		Diverticulitis
Mural		Tuberculosis, actinomycosis
	Malignant neoplastic	Primary small bowel neoplasm (adenocarcinoma, carcinoid, lymphoma, GISTs)
		Metastatic to small bowel (melanoma, lung, breast, sarcoma)
	Traumatic	Intramural hematoma
		Ischemic strictures
	Foreign bodies	Gallstone ileus
Intraluminal	Mechanical	Bezoars
		Enteroliths
		Intussusception

Clinical Presentation

Patients with SBO will often present with nausea, emesis, abdominal pain, and obstipation. They may, however, report passing some residual stool and gas. With proximal SBOs, patients usually experience profound emesis, food aversion, and diffuse crampy upper abdominal pain. Feculent emesis may occur in long-standing complete obstruction secondary to bacterial overgrowth. Severe crampy abdominal pain is suggestive of a complete or closed-loop obstruction, and the development of peritonitis is concerning for intestinal perforation. Acute intestinal ischemia is known for its marked abdominal tenderness, but it's early presentation may be remarkably mild and deceiving until signs of peritonitis develop.

A detailed history should cover both the provocative and palliative features of the abdominal pain, its severity and location (including referred pain), and its course over time. A history of bowel habits, the presence of hematochezia or melena, prior abdominal and pelvic surgeries, cancer history, history of inflammatory bowel disease, history of atrial fibrillation, and use of medications (especially chronic use of stool softeners and pain medications) should be sought.

Upon physical examination of the patient, signs of dehydration may be present in addition to obvious abdominal distention and tenderness. The abdomen must be examined for the presence of prior surgical scars or hernias. A rectal exam should always be performed to evaluate for rectal masses. Laboratory studies should be drawn including a complete blood count (CBC), basic metabolic panel (BMP), and lactate, as well as additional tests including liver and pancreatic enzymes. Often patients will present with a leukocytosis, elevated hematocrit, and elevated serum creatinine due to hemoconcentration from dehydration and third-spacing. Profound leukocytosis or bandemia is concerning for bowel ischemia and warrants an expedited evaluation.

Imaging Studies

Plain Abdominal Radiography

Both inexpensive and readily obtained, plain radiographs are often the first imaging study ordered for a patient with a suspected SBO and have a sensitivity that ranges from 60% to over 90% [8]. Dilated loops of small bowel with a paucity of gas in the colon (Fig. 5.1) are characteristic; however, it may be difficult to definitively distinguish an SBO from an ileus on plain films alone. Free-air under the diaphragm is an indication of bowel perforation and is a surgical emergency. Bowel perforation can also be suggested by an enhanced ability to delineate both the luminal surface and the serosa of bowel due to the contrast effect of intra-abdominal free air on a radiographic film.

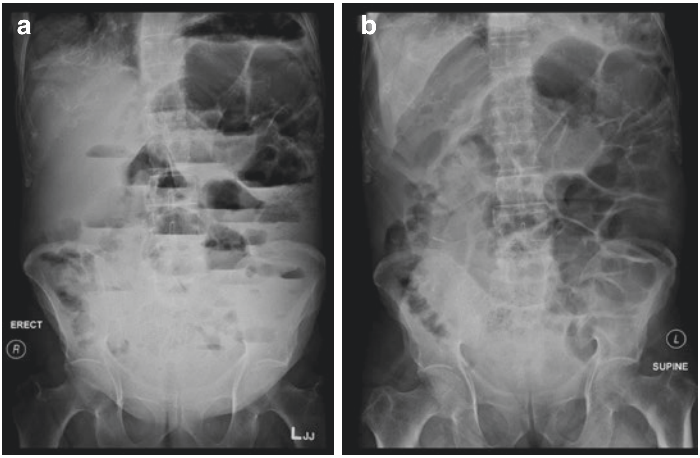

FIGURE 5.1 Upright and supine abdominal radiograph with features suggestive of SBO. (**a**) Erect radiography exhibiting stepwise air-fluid levels characteristic of SBO with a paucity of colonic gas. (**b**) Supine radiography demonstrating distended loops of bowel with fecalization

Computed Tomography

CT imaging of the abdomen and pelvis with intravenous (IV) contrast is recommended to further characterize the type and cause of obstruction in most cases. The diagnosis of SBO by CT scan has a sensitivity of 90–96% and specificity of 96% [9–12]. Loops of small intestine that are >3 cm in diameter are considered dilated. Proximal small bowel distention with distal collapse is the *sine qui non* of a small bowel obstruction (Fig. 5.2).

FIGURE 5.2 CT-axial cross-section of SBO. Arrow indicates fecalization of small bowel. Proximal small bowel dilatation and distal collapse are demonstrated

Diffuse small bowel dilatation without an abrupt transition point suggests alternative diagnoses and virtually excludes a true SBO. Fecalization of the small bowel may be seen with intestinal fluid stasis mixed with bacterial gas. In the past, fecalization of dilated small bowel was thought to be a prognostic sign for failure of nonoperative management or of impending intestinal compromise. Yet, current data suggests that fecalization often identifies the area of the transition zone, but does not predict either the failure of nonoperative management or progression to ischemia [13, 14].

CT imaging can localize the transition point of an obstruction, the presence of a closed loop (defined as more than one transition point), or the presence of internal hernias. It may also reveal intrinsic bowel wall or intraluminal sources of SBOs including intussusception, intraluminal masses, intramural hematomas, or strictures from causes such as Crohn's disease, the sequalae of radiotherapy, or prior surgical anastomoses. Extrinsic causes of SBO revealed on CT scan include adhesive disease, abdominal wall or internal hernias, and malignant compression.

Signs of ischemic and injured intestine include bowel wall thickening (secondary to edema or hemorrhage; >3 mm), mesenteric fat stranding and edema (Fig. 5.3), the presence of inter-loop mesenteric fluid, pneumatosis intestinalis, or development of portal-mesenteric gas. Examination of the small bowel mesentery for edema or congestion or for obliteration of the vasculature is also helpful. Swirling of the mesentery ("whirl sign") may be observed in closed-loop obstructions from volvulization or internal hernias. The use of IV contrast is vital to assessing bowel wall compromise as evidenced by decreased, asymmetric, or delayed bowel wall attenuation. A meta-analysis suggests that reduced IV contrast enhancement of the bowel wall is the most specific sign of tissue ischemia (95% CI: 75–99%) [15]. A CT angiogram of the mesenteric vessels can readily demonstrate a complete obstruction from emboli or thrombus in a patient with atrial fibrillation, or hemodynamically significant vessel stenosis from chronically calcified vasculature. Both arterial and venous phases should be evaluated.

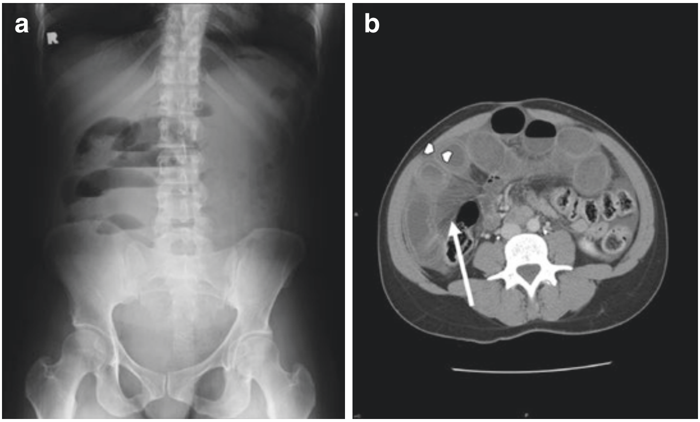

FIGURE 5.3 Closed loop small bowel obstruction. (**a**) Upright plain radiograph demonstrates air fluid levels with a paucity of small bowel gas. (**b**) CT scan reveals evidence of possible ischemia. White arrow indicates mesenteric fluid and stranding. Bowel wall thickening, edema, and enhancement demonstrated by white carrots

Other Imaging Modalities

Magnetic resonance imaging (MRI) is less frequently employed but can reveal the same findings as those seen in CT. It is most often reserved for patients with a contraindication to radiation (e.g., pregnancy) or severe iodine contrast allergic reactions but may have a unique role in imaging patients with inflammatory bowel disease.

Ultrasound (US) may also be used to determine bowel wall thickness, dilation, and motility. Tracing the patterns of the valvulae conniventes may elucidate the site of obstruction. US can also reveal free air, abdominal fluid, and bowel akinesis (>5 min) suggestive of bowel wall compromise. Studies suggest US based diagnosis of SBO has both a 92.4% sensitivity (95% CI: 89.0–94.7%), 96.6% and specificity (95% CI: 88.4–99.1%). Although attractive, it is highly user-dependent and not considered the standard of care in adults.

Contrast Studies

Upper GI series with small bowel follow-through (UGI/SBFT) using a water-soluble contrast (such as Gastrografin) is a diagnostic and potentially therapeutic study of dynamic transit through the bowel. The hyperosmotic structure of Gastrografin is believed to help draw edema out of the bowel wall and promote resolution of obstruction, and observation of contrast in the colon means that a complete obstruction is not currently present. Recent data from a multi-institutional prospective study in which Gastrografin challenge UGI/SBFT was used as an adjunct following CT scan demonstrated that its use was associated with a lower rate of bowel resection (6.9% vs. 21.0%, $p < 0.001$), lower exploration rates (20.8% vs. 44.1%, $p < 0.0001$), shorter hospital stays, and was independently associated with successful nonoperative management [16]. As described below, a Gastrografin challenge has become an integral part of the recommended workup for adhesive small bowel obstruction.

Management

SBOs result in profound fluid losses by emesis, dehydration from food and liquid aversion, and from inflammatory bowel wall edema. The administration of isotonic intravenous fluid is required to account for fluid loss, using urine output as an end-point for adequate resuscitation. In sicker patients with hypotension or pre-existing medical comorbidities (e.g., cardiac failure and renal failure), the placement of a central venous catheter is advised. Severe electrolyte derangements may occur with both dehydration and concomitant emesis and should be appropriately replaced. Nasogastric tube (NGT) decompression is used to decompress the stomach, relieve vomiting, and minimize the further accumulation of intestinal air and gas.

Patients with SBO who have signs of peritonitis, or imaging studies consistent with bowel compromise, should be operated upon without delay. However, nonoperative management, coupled with close serial observation and a Gastrografin challenge, may be attempted in an otherwise nonacutely ill patient. In 2012, the Eastern Association for the Surgery of Trauma issued practice management guidelines for the evaluation and management of SBOs [17]. Other groups such as the Bologna Guidelines from *World Society of Emergency Surgery – Adhesive Small Bowel Obstruction(ASBO) Working Group* [18] (2013) and the University of Florida [19] (2015) have come up with similar recommendations. These practice guidelines have slight differences among them but share the same overall themes:

1. Patients with findings of generalized peritonitis on physical examination or clinical deterioration (i.e., fever, leukocytosis, tachycardia, metabolic acidosis, and continuous pain) should undergo timely surgical exploration.
2. In addition to a thorough physical exam, the laboratory workup should include WBC, lactate, electrolytes, BUN/creatinine, and liver and pancreatic enzymes.
3. Cross-sectional imaging of abdomen and pelvis should be considered in all patients with SBO.
4. Patients without findings of peritonitis nor with clinical deterioration can safely undergo initial nonoperative management for both partial and complete SBO.
5. NGT decompression, IVF administration, and serial abdominal exams are performed, best through admission to a surgical service.
6. Water-soluble contrast study should be considered in patients who fail to improve within 48 hours of nonoperative management (some of the groups advise this at hour 0, others at 24–48 hours).
7. In the place of a formal UGI/SBFT, KUB films at designated intervals (such as at 8, 24, and 48 hours) can also be used and may simplify protocolized management.
8. Operation is performed upon patients who develop increased abdominal pain, peritonitis, progressive nausea, worsening fever and leukocytosis, or failure to pass contrast to the colon after 24–48 hours; otherwise a feeding challenge is begun.

Nonoperative Management

Patients who are candidates for a period of observation and Gastrografin challenge should be made nil per os (NPO); have ongoing IV hydration, strict recording of total and net fluid balance, and NGT placement; and have the head of bed elevated to decrease aspiration risk [20]. They should also undergo documented serial abdominal exams. This approach particularly appealing in cases of partial SBO or early postoperative SBO. One study examining the nonoperative management of SBOs revealed that 88% of cases resolved within 48 hours, and only 2.4% patients who required surgery demonstrated bowel strangulation on exploration [21]. Numerous societies recommend performing an UGI/SBFT within 48 hours of admission, and failure of contrast to reach the cecum in the following 24–48 hours is an indication for operative exploration [17, 18, 22]. We recommend performing this study within the first 24 hours of encounter, and usually order the test after the first morning rounds after admission, if the patient has not begun to show signs of "opening up" on their own after getting rehydrated. A delay in needed operative therapy places the patient at risk for increased mortality, surgical site infections, pneumonia, urinary tract infection, sepsis, and septic shock [23].

Operative Management

Open Approach

The operation is ideally performed through a midline incision, although it is advisable to enter the abdomen in a location away from prior abdominal or pelvic surgeries. Care should be taken when handling dilated bowel to prevent inadvertent bowel wall injury or perforation. Decompressed bowel is sequentially run proximally until the point of obstruction is noted. If adhesions are encountered, they are lysed sequentially with sharp dissection or with careful surgical energy. The obstructed bowel is then examined for signs of ischemia or necrosis. The entire small bowel is rerun from the cecum to the ligament of Treitz, and compromised areas of bowel are noted. Vascular supply can be assessed using doppler ultrasound of the mesenteric vessels, and relative bowel perfusion can be assessed with the use of Wood's lamp following administration of intravenous fluorescein. Compromised bowel is resected, but partially ischemic bowel may be left in situ, especially if intestinal length is an issue, without fascial closure and a second-look operation planned. Similarly, if the patient is hemodynamically unstable, acidotic, coagulopathic, or hypothermic, the intestines may be left in discontinuity and the patient taken to the ICU for further resuscitation with a nasogastric or orogastric tube in place to provide proximal decompression and a second-look operation scheduled within 24–48 hours to reassess bowel viability.

Commonly, side-to-side functional or end-to-end stapled anastomoses are performed. However, some surgeons may choose hand-sewn anastomoses, especially in cases of relative bowel wall edema or a discrepancy in bowel lumen size. In hostile abdomens in which bowel obstruction cannot be relieved (e.g., malignant bowel obstruction, or a completely frozen abdomen), intestinal entero-entero bypass of the obstruction, or the placement of a decompressive gastrostomy tube may be palliative.

In cases of marked bowel luminal distension, intestinal decompression by passing a sump NGT proximally through an enterotomy may be helpful. Gentle retrograde milking of proximal small bowel contents back toward an awaiting NGT can also be performed. The surgeon must take care when handling markedly distended bowel because with increased diameter both the wall thickness decreases and wall tension forces increase, which may result in tissue injury. Additionally there is small-animal experimental evidence to suggest that excessive manipulation of distended bowel can result in increased rates of bacteremia [24].

The fascia is closed in the standard fashion, but in cases with purulent or feculent abdominal fluid, the skin should be left open and packed or closed loosely over a fenestrated Penrose drain to promote drainage. In cases in which the bowel edema is too great to allow for comfortable fascial closure, a temporary fascial closure device such as an abdominal wound-Vac can be placed and diuresis begun in the ICU as hemodynamics permit. These devices are changed every 48–72 hours until their final removal and completed fascial closure. Often the far ends of the fascia can be serially closed, and the overall incision length shortened at each wound-Vac change.

Laparoscopic Adhesiolysis

Rates of laparoscopic management of SBOs have increased more than threefold from 2005 to 2014 [25, 26]. Numerous studies have shown that laparoscopy can result in fewer postoperative adhesions, decreased morbidity, shorter lengths of stay, and faster functional recovery. One recent meta-analysis revealed a reduced overall complication rate, reduced ileus, and decreased pulmonary complications with no differences in rates of intraoperative bowel injury, wound infections, and mortality [27]. These data were re-confirmed in a second meta-analysis in which laparoscopic surgery resulted shorter hospitalization and decreased mortality [28]. Most studies, however, have suggested increasing rates of bowel injury with laparoscopy [25], prompting the surgeon to exercise careful judgment when deciding to perform laparoscopy for SBO.

In the presence of dilated small bowel, safe entry into the abdomen for abdominal insufflation is key. Pneumoperitoneum may be achieved by either performing a Hasson entry at the midline or a Veress needle entry at Palmer's point. As with open surgery, the location of abdominal entry should be as far away from prior surgical scars as possible. During insufflation, both the surgical and anesthetic teams should be aware of changes in hemodynamics. In an under-resuscitated patient, abdominal insufflation can result in hypotension and cardiovascular collapse. Should this occur, the abdomen is immediately desufflated and laparoscopy aborted.

Decompressed bowel is run proximally until the site of obstruction is found, and adhesions are released by sharp dissection. If strangulated bowel is encountered, the procedure is frequently converted to an open operation and a bowel resection performed. Once the adhesions have been lysed, the bowel is run from the cecum to the ligament of Treitz. Extreme care must be exercised when manipulating distended bowel laparoscopically, as laparoscopic instruments focus their force over a small surface area and can result in bowel injury.

Early conversion to an open procedure is the safest approach if there are any questions about being able to perform the surgery laparoscopically. Commonly, experienced laparoscopic surgeons will only allow themselves a maximum fixed period of time, say 10 minutes, to significantly move the case forward when confronting a difficult adhesion before they will convert to an open procedure, as the risk of inadvertent bowel injury increases with ineffective timely progress. This is not considered a failure; rather it is the proper course of action to take.

Conclusions

The evaluation and management of SBO has become somewhat protocolized in the past decade, employing both CT scans and Gastrografin challenges in the workup nonacutely ill patients. Failure of contrast to reach the cecum in 24–48 hours suggests that nonoperative management will not be possible, and an operation should be performed. A laparoscopic approach can be performed in patients with favorable anatomy.

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Chapter 6
Colon Emergencies

Michael S. Truitt, Christopher Pearcy, Paul Deramo, Nathalie Sela, and Nawar A. Alkhamesi

Background

Diverticulitis

Diverticula of the colon are present in up to 60% of people over the age of 60 [1]. Diverticula of the colon are false, pulsion diverticula which are formed when increased intraluminal pressure causes the mucosa and submucosa of the colon to protrude outwardly through the muscularis propria [2] (Fig. 6.1). This commonly occurs at sites of weakness where the vasa recta perforate the muscular layer. Diverticula are predominantly left sided in western countries and involve the sigmoid colon, while right-sided diverticula are more common in Asia; however, an increasing incidence of left-sided diverticula has been noted in westernized Asian countries [3].

Diverticulitis is increasing in frequency worldwide and specifically among younger patients. Only 15–20% of those with diverticulosis will ultimately develop diverticulitis.

M. S. Truitt · C. Pearcy · P. Deramo
Department of Surgery, Methodist Dallas Medical Center, Dallas, TX, USA

N. Sela · N. A. Alkhamesi (✉)
Department of Surgery, Schulich School of Medicine and Dentistry, Western University and University Hospital, London Health Sciences Centre, London, ON, Canada
e-mail: nalkham2@uwo.ca

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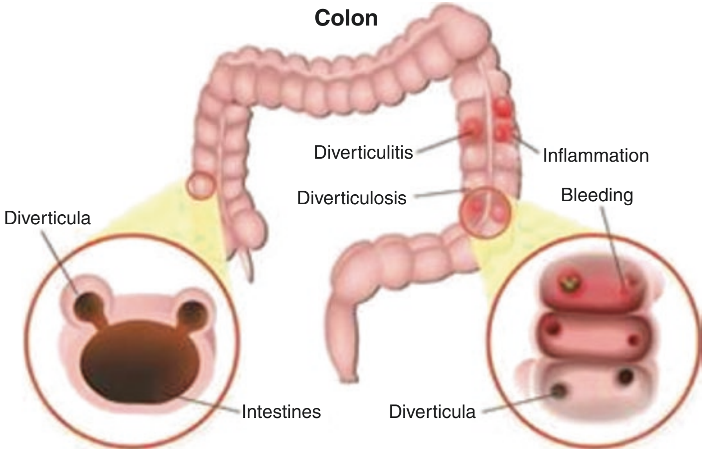

FIGURE 6.1 Diverticulitis. (*Courtesy of NIH Open Source Images Library*)

Additionally, approximately 80% of those who experience an episode of acute diverticulitis will never have another flare, while the remaining 20% will go on to have continued or recurrent episodes [4]. Diverticulitis often involves multidisciplinary care, though given the multitude of interventional and surgical options available, surgeons should be consulted early in the clinical course.

Diverticulitis covers a spectrum of disease and can be divided into complicated and uncomplicated disease. *Complicated diverticulitis* refers to the presence of perforation, obstruction, abscess, or fistula formation and accounts for 25% of patients with their first bout of acute diverticulitis. Most (90–95%) require procedural intervention (percutaneous drain, surgery, etc.), and a few (2–11%) experience a recurrence. For the 75% of patients with *uncomplicated diverticulitis,* the majority (85%) will respond to conservative therapy. Of these, 30–40% will remain asymptomatic, 30–40% will have episodic cramps without diverticulitis, and 30% will suffer a second attack. Approximately 15% will require surgery for their first episode of diverticulitis [5].

Clinical Presentation

Patients with acute diverticulitis present in a variety of ways. Patients with classic diverticulitis typically complain of slow onset, progressively worsening, left lower quadrant abdominal pain; however, the spectrum of presentations is broad. Alternate presentations include nausea and vomiting, ileus, pneumaturia or fecaluria due to a fistula, obstruction, or frank perforation. Fortunately, most patients present early in the course of disease, and these more advanced clinical scenarios are less common.

Diagnosis

Several imaging modalities aid in the diagnosis of diverticulitis, but the diagnosis can frequently be made with a careful history and physical exam. When the differential diagnosis includes diverticulitis, a computed tomography (CT) scan of the abdomen represents the gold standard for determining the diagnosis and is widely available. Uncomplicated diverticulitis is characterized by pericolonic fat stranding, phlegmon, and colonic wall thickening without signs of perforation (Fig. 6.2). Conversely, complicated diverticulitis is characterized by the presence of an abscess, peritonitis, obstruction, fistula, or extraluminal free air (Fig. 6.3). Abdominal ultrasound may be useful in identifying hypoechoic inflammatory changes, abscess with or without gas, and colonic wall thickening, but is not widely employed in the USA. Magnetic resonance imaging (MRI) has been used and demonstrates similar findings to a CT scan with the benefit of avoiding ionizing radiation; however, studies have not been performed to determine the relative sensitivity or specificity of this modality [6].

Management

The specific management of acute diverticulitis depends on whether the episode is characterized as uncomplicated or

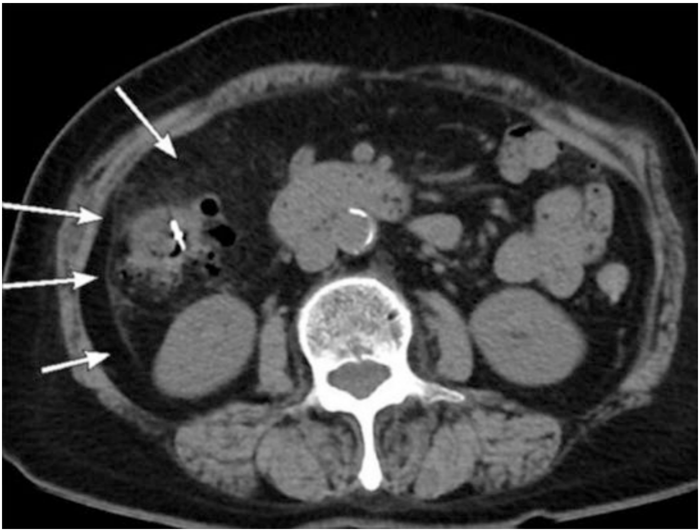

Figure 6.2 Uncomplicated diverticulitis. Adjacent fat stranding, thick-walled colon, no sign of abscess or free air. (*Courtesy of NIH Open Source Images Library*)

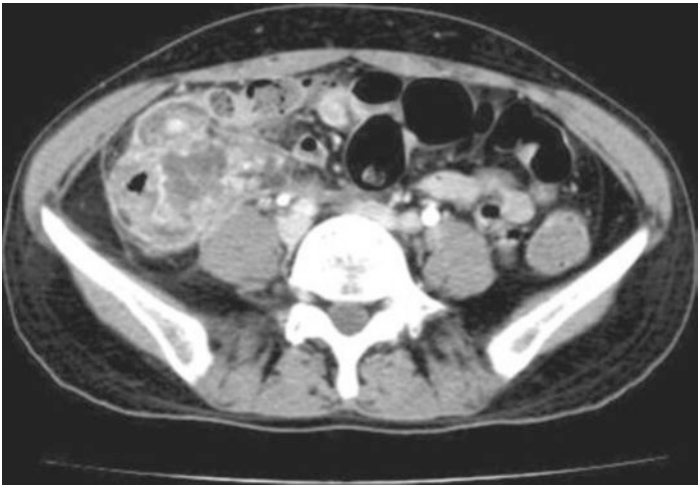

Figure 6.3 Complicated diverticulitis with formation of large pericecal abscess. (*Courtesy of NIH Open Source images*)

complicated based on the previously mentioned imaging findings and overall clinical picture.

Uncomplicated diverticulitis is typically managed with oral antibiotics and bowel rest for 7–10 days. Multiple recent studies including the DIABOLO trial have demonstrated that observation alone may be sufficient and leads to similar rates of resolution, recurrence, progression to complicated diverticulitis, and mortality when compared with patients treated with antibiotics [7]. Historically, uncomplicated diverticulitis was treated with elective partial colectomy in patients with two or more episodes, those requiring hospitalization for any episode, and in young patients. This was based on the notion that recurrent episodes of uncomplicated diverticulitis lead to higher complication rates and mortality with each subsequent episode. Further research has since demonstrated no increased risk in complications or mortality with recurrent uncomplicated diverticulitis. These patients should only be considered for an operation if they meet one of the indications for operation outlined in Table 6.1. All patients with uncomplicated diverticulitis should also undergo screening colonoscopy 4–6 weeks after resolution of symptoms to rule out an undiagnosed cancer [2].

The management of complicated diverticulitis is largely dictated by the Hinchey classification and clinical presentation. The Hinchey classification of complicated diverticulitis can be seen in Table 6.2 and Fig. 6.4.

For Hinchey I and II, the preferred method of treatment still consists of antibiotics and percutaneous drainage of abscesses if feasible. For those who go on to require an operation, there are multiple options available to the surgeon. In the cases of minimal contamination or when the abscess can be resected en bloc with the segment of affected colon, a one-stage segmental resection with primary anastomosis can be attempted. It is also crucial to consider the vascularity, degree of inflammation present, and mobility of the planned anastomotic site. In general, these patients should undergo bowel preparation prior to operation when possible [2, 6, 8, 9, 10]. Laparoscopic techniques are preferred when feasible and the technical expertise exists. These patients have been shown

Table 6.1 This table demonstrates the indications for emergent, urgent, and elective surgical intervention in patients with acute diverticulitis

Indications for *emergent* surgical intervention in patients with acute diverticulitis
Generalized peritonitis on physical examination
Hemodynamic instability
Indications for *urgent* surgical intervention in patients with acute diverticulitis
Failure of medical treatment
Obstruction
Abscess failing nonoperative management
Indications for *elective* surgical intervention in patients with acute diverticulitis
Acute diverticulitis with fistula
Chronic smoldering diverticulitis
Asymptomatic, high-risk patients including immunosuppressed and those patients with a previous history of complicated diverticulitis

Table 6.2 Hinchey classification of complicated acute diverticulitis

Stage I	Pericolonic abscess
Stage II	Pelvic abscess
Stage III	Perforation with purulent peritonitis
Stage IV	Perforation with feculent peritonitis

to have superior short-term outcomes including lower rates of wound infection, incisional hernia, blood transfusion, and postoperative ileus with comparable long-term outcomes to open surgery [11–14]. In patients with significant comorbid conditions, immunosuppression, or significant contamination, we recommend an ileostomy to protect the anastomosis at the index operation. This technique allows for primary anastomosis while mitigating the effects of a leak via fecal diversion. Recent studies have demonstrated similar morbidity and mortality rates with higher rates of ostomy reversal

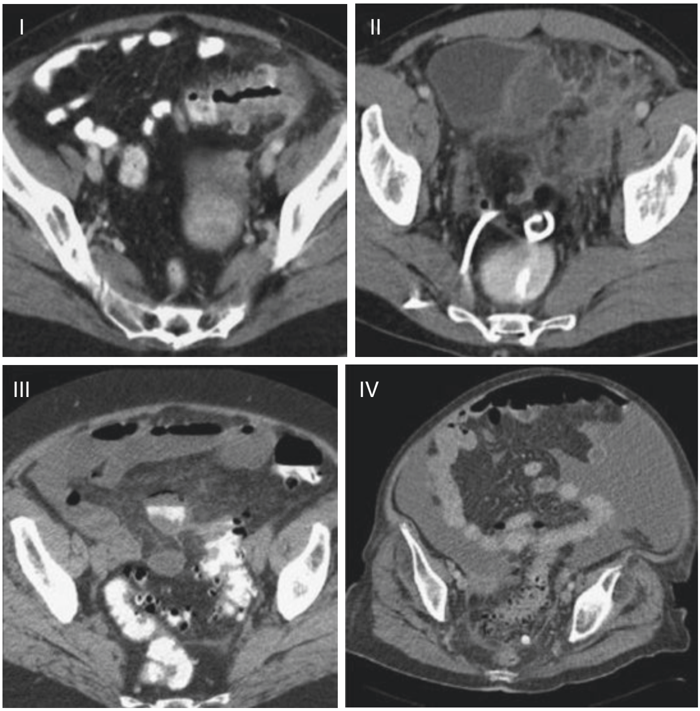

Figure 6.4 CT scans demonstrating representative images for Hinchey classes I–IV complicated diverticulitis. (*Courtesy of NIH*)

when compared to a Hartmann's procedure. The preferred method is still controversial and the surgeon should defer to his/her surgical judgment and individual expertise. If the contamination is excessive or there are additional factors that may predispose to leak, a two-stage Hartmann-type operation is preferred. The Hartmann's procedure has long been the gold standard for perforated diverticulitis and should still be utilized for Hinchey III and IV patients with ongoing sepsis or hemodynamic instability. The Hartmann's procedure consists of segmental resection of the diseased colon, end colostomy placement, and formation of a rectal stump (Fig. 6.5). The ostomy can usually be reversed approximately 12 weeks following the initial operation [2, 6, 8].

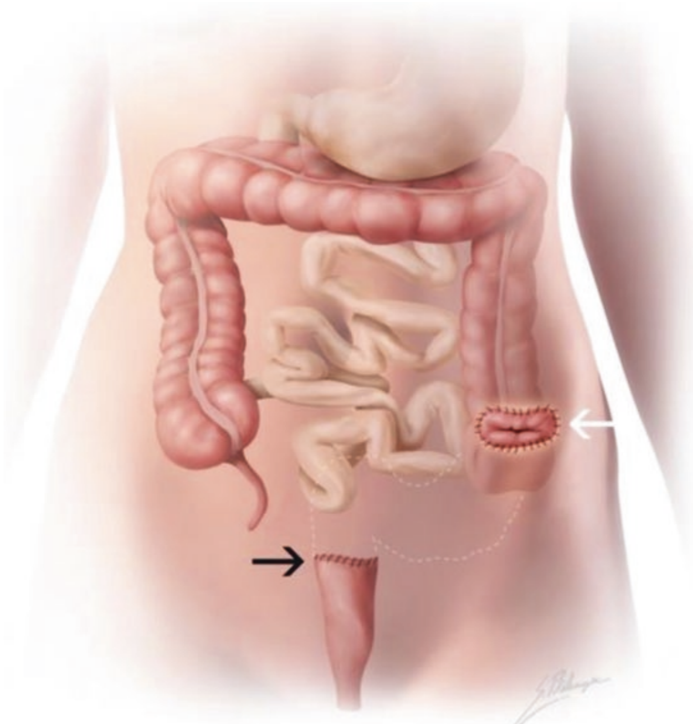

FIGURE 6.5 Image representing the Hartmann's procedure with removal of the diseased segment of bowel, a stapled rectal stump distally, and an end colostomy. (*Courtesy of NIH*)

Enthusiasm for laparoscopic lavage has increased in recent years. Multiple studies have demonstrated conflicting results. While the trials (SCANDIV, LOLA, and DILALA) all demonstrated similar overall rates of morbidity and mortality, there were significant differences in the reoperation rates, partially due to variable study designs and nonstandardized operative techniques. A recent international consensus conference between SAGES/EAES advocated for the use of laparoscopic lavage in Hinchey III, but not Hinchey IV patients. The avoidance of a stoma and the associated complications (ostomy care and takedown) make lavage an attractive option, but the ideal patient population, clinical parameters, and operative technique have yet to be clearly delineated [15–17].

The final option for treatment is drainage and diversion. This technique is a three-stage operation which is seldom used today. It involves washout and drainage with fecal diversion, followed by resection of the diseased colon, and finally restoration of bowel continuity with anastomosis. This procedure is largely a legacy procedure and is reserved for those patients who present with such significant inflammation that dissection cannot be accomplished at the initial operation without causing harm to surrounding structures (i.e., ureter, iliacs) [18].

Volvulus

Volvulus of the colon represents an uncommon, but potentially life-threatening emergency of the colon. The term volvulus refers to an organ which is twisted about its vascular pedicle. This can occur anywhere along the gastrointestinal tract but is most commonly seen in the cecum and sigmoid colon. When colonic volvulus occurs, the vascular supply to the affected segment of bowel can become compromised. Vascular congestion may progress to ischemic necrosis and perforation in a relatively short period of time; therefore, early identification and appropriate, timely treatment of colonic volvulus are essential.

Sigmoid Volvulus

The sigmoid colon is the most common site of volvulus and is involved in 60–80% of all volvuli but fewer than 10% of all intestinal obstructions. It occurs primarily in the seventh decade of life, particularly in recumbent patients. The pathophysiology of sigmoid volvulus is multifactorial but is known to involve chronic constipation and an elongated or redundant colon. An excessively mobile colon is predisposed to volvulus around the tethered rectal and descending colon attachments [19].

Presentation

Sigmoid volvulus is an obstructive disease process, and as such, patients typically present with symptoms of abdominal pain, distention, nausea, vomiting, and constipation. The pain is typically mild at onset but slowly progresses, sometimes over several days. It is common for patients to present late in the course of disease secondary to the insidious onset of symptoms. Additionally, spontaneous reduction of the volvulus and resolution of symptoms can occur and also contribute to a delay in presentation. Significant dilation of the colon can occur; tympany and marked abdominal distention are common. Symptoms including fever, tachycardia, hypotension, abdominal rigidity, guarding, and rebound tenderness may be present and should raise concern for irreversible ischemia or perforation.

Diagnosis

Initial history and physical examination should elicit symptoms of colonic obstruction when a volvulus is present. In the cases of colonic obstruction, malignancy is the most common cause overall, but differential diagnoses include acute diverticulitis, volvulus, inflammatory bowel disease, and toxic megacolon. Most patients have nonspecific lab abnormalities at the time of presentation; however, patients with delayed presentation may have leukocytosis or lactic acidosis indicative of ongoing bowel ischemia. Plain films of the abdomen are the first-line imaging modality and can diagnose up to 75% of volvuli. Classic X-ray characteristics are often described as the "omega sign," "bent-inner tube sign," or "coffee bean sign" (Fig. 6.6) which are typically directed from the left lower

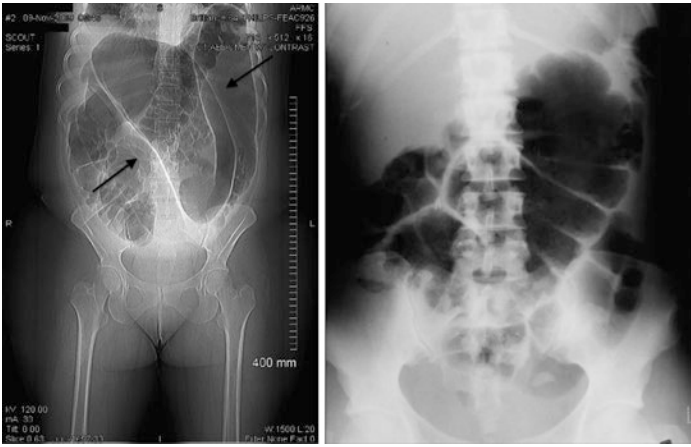

Figure 6.6 Coffee bean sign seen here to the left originating in the left lower quadrant extending up toward the right upper quadrant, characteristic of sigmoid volvulus. Conversely, cecal volvulus with dilated colon pointed back up toward left upper quadrant. (*Courtesy of NIH*)

quadrant toward the right upper quadrant. More alarming findings on a plain film are thumbprinting, linear pneumatosis of the colon wall, or free air.

If the diagnosis of volvulus is unclear on a plain film alone, water-soluble contrast enema may be given. The addition of the contrast enema increases the sensitivity to near 100%, and classically shows “bird’s beak appearance” at the site of twisting without contrast proximal to the obstruction. Alternatively, an abdominal CT scan is highly sensitive and specific in identifying sigmoid volvulus and may also evaluate other causes of obstruction. Images show a dilated sigmoid colon commonly associated with a “swirl sign” formed by twisting along the colonic mesentery. Furthermore, a CT scan can identify concerning features such as pneumatosis intestinalis, portal venous gas, and poor bowel wall enhancement with much higher sensitivity than plain film [20].

Management

The acute management of sigmoid volvulus centers on two main tenants: reduction of the volvulus and prevention of recurrence. The reduction of the volvulized segment of colon relieves vascular congestion and restores normal circulation to the affected segment. Unfortunately, recurrence of the sigmoid volvulus following acute reduction is not uncommon and so definitive treatment should be pursued [21].

In the acute care setting, abdominal catastrophe must be ruled out in the cases of volvulus. Concerning features include peritoneal signs on abdominal exam, hemodynamic instability coupled with leukocytosis or severe acidosis, as well as free air, pneumatosis, or portal venous gas on imaging. Any of these findings should prompt immediate laparotomy. Most cases, however, are managed with reduction of the volvulized segment of colon which can be accomplished in a variety of ways. Rectal tube insertion beyond the point of obstruction is the preferred method of reduction. This can be accomplished by either gentle insertion or with endoscopic assistance. Reduction may also be accomplished endoscopically which adds the ability to evaluate the colonic mucosa through direct visualization. If necrosis is visualized, immediate surgical intervention is indicated. Endoscopic reduction is achieved by advancing the scope to the point of obstruction which is often described as a spiral, sphincter-like segment of mucosa, typically within 25 cm of the anal verge (Fig. 6.7). Gentle insufflation and careful advancement of the endoscope proximally should reveal a dilated colon. Return of stool and gas confirms successful reduction and should be suctioned prior to withdrawal of the endoscope. A rectal tube may be placed beyond the site of obstruction to prevent recurrence. In general, minimal insufflation should be employed during endoscopy to prevent perforation. Multiple reductions and replacement of a slipped rectal tube may be necessary and

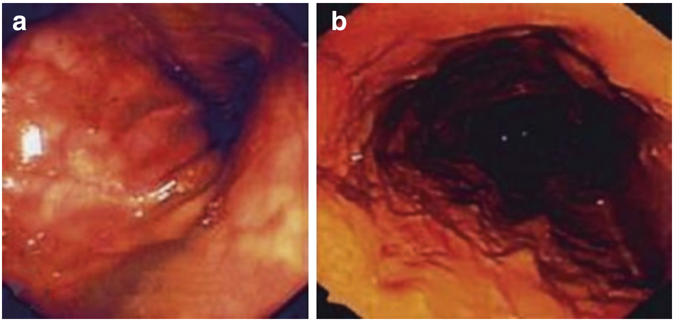

FIGURE 6.7 Endoscopic view of sigmoid volvulus with some mucosal friability and necrosis

attempts at reduction should continue until definitive treatment. As many as 80% of sigmoid volvuli can be reduced via a rectal tube, but up to 90% of those will recur after initial reduction [22, 23].

Any patients presenting with abdominal sepsis, gangrenous colon, or free perforation should be treated immediately with exploratory laparotomy. The procedure of choice in this setting is sigmoid resection with the Hartmann's procedure. For patients not exhibiting signs of gangrene at presentation, definitive treatment should occur during the index hospital admission. After successful reduction, fluid resuscitation, and preoperative optimization, sigmoid colectomy should be offered. Bowel preparation is preferred after successful reduction of a volvulus prior to definitive management whenever possible. This allows the surgeon to perform a primary anastomosis during the initial operation. Sigmoid resection can be performed via a laparoscopic or open approach. In patients with malnutrition or other risk factors for anastomotic complications, strong consideration should be given to sigmoid resection and end colostomy. Colopexy is not indicated for sigmoid volvulus as it is associated with increased rates of recurrence, morbidity, and mortality [24].

Cecal Volvulus

Volvulus of the cecum accounts for 15–30% of all colonic volvuli. In contrast to sigmoid volvulus, cecal volvulus typically occurs in younger patients with a mean age of presentation between 35 and 55 years of age. Two distinct types of cecal volvulus exist. A true cecal volvulus usually involves clockwise twisting of the terminal ileum, cecum, and right colon in the axial plane along the mesenteric pedicle (Fig. 6.8). Conversely, a cecal bascule refers to anterosuperior folding of a mobile cecum along the ascending colon. In a cecal bascule, obstruction may occur, but circulation is not compromised resulting in a much lower risk of ischemia and subsequent necrosis [25]. The etiology of cecal volvulus is multifactorial, but risk factors include chronic constipation, distal colonic obstruction, and previous abdominal surgery. There is some evidence to support the failure of fixation of the right colon to the retroperitoneum as a congenital risk factor. In addition, pregnant females seem to be a high-risk subgroup as volvulus has been shown to be responsible for up to 40% of large bowel obstructions in this population. This is thought to be caused by upward growth of the gravid uterus causing the cecum to kink. In these patients, diagnosis can be very difficult as practitioners want to avoid fetal radiation exposure. Thus, a high index of suspicion for cecal volvulus is important in this population [19, 20].

Clinical Presentation

Similar to sigmoid volvulus, patients with cecal volvulus present with intermittent obstruction. This manifests as recurrent abdominal pain, nausea, and vomiting. Abdominal distention is often present but is less pronounced in cecal volvulus as the proximal dilated segment is the terminal ileum rather than colon. Cecal volvulus may also present with signs of intestinal ischemia and necrosis as an acute abdomen. These patients often present in septic shock with fever, tachycardia, hypotension, leukocytosis, and acidosis.

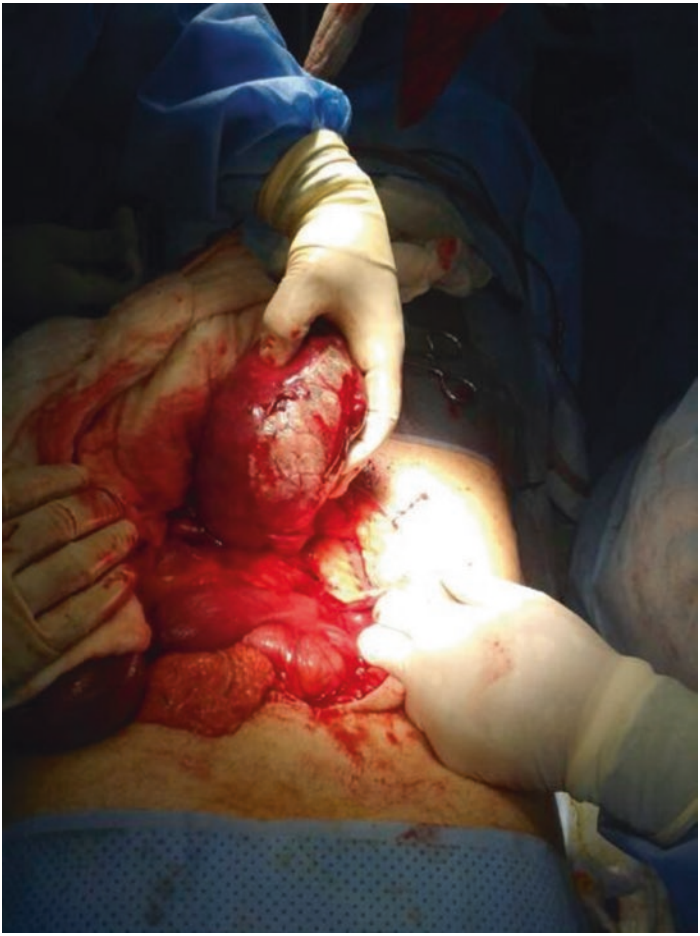

Figure 6.8 Cecal volvulus seen rotating along a vascular pedicle. (*Radiopaedia*)

Diagnosis

A CT scan is the gold standard for diagnosis of cecal volvulus secondary to its high sensitivity and specificity approaching 100%. Coffee bean, bird's beak, and swirl sign (Fig. 6.9)

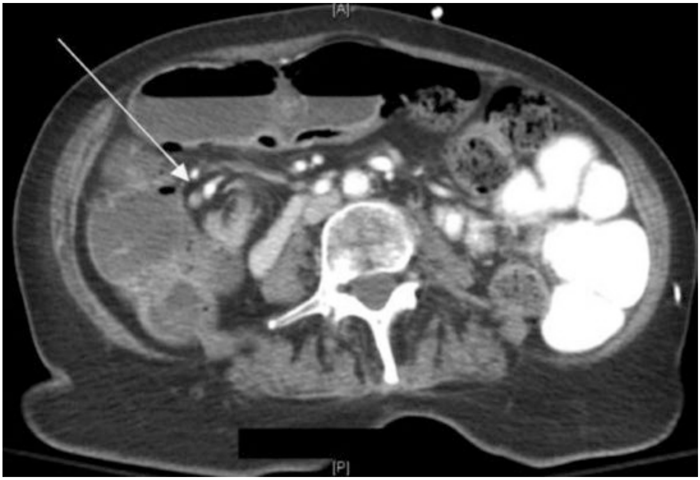

Figure 6.9 Cecal Volvulus. Image shows swirling of the mesenteric vessels

signifying mesenteric twisting are easily identifiable on a CT scan. An abdominal radiograph may demonstrate the classic "coffee bean" sign. The dilated loop of colon classically originates in the right lower quadrant and projects to the left upper quadrant in contrast to sigmoid volvulus. Barium enema may also be used and may show "bird's beak sign" at the level of obstruction [26].

Management

In contrast to sigmoid volvulus, cecal volvulus always requires surgical intervention. Endoscopic attempts at detorsion are not recommended given the distance from the rectum to the volvulized section of bowel. Additionally, lack of bowel preparation, poor visualization, and blind advancement of the endoscope significantly increase the risk of perforation. Once a cecal volvulus has been diagnosed, surgical intervention should not be delayed. The operation can be performed laparoscopically or through traditional laparotomy. The colon should be evaluated for viability, and a nonviable colon should be resected. It is important to note that even in cases where the colon appears viable, resection of the redundant segment is recommended to prevent recurrence. In the cases of frank necrosis, ligation of the blood supply to the affected segment prior to detorsion will prevent the issues associated with reperfusion. The definitive procedure for patients with cecal volvulus is a right hemicolectomy. The decision on whether or not to perform a primary anastomosis must be made at the time of operation depending on the patient's hemodynamic status, viability of the tissue, and overall clinical picture. End ileostomy may be performed if anastomosis is not an option. As an alternative approach, primary anastomosis after right hemicolectomy with protective ileostomy may be suitable. Two-stage procedures are also increasingly popular, allowing for resection and leaving the abdomen open with intestinal discontinuity in order to correct acidosis and optimize the patient before anastomosis and closure. Less invasive options such as cecopexy have been shown to have higher rates of recurrence and are rarely indicated unless the patient is unable to tolerate resection [27, 28].

Transverse Colon Volvulus

Volvulus of the transverse colon is exceedingly rare. Risk factors include neurological disorders such as cerebral palsy, chronic constipation, congenital megacolon, and dysmotility disorders such as Hirschsprung's disease. Presentation is similar to other types of volvulus and includes abdominal pain, nausea, and vomiting. Patients may demonstrate significant abdominal distention from a massively distended cecum proximal to the obstruction. Diagnosis is made primarily with a CT scan which can show a swirl sign indicating rotation about the transverse colon mesentery. Chilaiditi's sign (Fig. 6.10) has been described when the hepatic flexure of the colon is seen on imaging interposed between the liver and the right hemidiaphragm, though this can be a benign finding on routine imaging. Elevation of one or both hemidiaphragms

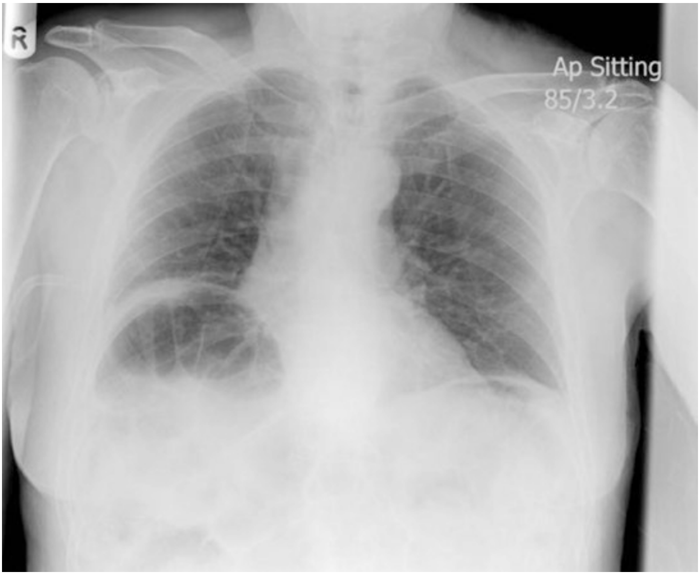

Figure 6.10 Chilaiditi's sign. Gaseous distended transverse colon seen under the right hemidiaphragm and above the liver. Also known as pseudopneumoperitoneum. (*Radiopaedia*)

may be seen on an abdominal plain film. Barium enema would likely show the bird's beak sign at the sight of obstruction in the transverse colon. Similar to the other types of volvulus, management involves resection of the affected bowel segment. Detorsion procedures with and without colopexy have also been described but are fraught with complications and have high rates of recurrence. Transverse colectomy with or without primary anastomosis is recommended (Fig. 6.11) [8, 28].

Ischemic Colitis

Intestinal ischemia occurs when the vascular supply to a segment of intestine, small or large, is compromised. In broad terms, colonic ischemia can be categorized into either

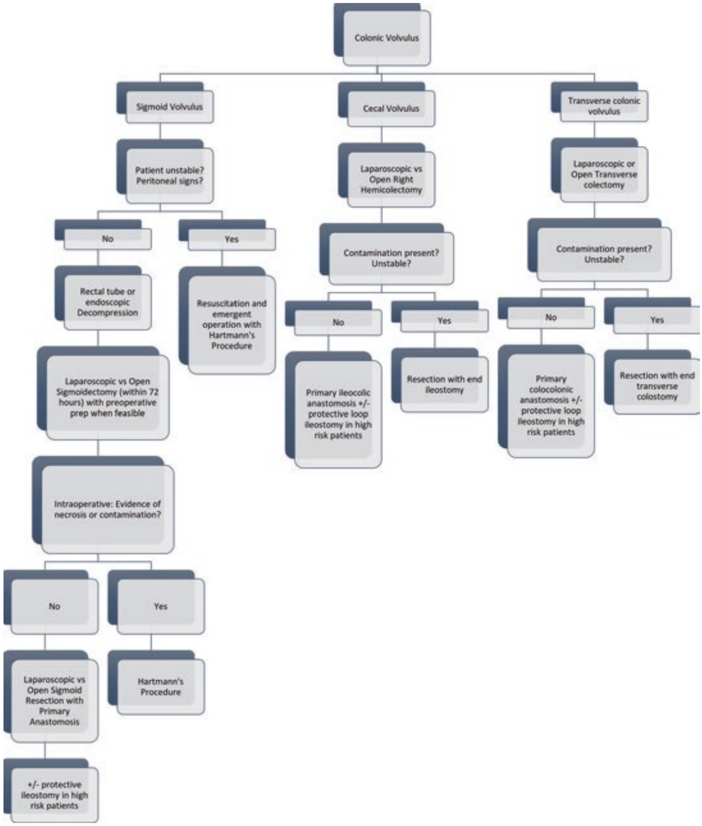

FIGURE 6.11 Treatment algorithm for the various types of colonic volvuli

decreased arterial inflow or occluded venous outflow. Impaired vascular inflow can lead to insufficient oxygen and nutrient delivery to the tissues, while venous outflow problems result in the accumulation of harmful toxins locally. Specifically, there are three main etiologies of intestinal ischemia: acute arterial occlusion (either embolic or thrombotic), occluding venous thrombosis, and nonocclusive mesenteric ischemia. All of the subtypes may result in transmural necrosis and perforation of the affected segment of bowel.

The incidence of colonic ischemia is estimated at 16 persons per hundred 100,000 and is increasing. Ischemic colitis primarily affects the elderly with mean age of presentation between 50 and 60 years of age and appears to have a predilection for females. Of all patients presenting with ischemic colitis, approximately 15% of them will present with gangrene of the colon. Prompt diagnosis and surgical intervention greatly reduce the associated mortality [29].

The blood supply to the colon is derived from the superior mesenteric artery (SMA) as well as the inferior mesenteric artery (IMA) (Fig. 6.12). The SMA supplies the cecum, ascending, and proximal two-thirds of the transverse colon, while the IMA supplies the distal one-third as well as the descending and sigmoid colon, and the superior portion of rectum. There are named collateral vessels such as the Arc of Riolan and the Marginal Artery of Drummond which serve to protect the colon from ischemia even after ligation of the IMA; however, there are also numerous

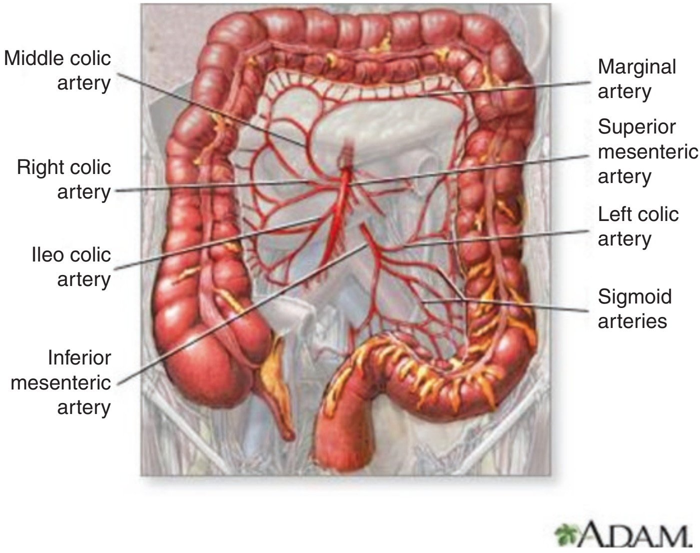

FIGURE 6.12 Colonic and vasculature. (*Courtesy of NIH*)

unnamed collaterals in the arcades supplying the colon. These arcades are particularly robust in the small bowel and to a lesser degree in the colon especially in the splenic flexure and the rectosigmoid junction. These areas, named Griffith's point and Sudeck's point, respectively, are watershed areas with fewer collaterals than the rest of the colon and are particularly susceptible to ischemia. Hypoperfusion of the colon can progress to transmural necrosis in as few as 8 hours [30].

Nonocclusive colonic (or mesenteric) ischemia (NOMI) is the most common etiology of ischemic colitis accounting for 95% of all cases. NOMI is less likely to progress to transmural necrosis due to its transient nature. NOMI is characterized by decreased flow to a colonic segment which can be secondary to hypovolemia, shock, congestive heart failure, vasopressors, cocaine abuse, arrhythmias, or dialysis. NOMI tends to affect the left colon, particularly at the splenic flexure and rectosigmoid watershed areas. Restoring circulating volumes, improving cardiac output, avoiding hypotension, and discontinuing vasoactive medications can all help to improve intestinal ischemia in the cases of NOMI [30, 31].

Acute embolic occlusion occurs when an embolus travels from a proximal source, usually the heart, and lodges in a distal branch of the SMA or IMA. Risk factors include recent MI, known mural thrombus, and arrhythmia. Previous research has implicated the heart as the source of emboli in >60% of all embolic colonic ischemia cases [32]. Emboli usually result in well-defined segmental ischemia and necrosis (Fig. 6.13), and do not necessarily involve the watershed areas as NOMI does. One important potential cause of emboli is iatrogenic following endovascular operations or instrumentation of the aorta. Conversely, in thrombotic mesenteric ischemia, thrombus slowly accumulates in the SMA and IMA over time. Worsening mesenteric atherosclerosis eventually manifests as acute thrombotic colonic ischemia when the degree of stenosis in the vessels becomes so great that collateral flow cannot be maintained. More than 75% of patients who develop acute thrombotic mesenteric

Figure 6.13 Segmental ischemic colitis of the right and proximal transverse colon

ischemia are currently or were formerly smokers, making tobacco abuse the single most significant risk factor for this condition [33].

Finally, ischemia may be caused by mesenteric vein thrombosis, but this only rarely affects the colon. This condition occurs more commonly in the small bowel, but occasionally affects the proximal colon as well. Venous thrombosis occurs as a result of fibrosis and calcific sclerosis which eventually leads to occlusion. The increased resistance of the veins leads to decreased arterial inflow and diversion away from the diseased segment. This can eventually lead to bowel wall edema and obstruction. When an entire arcade is involved, infarction may occur [34].

Clinical Presentation

Acute colonic ischemia typically presents with an acute onset of cramping abdominal pain. The pain is classically described as out of proportion to physical exam. Patients may report hematochezia in addition to abdominal pain, and, rarely, bloody stools will be the presenting symptom without abdominal pain. Bleeding is most often indicative of left-sided colonic ischemia, occurring in up to 83% of patients with left colon disease. The course of disease begins with frequent passage of blood-tinged stools and the urge to defecate. This is followed by a decrease in the frequency of bowel movements and intensity of abdominal pain. Abdominal distention occurs during this phase, and physical exam may reveal hypoactive bowel sounds. Only around 10–20% of patients will progress to the third phase: shock. During the final phase, transmural necrosis (see Fig. 6.13 above) and gangrene develop resulting in massive tissue damage, fluid loss, and electrolyte abnormalities. Patients will likely exhibit leukocytosis and acidosis although these are nonspecific. Patients who do reach the shock phase require urgent surgical intervention.

Patients with chronic ischemia typically present with a longer, indolent course and less severe symptoms. They classically present with "food fear" and may appear malnourished. They may experience early satiety and weight loss, and periumbilical abdominal pain shortly after ingestion of food which can last anywhere from 1 to 4 hours. They may still have bleeding per rectum and abdominal pain on presentation.

Diagnosis

Most laboratory findings in ischemic colitis are nonspecific and may not be present until late in the course of disease. Fever, hypotension, and tachycardia may be present. Leukocytosis, acidosis, hemoconcentration, and elevated creatinine may be present as well. An abdominal radiograph may be used as an initial study but is nonspecific. Colonic distention or pneumatosis intestinalis may be seen late in the course of disease. A CT scan with IV and PO contrast when possible adds additional information, but most of the findings are nonspecific as well. Colonic distention and pneumatosis may again be seen. Thumbprinting or the "double-halo" appearance may be visible and indicates an edematous colonic submucosa. Additionally, if ischemia has progressed to necrosis or perforation, CT will detect pneumatosis, portal venous gas, and free air when present. Conventional catheter-based angiography has largely gone by the wayside with the popularization of CT angiogram. CT angiogram may help to localize the area in question of which vascular intervention is to be attempted (Fig. 6.14). Lower endoscopy can be considered but should be used with caution as insufflation of a necrotic colon can

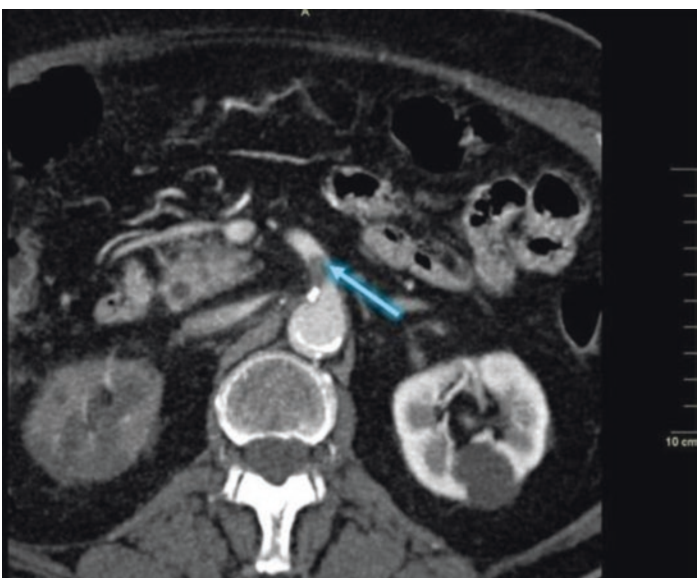

Figure 6.14 Embolus of the superior mesenteric artery. (*Courtesy of NIH*)

quickly lead to perforation and abdominal sepsis. For that reason, we recommend early endoscopy during the first 48 hours of presentation in a patient with suspected colonic ischemia. It is contraindicated in any patients with peritoneal signs on exam. Concerning findings on endoscopy include edematous and friable mucosa, hemorrhagic nodules with interspersed pale segments of mucosa, and frank perforation [33, 34].

Treatment

Treatment of colonic ischemia depends largely upon etiology as well as the clinical condition of the patient. Many cases of colonic ischemia will improve with supportive care alone. A risk stratification method has been previously described; the components are listed in Table 6.3a. Based on these factors, and imaging characteristics, patients are stratified into mild, moderate, or severe colonic ischemia in Table 6.3b.

Patients with only mild colonic ischemia and no risk factors may be treated with supportive care alone. Antibiotics can be started empirically but may be discontinued if endoscopy fails to show ulceration. Cardiac output should be optimized, and patients put on supplemental oxygen. Reversal of potentially inciting events such as cardiac arrhythmias should be pursued, and vasopressor medications should be stopped whenever clinically acceptable.

Moderate-risk (those with one to three risk factors) patients should undergo advanced imaging such as CT angiography to look for evidence of major vascular occlusion. If absent, endoscopy is the next step and supportive measures employed based on findings as in patients with mild disease. If there are signs of major vascular occlusion, patients will need systemic anticoagulation in addition to supportive measures and may need an endovascular intervention.

Signs of severe colonic ischemia should prompt urgent abdominal exploration and segmental colon resection. These signs include peritonitis on exam, hemodynamic

Table 6.3 (**a**, **b**) American Society of Gastroenterology risk stratification for poor outcomes in colonic ischemia. (**b**) shows how patients are classified as mild, moderate, or severe ischemic colitis. Differentiation of the severity guides treatment

(a) *American College of Gastroenterology risk stratification for poor outcome in acute colonic ischemia*

Male gender
Hypotension (Systolic blood pressure (SBP) <90 mmHg)
Tachycardia (Heart rate (HR) >100 bpm)
Abdominal pain (not associated with bleeding)
BUN >20 mg/dL
Hemoglobin <12 g/dL
Lactate dehydrogenase (LDH) >350 U/dL
Serum sodium <136 mEq/L
White blood cells >15,000/mm^3

(b) *Classification of the severity of colonic ischemia*

All patients are presenting with signs and symptoms consistent with ischemic colitis as well as either imaging findings or endoscopy findings consistent

+0 risk factors for poor outcome	+3 or fewer risk factors for poor outcome	>3 risk factors for poor outcome
Mild colonic ischemia	*Moderate colonic ischemia*	*Severe colonic ischemia*

instability, failure to progress with supportive measures alone, or visible necrosis on endoscopy. Bowel preparation is generally avoided in these patients as it has been shown to increase risk of perforation. Diagnostic laparoscopy is an appropriate first step to confirm the diagnosis [35, 36]. If a laparoscopic approach is preferred, pneumoperitoneum should be maintained at a pressure of 10 mmHg. This theoretically decreases the risk of compromising mesenteric blood flow. The specific operation performed depends on the distribution of compromised blood flow. Right-sided ischemic segments are resected and may undergo either primary anastomosis or ileostomy with transverse colon mucous fistula. In patients with left-sided ischemia, sigmoid resection or left hemicolectomy is the operation of choice. These are performed with a proximal end colostomy and distal mucous fistula, or a Hartmann's procedure. In the cases of pancolonic involvement, subtotal colectomy with end ileostomy is required. In patients with ongoing risk for ischemia, primary anastomosis should be avoided in the acute setting. Second-look operations are a good option in this patient population. Returning to the OR within 24–48 hours following the index operation allows for careful assessment of the remaining bowel. It is worth noting that patients who receive an ostomy should be considered for reversal when appropriate based on clinical condition and recovery. All patients should also undergo colonoscopy 3–6 months after initial presentation to rule out segmental ulceration, ongoing colitis, or stricture prior to ostomy reversal [30, 31, 33].

Fulminant *Clostridium difficile* Colitis

Introduction

Clostridium *difficile* is an obligate Gram-positive, anaerobic, spore-forming, toxin-producing bacillus. It is the most common infectious cause of health-care-associated diarrhea and a significant cause of morbidity and mortality among hospitalized patients. Most cases of *C. difficile* infection (CDI) in the USA are associated with inpatient or outpatient contact with a health-care setting. Its incidence and associated morbidity and mortality are steadily rising in the western communities [37, 38].

Clinical Manifestation

Clostridium difficile is transmitted via the fecal-oral route. Spores are dormant cells that are highly resistant to environmental conditions. In addition to antibiotic consumption, other risk factors associated with CDI include advanced age, immunosuppression, chronic kidney disease, diabetes, and malnutrition. However, in community-acquired CDI, proton pump inhibitor usage has been implicated in approximately one third of *C. difficile* infections in those without previous exposure to antibiotics. The clinical symptoms associated with CDI range from asymptomatic carrier to fulminant colitis and perforation. Three or more watery nonbloody stools per 24-hour period are the hallmark of symptomatic illness. Recent guidelines by the American College of Gastroenterology and the European Society of Clinical Microbiology and Infectious Diseases defined mild CDI as *C. difficile* infection with diarrhea as the only clinical manifestation. Moderate CDI was characterized as *C. difficile* with diarrhea in addition to other symptoms/signs that do not meet the definition of severe CDI. Severe CDI is *C. difficile* infection with any of the following: white cell count $\geq 15 \times 10^9$ /L, hypoalbuminemia <30 g/L, or abdominal tenderness. Complicated or fulminant CDI is defined as development of at least one of the following when *C.* difficile infection is already present: Admission to ICU, hypotension with or without the use of vasopressors, temperature ≥38.5 °C, ileus or substantial abdominal distension, changes in the mental status, white cell count $\geq 35 \times 10^9$ /L, serum lactate >2.2 mmol/L, or any evidence of end organ failure [9, 10]. Although these criteria have not been validated yet, they can be used to direct patient care in the cases of severe CDI since the specificity of this index increases with each criterion [39, 40].

Diagnosis

Accurate and quick diagnosis of CDI is challenging yet important in order to promptly implement therapeutic strategies to reduce morbidity and prevent mortality. The diagnosis of CDI depends on the presence of clinical symptoms in addition to laboratory tests to confirm the presence of toxin-producing *C. difficile* in the stool. Several unique assays are available, and these vary in cost, ease of performance, turnaround time, sensitivity, and specificity. The diagnostic tests for *C. difficile* can be classified into test for toxins, culture methods (toxigenic culture), and nucleic acid amplification (PCR). The test selection is vital to distinguish between patients with CDI and asymptomatic carriers. It is also vital to exclude other viral and bacterial causes of diarrhea particularly in high-risk populations. Endoscopic confirmation of CDI is indicated when there is a high clinic suspicion of CDI in the absence of laboratory confirmation or if there is a concern for other pathology. The finding of pseudomembranes on flexible sigmoidoscopy or colonoscopy is pathognomonic for *C. difficile* colitis (Fig. 6.15). The pseudomembranes appear as elevated yellowish white plaques measuring 2–12 mm in diameter in association with erythematous and edematous mucosa [41–45].

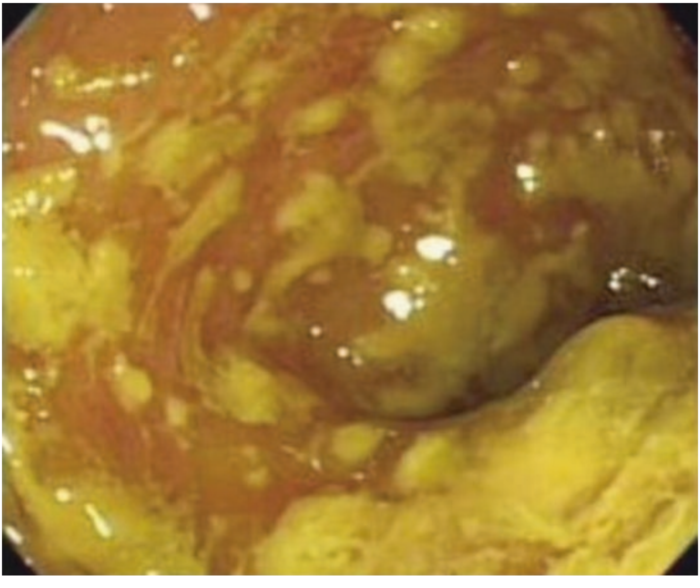

FIGURE 6.15 Colonoscopy demonstrating pseudomembranes indicative of *C. difficile* colitis. (*Courtesy of NIH*)

Radiographic imaging in CDI is neither sensitive nor specific for *C. difficile* colitis. X-ray findings include mucosal thickening, haustral thickening, and colonic distension. CT may show low-attenuation colonic mural thickening consistent with mucosal and submucosal edema, pancolitis, pericolonic fat stranding, pneumatosis coli, and free air/fluid in the cases of perforation [42, 45–47].

Management

The management of CDI can be divided into nonoperative and operative treatments. Treatment requires a multidisciplinary approach that involves the entire health-care team. Due to the high mortality associated with fulminant CDI that can reach up to 80%, operative intervention has effectively been employed with a resultant improvement in outcomes. The optimal timing of surgical consultation and intervention are not clearly defined, but it is prudent to involve surgery early in the clinical course. Clear indications for operative interventions are generalized peritonitis, deteriorating clinical status, and colonic perforation. Other indications for surgery include failure of nonoperative therapy and toxic megacolon [41, 48–52].

Based on the disease process that usually involves the entire colon and the difficulty in macroscopically assessing the colon intra-operatively, the standard surgical intervention is total abdominal colectomy with end ileostomy. The procedure is usually performed via midline laparotomy owing to the urgent nature of the intervention and the clinical status of the patient. However, when the circumstances are favorable and the patient's clinical condition permits, laparoscopic total colectomy can be performed safely in experienced hands. In either case, we recommend leaving a rectal tube to drain the rectal stump and prevent blowout. Moreover, the tube can be used to deliver antibiotics directly to the stump [53–55].

Another surgical approach that has gained favor in recent years is to perform a loop ileostomy, intra-operative colonic lavage with polyethylene glycol, and antegrade vancomycin flushes through the ileostomy into the colon. The aim of this approach is to minimize operative trauma in the acutely ill patient and preserve the colon while achieving similar rates of cure. The procedure can be performed via an open or laparoscopic approach in an expeditious manner. The ideal timing and patient population to utilize this technique is currently under investigation. To date, it has typically been used in moderate to severe cases and has shown promising results. We recommend against its use in the hemodynamically unstable patient at this time given the significant consequences of failure and lack of data in this population [47, 48, 54–56].

Malignant Colonic Emergencies

Introduction

Colorectal cancer is the second leading cause of cancer death for men and women in the USA with 100,000 new cases and 50,000 deaths annually. Despite screening programs implemented in North America, up to 40% of the population in the USA do not participate. As a result, 33% of patients with colorectal cancer present acutely with complications and 15% present with bowel obstruction or perforation. In the initial stages of the disease, patients may present with symptoms secondary to local and invasive malignancy. In the later stages, patients will present with metabolic and infectious complications due to the malignancy. Risk factors which increase patient likelihood to present with an acute emergency due to colorectal cancer are advanced stage and age. Patients may present with a variety of ailments including obstruction and perforation. This overview will cover the presentation, diagnosis, and management of bowel obstruction and perforation secondary to colonic malignancy [57].

Malignant Bowel Obstruction

Large bowel obstructions are defined as an intestinal obstruction distal to the ileocecal valve. Large bowel obstructions can be mechanical or functional and the etiology can be extrinsic or intrinsic to the colon. Malignancy is the most common cause of large bowel obstruction. Other causes include diverticulitis, volvulus, hernia, and extrinsic compression. Malignant bowel obstructions can be partial or complete. A closed loop bowel obstruction can occur in the scenario of multiple tumor deposits or competent ileocecal valve. This confers a higher risk for ischemia and perforation. Functional bowel obstructions result in ileus and can be due to narcotic pain medication or neurovascular invasion of malignant tissue compromising colonic motility in the setting of malignancy. In mechanical bowel obstruction, the large volume of fluid and gases in the colon cause intestinal dilatation proximal to the point of obstruction. The dilation and increased intraluminal pressure can progress to cause venous congestion, edema, and increased permeability of the bowel wall. If there is no relief of the obstruction and intraluminal pressure rises even further, perforation of the bowel can occur due to necrosis. Moreover, with intestinal dilation and resulting diaphragmatic elevation, respiratory and cardiac function may be impaired. Therefore, patients presenting with bowel obstruction secondary to malignancy require surgical consultation and early intervention [58–60].

Colonic Perforation

Colonic perforation secondary to malignancy is a known complication of colorectal cancer and often presents with severe abdominal pain. The site of perforation may be at the primary site of the tumor or at the cecum due to distension from distal obstruction. Perforations are classified as free or contained. A free peroration occurs when intestinal contents/air are released into the abdominal cavity. Contained perforations occur when adjacent organs/tissue wall off the site of perforation. There are multiple mechanisms thought to cause colonic perforation. Primary tumors or metastatic deposits can create colonic obstruction which eventually leads to perforation as described above. Certain types of colonic cancers such as leukemia and lymphoma may invade the colonic wall and cause perforation [60]. Tumor lysis syndrome can cause loss of gastrointestinal wall integrity. Immunocompromised patients are at risk of neutropenic enterocolitis and gastrointestinal infections which cause wall damage, necrosis, and perforation. Patients with perforation can present in extremis and require urgent surgical consultation and intervention [61–63].

Presentation: Signs and Symptoms

The clinical presentation of patients with colorectal emergencies depends on the primary cause. Colorectal emergencies may present with lower gastrointestinal bleeding, obstruction, or perforation. The clinical course of the patient also depends on their age, co-morbidities, onset of symptoms, and nutritional status. Patients presenting with obstruction will experience abdominal pain, distension, constipation, and vomiting. Tenesmus can be seen in 10% of patients with a colon malignancy. As the obstruction progresses, patients may become severely dehydrated. The minority of patients present with frank perforation of the colon and will exhibit signs of fever, septic shock, and peritonitis. Fecal peritonitis is seen more commonly with left-sided lesions compared to abscess formation and contained perforation seen in right-sided lesions.

Diagnosis

The diagnosis of a patient with an emergent condition related to a colonic malignancy involves several investigations. A thorough history and physical may indicate the presence of a colonic malignancy. However, the diagnosis likely also involves laboratory and radiographic studies. A complete blood count may reveal leukocytosis suggestive of colonic ischemia or perforation. A high hemoglobin may indicate hemoconcentration and severe dehydration secondary to obstruction. Electrolyte abnormalities and increasing creatinine may reflect dehydration suggestive of intestinal obstruction or sepsis.

Radiographic studies are important in the diagnosis of acute colonic emergencies. Findings on an abdominal series which suggest obstruction include bowel distension and air fluid levels. An abdominal radiograph has a 30% sensitivity and 88% specificity for colonic perforation. Free air on abdominal series indicates intestinal perforation until proven otherwise. However, an abdominal X-ray may not be able to differentiate mechanical versus adynamic obstruction of the colon. A CT scan is likely to provide further information and delineate both the cause and severity of the disease. A CT scan has a 95% sensitivity and 97% specificity for the diagnosis of colonic obstruction and perforation if it is performed with oral and intravenous contrast. CT scan findings suggestive of perforation or ischemia include free air, pneumatosis intestinalis, portal venous air, extraluminal air or abscess formation at site of perforation, or leakage of oral contrast. A CT scan can also reveal the location and anatomic detail of the malignancy and the extent of metastatic disease (Figs. 6.16 and 6.17) [59, 61, 62].

Once the diagnosis of colonic malignancy associated emergency is made, one can consider additional investigations to reveal the extent and stage of the disease. If the patient stabilizes and is not in extremis, a CT scan of the thorax abdomen and pelvis should be performed to delineate the extent of disease and whether there is a presence of metastatic disease. If emergent resection is required, tumor markers should be drawn before resection, as this can guide later patient treatment. The clinical status of the patient and the extent of the disease determine the management strategies and type of intervention performed to resolve the acute emergency condition [61].

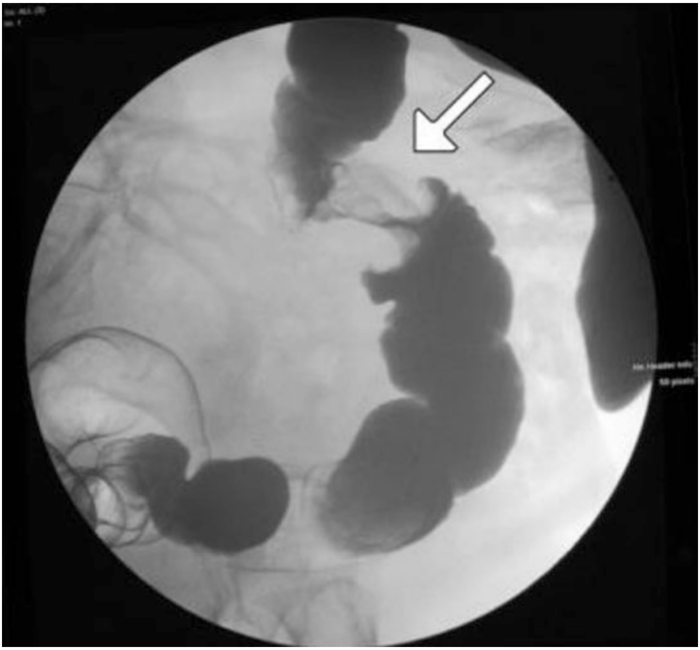

FIGURE 6.16 Fluoroscopic image showing characteristic "apple-core" appearance of the colon. (*Courtesy of NIH*)

Management and Treatment

Resuscitation

The initial management strategy for an emergency of the colon involving a malignancy is resuscitation. Colonic obstruction causes volume depletion and electrolyte abnormalities which require aggressive volume repletion and correction of electrolytes. Volume resuscitation is performed with crystalloid. The systolic blood pressure target for resuscitation should be above 100 mmHg. Urinary catheter placement should be considered to follow urinary output and guide the resuscitation strategy. Broad-spectrum antibiotics covering anaerobes and Gram-negative organisms should be used in colonic ischemia and

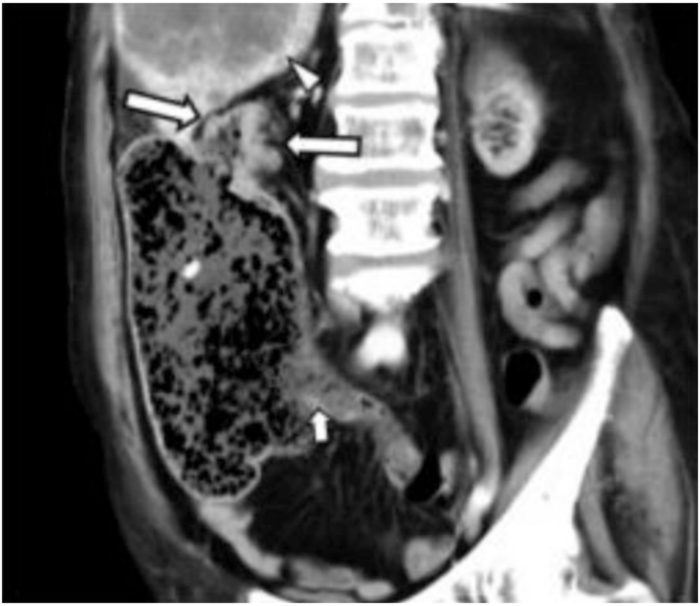

FIGURE 6.17 CT scan demonstrating distal ascending colon mass with significant dilation and fecalization of proximal colon. Note that the terminal ileum is collapsed and nondilated indicating the presence of a competent ileocecal valve resulting in a closed loop obstruction

perforation. A short course (3–5 days) of perioperative antibiotics may be indicated if contamination is significant and/or ongoing. Given the likelihood of ileus or obstruction, a nasogastric tube should be placed. Therefore, initial management of colonic obstruction and perforation includes fluid resuscitation, electrolyte correction, intestinal decompression, and initiation of broad-spectrum antibiotics [64].

Surgical Strategies and Techniques

The surgical options in the management of patient with colonic malignancy emergencies depend on the location of the tumor, extent of disease, and patient clinical status at presentation. The general principle of surgical management of colonic malignancies includes the removal of the offending lesion, if possible. In the absence of metastatic disease, the surgeon should consider curative resection for the individual patient. In the presence of metastatic disease, resection of the colonic malignancy should be considered to resolve patient symptoms and improve quality of life. If possible, biopsy of metastatic lesions should be done at the time of operation to accurately stage the patient. In the case of colonic perforation, primary anastomosis should not be performed in hemodynamically unstable patients, poor bowel quality, and significant feculent contamination. The location of the tumor and extent of disease dictate the surgical options which can be performed in the emergency setting [65].

1. *Right colon*
   Colorectal cancer occurs on the right side of the colon in 25% of patients. Of these patients, 25% will require emergency right colectomy which involves the resection of portion of terminal ileum, cecum, ascending colon, and possibly portions of the transverse colon. The treatment for right colonic malignancies is well established with little debate among experts. A right colectomy with primary anastomosis is the procedure of choice for obstructing or perforated colonic malignancy. In cases where anastomosis should be avoided, a right colectomy with ileostomy and mucous fistula can be performed. However, ileostomies are associated with several complications, especially when performed emergently. The mortality rate of a right colectomy and primary anastomosis in obstructed and perforated right colonic malignancies is 5–6%. The rate of wound complications in these procedures is approximately 16%. Both operative mortality and wound infection complications were higher in emergency cases compared with elective cases.
2. *Left colon*
   The operative management of an acutely obstructed left colon secondary to malignancy is a matter of debate among

experts in the field. The most important aspect of surgical treatment of left colon malignancy is whether the cancer should be resected with primary anastomosis or resected with a staged procedure. Most studies demonstrate that segmental colonic resection with primary anastomosis can be performed safely in colonic obstruction or perforation secondary to malignancy. A contraindication to segmental resection and primary anastomosis may include frank feculent peritonitis, hemodynamic instability, malnutrition, or poor bowel quality. In these cases, a staged procedure or primary anastomosis with protective ileostomy should be considered.

There are several options to consider for staged procedures involving the left colon. There are two- and three-stage procedures. The two-stage procedure involves segmental resection of the colonic malignancy with formation of left-sided colostomy and reanastomosis after a few months. In the three-stage procedure, the patient undergoes colostomy to divert the fecal stream, followed by elective segmental resection, and finally reversal of the colostomy. This procedure is associated with the longest hospital stay, costs, and complications but may be indicated when resection is unsafe at the index operation. Staged procedures should be considered for contraindications to primary anastomosis as well as for elderly patients with multiple comorbidities, immunocompromised patients, and in advanced disease. Along with subjecting the patient to multiple operations, only 50% of patients undergoing staged procedures have their intestinal continuity restored. The staged procedure is associated with 10% mortality and 40% morbidity.

In left colonic malignancies, the preferred surgical option is segmental resection and primary anastomosis with/without a protective ileostomy depending on the clinical circumstances.

3. *Subtotal colectomy*

Subtotal colectomy for colorectal cancers has been described in several studies. This surgical option has several advantages and is reserved for certain patient clinical scenarios. In patients presenting in the acute setting, 6.8% have synchronous lesions at the time of presentation. In this scenario, the advantage of a subtotal colectomy is definitive resection of existing cancers and prevention of future malignancy as well. Subtotal colectomy carries a mortality risk of approximately 8%. The disadvantage of a subtotal colectomy is the increase in frequency of bowel movements and postoperative diarrhea. This decreases if more than 10 cm of the colon is left above the peritoneal reflection. In a patient with a left-sided lesion that has caused a right-sided perforation, this is the operation of choice.

4. *Laparoscopic surgical techniques*
   Laparoscopy in the emergency setting provides short- and long-term benefits. Laparoscopic techniques are associated with decreased hospital length of stay and improved pain control, while preserving oncologic outcomes. In contrast, laparoscopy has been associated with increased operative times and conversion rates in the acute setting. Overall, studies have demonstrated the use of laparoscopy in the emergency setting is safe in the hands of experienced laparoscopic surgeons. Minimally invasive techniques should be employed whenever possible, but conversion to an open procedure should occur early rather than later if the operation is not progressing [66].
5. *Colonic stenting*
   Colonic stenting is an intervention described for both benign and malignant colonic obstructions. With the advent of self-expanding metal stents, an alternative to surgery became available to relieve colonic obstruction. Stenting is an effective and nonoperative approach which can achieve colonic decompression.
   There are two major indications for colonic stenting. The first is palliation of advanced disease and the second is decompression of colonic obstruction as a bridge to elective surgery. The latter allows the patient to be optimized prior to more definitive surgery. Other benefits include full

bowel evaluation to rule out synchronous lesions and enabling patients to receive systemic neoadjuvant chemotherapy. Studies have shown that colonic stenting with subsequent resection receives a primary anastomosis 84% of the time compared with 40% without stenting. Other potential benefits of colonic stents are a decrease in wound infection and anastomotic leaks.

Colonic stenting has a reasonable complication profile but can be associated with perforation, migration, and occlusion. A randomized control trial assigning patients with left-sided colorectal cancers terminated early due to increased number of adverse events in the stent group. Stent-related perforation and migration occur at a rate of 5% and 9%, respectively. Perforations are more likely to occur in sigmoid colon due to angulation and redundancy. Other risk factors include previous radiation therapy and chemotherapy, multifocal obstructions, extrinsic compression, and strictures longer than 10 cm. Stent migration usually occurs within the first 5–7 days after placement. Risk factors for migration include small caliber stents and non-obstructing lesions.

Despite the potential for complications, experienced endoscopists achieve a 90% success rate with colonic stenting. Success is defined as colonic decompression and oral feeding. Therefore, colonic stenting can be an attractive option for certain high-risk surgical candidates [61, 64–66].

Prognosis

Colorectal cancer presenting as a surgical emergency is associated with a poorer prognosis compared to the elective setting. The postoperative mortality rate is higher in patients presenting emergently compared to elective patients. Patients who underwent surgery in emergency setting had an 11% 30-day mortality rate compared to 5% in the elective patients.

Moreover, the 2-year survival is lower for emergency patients at 42% compared to 65% in the elective setting. In addition, the cure rate for emergency surgery is lower at 60% compared to 70% in the elective patient. Studies have shown that patients who present in the emergency setting with colorectal cancer have more advanced tumors and poorer clinical status and are older in age compared to their elective counterparts. Therefore, patients presenting in the emergency setting with colonic malignancy have a poorer prognosis both in the short and long term compared to patients undergoing elective surgery [64–67].

Ogilvie's Syndrome

Clinical Presentation

Ogilvie's syndrome, also known as acute colonic pseudo-obstruction, was initially described in 1948 by Sir William Ogilvie in two patients with retroperitoneal cancers invading the celiac plexus who developed progressive colonic dilation. Ogilvie attributed this clinical entity to "sympathetic deprivation" of the bowel [68]. To this day, the pathophysiology of Ogilvie's is poorly understood; however, it is generally thought to be due to an impairment of autonomic regulation of the colon, with sympathetic tone exceeding parasympathetic input [69, 70]. It most commonly occurs in hospitalized, severely ill, or institutionalized patients. A 1986 review of 400 cases found Ogilvie's to predominate in men (60%), at an average age of 60. Nearly all of these patients (94.5%) had an associated condition, either medical or surgical. The most common inciting event was nonoperative trauma, followed by infection and cardiac disease [71]. Ogilvie's generally presents with abdominal pain, nausea, vomiting, and increasing abdominal distension over a period of 3–7 days, though it can happen as quickly as 24 hours [72].

Diagnosis

In addition to Ogilvie's syndrome, important considerations in the differential diagnosis of acute colon distension include mechanical obstruction and toxic megacolon secondary to *C. difficile* colitis. A diagnosis of Ogilvie's is typically made based upon clinical presentation, the exclusion of other etiologies, and plain films showing dilation throughout the entirety of the colon. If there is concern for mechanical obstruction, a water-soluble enema or computed tomography scan with PO contrast can be used [72]. Others suggest starting with a CT scan and using serial radiographs to monitor the size of the cecum and assess for risk of perforation.

Treatment

The goal of the treatment of Ogilvie's is to decompress the colon to avoid perforation. This is initially done conservatively, with correction of any electrolyte derangements, cessation of any possible inciting medications such as anticholinergics or narcotics, and *nil* per os. The patient is then followed with daily labs, serial abdominal exams, and radiographic imaging. A rectal tube may be placed, but nasogastric decompression is generally not necessary. If 24–48 hours of conservative treatment fails, the next step is medical management with a one-time dose of neostigmine (1–2 mg intravenous, given slowly over 5 minutes), which works quickly (within 20 minutes) and has been found to be successful 89% of the time [73]. A side effect of neostigmine is significant bradycardia; thus its administration should be followed by at least 30 minutes of cardiac monitoring, with atropine available [74]. Further interventions include colonoscopy, with or without placement of a decompressive tube in the right or transverse colon, though this carries a risk of iatrogenic perforation [75]. Surgical management of Ogilvie's in the nonperforated patient consists of percutaneous cecostomy placement. For patients with perforated or ischemic bowel, segmental resection or subtotal colectomy may be necessary, depending on the viability of the bowel.

Complications

Ogilvie's results in perforation approximately 3% of the time [76]. Risk factors for perforation include dilation of greater than 12 cm and a duration of symptoms greater than 2–3 days [77]. Ogilvie's does carry a significant risk of mortality: up to 15% in patients with nonperforated bowel and 36–44% in patients with compromised bowel [71]. As such, early diagnosis and intervention are critical to good patient outcomes.

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Chapter 7
Acute Gastrointestinal Bleeding

Luis R. Taveras, Holly B. Weis, Joshua J. Weis, and Sara A. Hennessy

Introduction

Acute gastrointestinal bleeding (GIB) is a common problem with mortality rates that approach 3–5% [1]. GIB is categorized based on the anatomical site, with upper GIB (UGIB) localized proximal to the ligament of Treitz, while lower GIB (LGIB) is distal to the ligament of Treitz. The latter represents 20% of all cases [2], most of them from diverticulosis [3]. Known risk factors include increased age, male sex, smoking, disability, use of oral anticoagulants and nonsteroidal anti-inflammatory drugs (NSAIDs) [4], and hepatic and renal disease [5].

An algorithm for GIB workup and management from presentation to therapy is suggested in Fig. 7.1.

Initial Management

Patients will typically present to the hospital with hematemesis (vomiting blood or coffee ground emesis), hematochezia (bright red blood from the rectum), or melena (black, tarry

L. R. Taveras · H. B. Weis · J. J. Weis · S. A. Hennessy (✉)
Department of Surgery, University of Texas Southwestern Medical Center, Dallas, TX, USA
e-mail: sara.hennessy@utsouthwestern.edu

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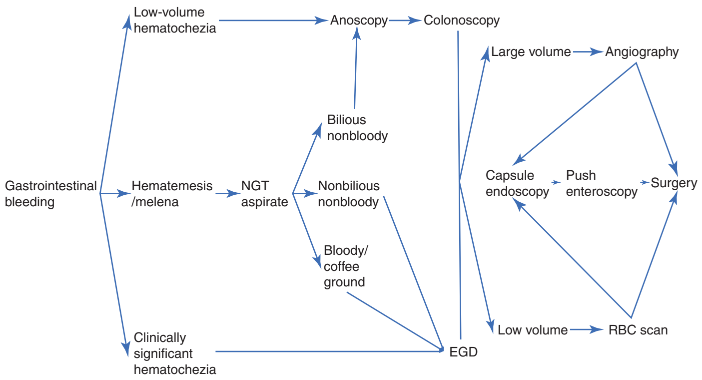

FIGURE 7.1 Algorithm – workup and management of gastrointestinal bleeding. Abbreviations: *EGD* esophagogastroduodenoscopy, *NGT* nasogastric tube, *RBC* red blood cell

stools). Hematochezia is usually a sign of LGIB, while hematemesis or melena favors a UGIB source. In severe cases, brisk UGIB patients can present with hematochezia and hypotension. Patients should be triaged to the intensive care unit, regular floor, or home based on evidence of active bleeding, hemodynamic instability, and presentation.

Initial assessment includes performing a rapid history and physical exam to help determine the severity of the bleed and any potential sources. Pertinent past medical history includes the history of GIB, cirrhosis or portal hypertension with varices, NSAID use, tobacco use, peptic ulcer disease, *Helicobacter pylori*, abdominal aortic aneurysm repair, and previous gastric surgery (marginal ulcer). Patients on anticoagulation or antiplatelet therapy can have promoted bleeding. Symptom assessment (dizziness, confusion, palpations) can indicate significant blood loss and other signs of hypovolemia that include tachycardia, hypotension, tachypnea, and altered mental status. Physical examination can guide resuscitation and could indicate a potential source of the GIB. Epigastric pain may indicate an UGIB and peritonitis may indicate perforation. A thorough history and physical exam will allow for a guided plan for resuscitation, the initiation of medical therapy, and diagnostic evaluation and treatment.

All patients should receive general support with supplemental oxygen and initial resuscitation with crystalloid solution via two large-bore intravenous lines. Rapid assessment of respiratory status and mental status is important to determine the need for endotracheal intubation. Elective endotracheal intubation has been associated with poor outcomes and cardiopulmonary complications [6]. However, patients who are at high risk for aspiration should be intubated. In the presence of hypovolemic shock, individualized management is recommended, according to rate of blood loss and expected future losses. Intravascular volume replacement can be monitored with clinical parameters including hemodynamic response, mental status fluctuations, urine output, and laboratory markers of perfusion (lactate, acid-base status). In patients with ongoing resuscitation, a urinary catheter should be placed to assess the efficacy of resuscitation.

A baseline laboratory workup establishes basic physiologic parameters and aids in assessing precipitating risk factors but might not accurately indicate the volume of the hemorrhage. GIB patients lose whole blood; therefore, the initial hemoglobin might not start declining until 24 hours later when intravascular blood starts to be diluted by the influx of extravascular fluid and resuscitation. A blood type and cross-match, complete blood count, basic metabolic panel, liver function tests, and coagulation profiles are relevant tests to obtain.

A hemoglobin threshold of 7 g/dL for the transfusion of packed red blood cells is safe, improves mortality, and decreases adverse events when compared to more liberal strategies; however, individualized care is recommended with early use in those with limited cardiopulmonary function, those prone to recurrence, or those in whom continued bleeding is expected (e.g., patients with large-volume bleeding, cirrhotic patients) [7–9]. In patients with variceal bleeding, a hemoglobin level goal of 7–9 g/dL improves survival, while over-transfusing to a hemoglobin of >10 g/dL can worsen bleeding [7, 10, 11]. Coagulopathy (international normalized ratio (INR) >1.5) in non-cirrhotic patients should be addressed with fresh frozen plasma and thrombocytopenia (50,000 x 10^9/L) with platelet transfusion. In cirrhotic patients, INR is not a good indicator of coagulopathy; therefore, INR correction should be secondary to the reduction of portal pressure and interventional hemostasis. The decision to transfuse fresh frozen plasma should be weighed against the risks of increasing portal hypertension.

Approximately 75% of GIB will stop without any intervention other than volume resuscitation. Hence, it is important to determine which patients are at a higher risk of needing an increased volume of blood product transfusion, re-bleeding, and mortality. Several prognostic systems are used to identify these high-risk patients who benefit from in-hospital care [12]. The Rockall Risk Scoring System (Tables 7.1 and 7.2), which is based on age, presence of shock, comorbidity, diagnosis, and endoscopic stigmata of recent bleeding, estimates re-bleeding rates and mortality for UGIB patients [13]. This tool requires endoscopic evaluation for complete assessment, while the Glasgow-Blatchford Bleeding Score is based only on clinical and laboratory markers (Table 7.3). The Glasgow-Blatchford score is based on blood urea nitrogen, hemoglobin, systolic blood pressure, pulse, and presence of melena, syncope, hepatic disease, and cardiac failure. Patients with a Rockall score of ≤2 are considered low risk and can receive early discharge, while those with Glasgow-Blatchford scores of ≤1 can be safely managed as outpatients [8, 14, 15]. It is important to know that patients who present with hematemesis or bloody nasogastric tube aspirate are at particularly high risk for re-bleeding within the first 72 hours [16], which might impact the decision of early hospital discharge. While capsule endoscopy has been used in the ER to identify high-risk patients with UGIB, it is currently not a standard of care [17]. Finally, AIMS65 is another scoring system that is based on albumin (<3.0 g/dL), INR (>1.5), altered mental status (Glasgow Coma Scale <14), systolic blood pres-

Table 7.1 Rockall Risk Scoring System

	Score			
	0	**1**	**2**	**3**
Age	<60 years	60–79 years	>80 years	
Shock	No shock	Tachycardia	Hypotension	
Comorbidity	No major comorbidity		Congestive heart failure, ischemic heart disease, any major comorbidity	Renal failure, liver failure, widespread malignancy
Diagnosis	Mallory-Weiss tear	All other diagnoses	Malignancy	
Stigmata of recent bleeding	None or dark spot only		Fresh blood in GI tract, adherent clot, visible or spurting vessel	

TABLE 7.2 Predicted outcomes based on Rockall Risk Scoring System

Score	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8+**
Re-bleed (%)	4.9	3.4	5.3	11.2	14.1	24.1	32.9	43.8	41.8
Death (%)	0	0	0.2	2.9	5.3	10.8	17.3	27.0	41.1

TABLE 7.3 Glasgow-Blatchford Score

	Score	
BUN (mg/dL)	≥18.2 to <22.4	2
	>22.4 to <28	3
	>28 to <70	4
	>70	6
Hgb ♂ (g/dL)	>12 to <13	1
	≥10 to <12	3
	<10	6
Hgb ♀ (g/dL)	≥10 to <12	1
	>10	6
Systolic blood pressure (mm Hg)	≥100 to <109	1
	>90 to <99	2
	>90	3
Other markers	HR ≥100 bpm	1
	Presentation with melena	1
	Presentation with syncope	2
	Hepatic disease	2
	Heart failure	2

Abbreviations: BUN blood urea nitrogen, *Hgb* hemoglobin, *HR* heart rate, *bpm* beats per minute sure (<90 mm Hg), and age (>65) and has been shown to be a good indicator of inpatient mortality in UGIB [18]. In most cases, the preference of a scoring system will be influenced by resources available within a specific practice or hospital system. Our group has liberal access to endoscopy, and consequently we value the prognostic features of the endoscopic evaluation in the Rockall Risk Scoring System.

The identification of the source of bleeding should follow resuscitation or at least occur as a parallel process. Gastric lavage can detect or confirm the presence of hemorrhage and coffee-ground aspirate, which are specific signs of a UGIB source [15, 19]. Instillation of 250 mL of saline solution via a nasogastric tube is used, which also clears the stomach for subsequent endoscopy. However, gastric lavage may not be positive if the lesion was no longer bleeding or the lesion was distal to the pylorus. Gastric lavage of bilious fluid could suggest that there is no active UGIB. Clinical studies looking at the use of gastric lavage have not demonstrated any improvement in clinical outcomes, including mortality, length of stay, or transfusion requirement [20]. Most recommend its use to clear out food particles, fresh blood, or clots to facilitate endoscopy.

Patients presenting with melena or hematemesis and positive gastric aspirate are suspected to have an UGIB and should undergo early endoscopy (within 24 hours of presentation). For patients presenting with hematochezia associated with hemodynamic instability, an esophagogastroduodenoscopy (EGD) should be performed prior to colonoscopy because even in the absence of clinical signs of UGIB, an upper gastrointestinal source is suspected [21, 22].

An EGD includes a complete evaluation of the esophagus, stomach, and proximal duodenum. A view in retroflexion of the gastroesophageal junction is necessary. Upper endoscopy can identify the site of bleeding in up to 98% of UGIB cases [23]. Early EGD results in a decreased transfusion requirement, shorter length of stay, and a reduction in the need for surgery [24–27]. However, high-risk patients with hemodynamic instability and those with large-volume hematemesis benefit from urgent endoscopy after resuscitation has been established and the patient is stable [26, 27]. At the same time, the data is not clear if this improves survival. Findings during upper endoscopy can be used to predict re-bleeding with rates ranging from less than 5% in patients with a clean ulcer base (Fig. 7.2) to 55% in those with active bleeding [28].

Bright red blood per rectum is a sign of LGIB, and anoscopy should be performed first to exclude anorectal causes. The evaluation of LGIB proceeds with colonoscopy. The accuracy improves in continued, but not massive, bleeding. Mechanical bowel preparation is recommended prior to colonoscopy [22], but adequate visualization of the mucosa is possible even in an unprepped bowel [29]. The rationale to obviate bowel preparation is to decrease the time to colonoscopy; however, urgent colonoscopy has not shown better outcomes [21]. A colonoscopy performed within 24 hours of presentation appears to be safe in most cases. Identification of the bleeding source requires visualization of active bleeding or a clot fixed to the lumen. It is important to remember

Figure 7.2 Gastric ulcer with a clean base

that blood can move antegrade or retrograde in the intestines; therefore, the presence of loose clots of blood is not indicative of a bleeding source.

Selective arteriography is an option in patients with contraindications to endoscopy or in which endoscopy has been unsuccessful. It can detect bleeding rates greater than 0.5 mL/min. A major advantage of this modality is the therapeutic potential with selective embolization of the bleeding vessel; however, ischemic complications can occur. In slower bleedings, a technetium-tagged red blood cell scintigraphy (Fig. 7.3) might be more suitable. It can detect bleeding rates as low as 0.04–0.1 mL/min [30, 31] and thus can be especially useful in detecting lesions with slow or intermittent bleeding. In young patients with LGIB where a Meckel diverticulum is suspected, this radionuclide scanning can be diagnostic.

Computed tomography has a limited role in the workup of gastrointestinal hemorrhage since it lacks sensitivity for the evaluation of mucosal GIB although it can be useful to narrow the areas of interest in an angiographic evaluation [32]. The presence of intraluminal contrast extravasation represents a sign of active bleeding and it is observed in rates of at least 0.3 mL/min [1].

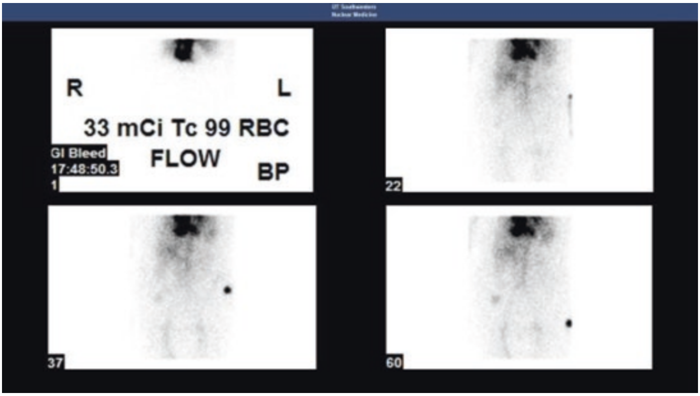

FIGURE 7.3 Tagged red blood cell scintigraphy

Upper Gastrointestinal Bleeding

Annually, 1 out of 1000 individuals will be hospitalized for an acute UGIB, which is sixfold higher than that for an acute LGIB [33]. The incidence of a UGIB increases with age and is higher in men than in women [34]. The causes of UGIB can be grouped in four major categories: ulcerative and erosive, vascular, mass, and traumatic lesions (Table 7.4). However, in 10–15% of patients, the source of bleeding cannot be determined either due to a lesion that is difficult to identify, clot burden, or the cessation of bleeding at the time of endoscopy.

Etiology

Peptic ulcer disease is the most common cause of acute UGIB and accounts for approximately 32% of cases [31]. Risk factors for having a bleeding gastroduodenal ulcer are *H. pylori*

Table 7.4 Causes of gastrointestinal bleeding

Causes of upper gastrointestinal bleeding	**Causes of lower gastrointestinal bleeding**
Neoplasms	NSAID-induced ulcers
Stress gastritis	Meckel diverticulum
Esophagitis	Neoplasms
Severe or erosive gastritis/ duodenitis	Inflammatory bowel disease
Portal hypertensive gastropathy	Colitis (radiation, infectious, ischemic)
Angiodysplasia	Benign anorectal diseases
Gastroduodenal ulcers	Diverticula
Mallory-Weiss syndrome	Postpolypectomy bleeding
Variceal bleeding	Arteriovenous malformation
Hemobilia	Aortoenteric fistula

Abbreviations: *NSAID* nonsteroidal anti-inflammatory drugs infection, the use of NSAIDs, and stress-induced or elevated gastric acid production. A previously common source of UGIB was stress-induced gastritis. It is the consequence of inadequate gastric mucosal blood flow in critically ill patients. Patients with stress-induced bleeding gastritis or ulcers have a higher mortality than patients who present to the hospital with a primary UGIB [35]. The lesions are multiple and superficial, typically in the fundus or the body, but can affect the entire gastric mucosa and appear within 12–14 hours of illness onset or injury. Stress ulcer prophylaxis is recommended for critically ill patients at increased risk for such ulcers. These include patients with at least one major risk factor (intrinsic coagulopathy, mechanical ventilation longer than 48 hours, history of GI ulcer bleeding within the last year, and traumatic brain or spinal cord injury or burn injury) or two or more minor risk factors (sepsis, ICU stay >1 week, occult GI bleed, or immunosuppression therapy) [36].

Complications of portal hypertension leading to esophageal, gastric, and ectopic varices or portal hypertensive gastropathy are found in 20% of UGIB cases. Variceal bleeding is associated with a higher risk of recurrence, larger transfusion requirements, longer hospital length of stay, and increased mortality compared to other types of UGIB [37, 38]. Approximately 32% of the cases of acute UGIB are caused by peptic ulcer disease [39]. However, 30% of patients with portal hypertension and varices have an unrelated upper GI bleed.

Vascular lesions (angiodysplasia, Dieulafoy's lesion, gastric antral vascular ectasia), traumatic or iatrogenic lesions (Mallory-Weiss syndrome, Cameron lesions, aortoenteric fistulas, or postsurgical bleeding), and upper gastrointestinal tumors account for the majority of the remaining causes of upper GI bleeds.

Medical Therapy

Proton pump inhibitors (PPIs) should be started after the diagnosis of UGIB has been made [27]. The use of acid suppressive therapy with H_2 receptor antagonists has not been shown to decrease the rate of active ulcer bleeding. A bolus of intravenous PPI followed by high-dose, twice daily or continuous PPI infusion results in adequate pH control and reduces rates of re-bleeding when combined with endoscopic therapy [9, 26, 40]. An intermittent intravenous bolus of PPI has been shown to be as effective as a continuous infusion of PPI [41].

Prokinetic agents (erythromycin and metoclopramide) can be used to improve gastric visualization at the time of endoscopy by increasing the emptying of the stomach of food or clots. The use of erythromycin in particular has been shown to improve gastric visualization in multiple randomized controlled trials [42–44]. It has also been shown to decrease the need for repeat endoscopy [9, 45].

Patients should be tested for *H. pylori*, and any patient with evidence of active infection should be treated accordingly with triple therapy [8, 46]. Active infection can be diagnosed with a gastric mucosal biopsy on endoscopy, urea breath test, or stool antigen. Testing for *H. pylori* does not need to be immediate and can be performed once bleeding has resolved. Eradication of the bacteria decreases the rates of bleeding recurrence.

Vasoactive medications and antibiotics are recommended in patients with cirrhosis and acute variceal bleeding. Cirrhotic patients with UGIB have an increased risk of presentation with a concomitant infection or to develop an infection while hospitalized, which increases the risk of mortality. If patients are able to tolerate oral medication, norfloxacin is the preferred choice; otherwise, ciprofloxacin or ceftriaxone IV for a maximum of 7 days should be administered [8, 27, 47]. In this population, vasoactive medications such as octreotide and vasopressin are used to decrease portal pressure, which is associated with an increase in survival and a decrease in transfusion requirements [48]. The former appears to be more effective and have less cardiac impact [49]. Rescue strategies include the use of Sengstaken-Blakemore or Minnesota tubes for direct tamponade. They are infrequently used and are reserved for massively bleeding patients as a temporizing measure to allow time for resuscitation and further workup before definite treatment. The use of these tubes should be limited to 24 hours [10].

Antiplatelet and anticoagulation treatments should be withheld if possible in patients with a UGIB. The decision on whether to use these medications should balance the risk of thrombosis and subsequent complications with the severity and risk of the UGIB. These medications can be resumed once hemostasis has been achieved and the risks of re-bleeding versus thrombosis are determined, which are unique to each patient. If the patient was taking aspirin for the prevention of cardiovascular events prior to admission, it can be safely restarted after hemostasis has been achieved as the risk of re-bleeding is low [9, 27].

A gastroenterological consultation is necessary for any patient with an acute UGIB to allow evaluation and possible endoscopic treatment. Consultation with surgery or interventional radiology may be necessary depending on the cause of bleeding, severity of the bleeding, stability of the patient, and previous surgical history.

Endoscopic Treatment

Upper endoscopy, preferably within 24 hours, for patients with suspected UGIB is highly sensitive and specific for diagnosis and it also allows for therapeutic interventions to achieve hemostasis. During the upper endoscopy, the Forrest classification (Table 7.5) aids in predicting re-bleeding rates and can also guide management. Forrest category I and IIa lesions, which are indicative of active bleeding and visible vessels, respectively, are amenable to endoscopic treatment. If the upper endoscopy is negative and the patient has hematochezia or melena, a colonoscopy should be performed. Other endoscopic interventions if the upper endoscopy is negative can include small bowel enteroscopy or intraoperative enteroscopy.

Table 7.5 Forrest classification of endoscopic appearance of ulcers

		Re-bleeding risk (%) [78]
Ia	Spurting vessels	90–100
Ib	Nonspurting, active bleeding	>55 [28]
IIa	Visible vessel	40–50
IIb	Nonbleeding ulcer with overlying clot	20–30
IIc	Ulcer with hematin-covered base	5–10
III	Clean ulcer base	1–2

The selection of a specific endoscopic technique is based on the characteristics of the patient, endoscopic experience, and resources available at the hospital. Endoscopic therapies include injection therapy, thermal coagulation, hemostatic clips, fibrin sealant, argon plasma coagulation (APC), or combination therapies. Treatment of a UGIB with electrocoagulation includes the use of monopolar or bipolar devices as well as a laser or APC. Monopolar probes can heat tissues by applying high-frequency electrical current, causing coagulation necrosis of the vessel and the surrounding tissues. Its main disadvantages include the adherence of tissue, clot dislodgement, and the unpredictability of the depth of the thermal injury. Bipolar technology creates tissue coagulation that is tangential to the probe using three equidistant bipolar microelectrodes. For bleeding peptic ulcer disease, electrocoagulation is most commonly used for deeper lesions and APC is used for superficial lesions. Hemoclips can be difficult to apply to an ulcer bed unless there is a visible vessel. The injection of vasoconstrictors, such as epinephrine (1:10,000), can be used to achieve hemostasis. However, epinephrine injection alone is associated with a high risk of re-bleeding and should be done in conjunction with clips or thermal coagulation [9, 27, 46, 50, 51].

Sclerosant agents can be used to provoke thrombosis of the bleeding vessels and fibrosis of the surrounding tissues. Sodium morrhuate and ethonolamine oleate are commonly used for bleeding esophageal varices, while ethanol and polidocanol have been used for nonvariceal bleeding. For gastric varices, there is a suggestion that endoscopic sclerotherapy may be more effective than banding in preventing bleeding recurrence [52].

In acute esophageal variceal bleeding, 90–95% of the patients achieve hemostasis with endoscopic sclerotherapy, clipping, and banding. Patients with gastric varices are less successfully managed with endoscopic techniques. In those who fail, emergency portal decompression is indicated. This can be achieved with transjugular intrahepatic portosystemic shunting, which is successful in 95% of cases, or with surgery [27, 47]. Self-expanding esophageal stents have been used as an alternative, which show a better adverse event profile as a rescue therapy [53].

Repeat endoscopy after endoscopic management without signs of persistence of symptoms is not recommended; however, there might be a limited benefit in high-risk patients or those treated with thermal coagulation [26]. In cases of rebleeding, a second attempt at endoscopic treatment is successful in 75% of patients [54].

Angiographic Approach

Arterial embolization in acute UGIB is a reasonable alternative in patients who are at high risk for surgical complications. Transarterial embolization should be attempted in those who have failed endoscopic therapy [26]. Endoscopic marking with a metallic clip at the time of endoscopy increases the accuracy of embolization and diminishes the risk of misplacement of the coil. The upper GI tract is thought to be a safe area for embolization due to widespread arterial collateralization. However, patients with a prior surgical history in this anatomical area and the use of specific embolic agents can increase the risk of post-embolization necrosis. Duodenal stenosis can present as a chronic manifestation of ischemic complications [55]. Late embolization, higher transfusion needs, and previous failed surgical ulcer ligation are risk factors for angiographic failure [56].

Surgical Management

The decision for operative intervention is based on the magnitude of the hemorrhage, hemodynamic instability, the physiologic reserve of the patient to tolerate continued bleeding, and the probability of re-bleeding or failed endoscopic or angiograph embolization. Most surgeons consider ongoing blood loss requiring greater than six transfusions an indication for surgical intervention. Some of the factors associated with a high risk of re-bleeding are shock during initial endoscopy, an ulcer larger than 2 cm in diameter, and Forrest type I and II lesions [54]. Nevertheless, even in those who re-bleed, repeat endoscopic intervention can be successful in up to two-thirds of cases [57]. As such, the use of a transfusion threshold as an indication for surgery has fallen out of favor.

In bleeding peptic ulcer disease, management will depend on the location of the ulcer. When possible, the ulcer can be excised and the gastrostomy closed. If the bleeding ulcer is located near the gastroesophageal junction, hemostasis can be achieved by oversewing the ulcer [58]. In cases where the ulcer is left in place, a follow-up EGD should be performed in 4–8 weeks to confirm resolution and obtain tissue to rule out a neoplasia. Bleeding duodenal ulcers are treated with pyloromyotomy, oversewing of the bleeding vessel, and a pyloroplasty closure. The remainder of the duodenum and the gastric antrum should be inspected. The indications for truncal vagotomy have evolved with the use of antacid-secreting medications that have become common. Unsuccessful *H. pylori* treatment, previous ulcer complications, NSAID dependence or abuse, and *H. pylori*-negative chronic ulcers are common indications.

Bleeding secondary to Mallory-Weiss tears is usually self-limited. Nonoperative management is the recommended approach, using endoscopic coagulation, banding, or injection therapy [59]. Oversewing via a transgastric approach is sufficient in those who require operative management.

Lower Gastrointestinal Bleeding

LGIB presents in elderly patients, with mean age at presentation of 63–77 years. In 80–90% of the cases, bleeding will be self-limited. The most common presentation is with hematochezia, but specific details in the history can help reveal a bleeding source or comorbidities that may influence management. For example, the presence of abdominal pain may suggest associated inflammation such as ischemic or infectious colitis, while a change in bowel habits might suggest malignancy. In general, the causes of lower GI bleeding (Table 7.4) can be grouped into vascular, anatomic, inflammatory, neoplastic, and iatrogenic categories. Patients with acute LGIB typically present with normocytic anemia; microcytic or iron deficiency anemia suggests a chronic LGIB. While the most common causes of LGIB affect the colon, bleeding from the small bowel is possible and should be ruled out after a negative EGD and colonoscopies.

Patients presenting with significant hematochezia or hemodynamic instability commonly have bleeding from an upper GI source. However, a UGIB is unlikely if blood clots are present in the stool. Other associated findings include orthostatic hypotension and an elevated BUN-to-creatinine or urea-to-creatinine ratio. In this situation, an upper endoscopy is performed first.

Any LGIB warrants evaluation, particularly if there is visible rectal bleeding. Patients should be appropriately assessed and triaged as mentioned early in this chapter, and a gastroenterology consult should be obtained. Patients at high risk for complications from an LGIB who warrant urgent evaluation include those with hemodynamic instability, persistent bleeding, significant comorbidities, advanced age, LGIB during an unrelated hospitalization, a prior history of LGIB, prolonged prothrombin time, a non-tender abdomen, anemia, an elevated BUN, and an abnormal WBC.

Etiology

Diverticular disease and colitis are the most common causes of LGIB. Although colonic diverticulosis is common, less than 5% of patients develop bleeding. On presentation, these patients will describe a sudden lower abdominal pain and urgency followed by a maroon-colored stool. Though the hemorrhage from diverticulosis can be massive, three-quarters of patients have a spontaneous resolution of the bleeding [60].

Other less frequent causes of LGIB include angiodysplasia and ischemic colitis. Angiodysplasias are arteriovenous malformations of intestinal submucosal veins and mucosal capillaries associated with aging. In most affected patients, bleeding will stop spontaneously. Ischemic colitis commonly manifests with bleeding as a consequence of mucosal necrosis that can deteriorate to full-thickness perforation.

The diagnostic ability of colonoscopy is limited due to the interference of bowel content and blood itself; nonetheless, the colonoscopic evaluation of patients with LGIB is recommended. Anoscopic evaluation should be performed early in cases of scant hematochezia, as most distal colonic and anorectal bleeding presents in this fashion [61]. In patients who have not reached colorectal cancer screening age and present with asymptomatic rectal bleeding, colonic evaluation should be performed by endoscopy or imaging [62]. The timing can be determined on a case-by-case basis.

Postpolypectomy hemorrhage is a common complication after polyp removal. Hemorrhage risk is associated with the polyp size and the use of anticoagulants [63]. The hemorrhage can present immediately or in a delayed fashion. Most can be addressed with endoscopy.

Endoscopic Therapy

Colonoscopy should be performed within 24 hours in patients with continued bleeding or with high risk factors after adequate bowel preparation. Bowel preparation, even if only for several hours, has been shown to increase the success rate of endoscopic therapy and increases the rate of cecal intubation. There has been no evidence that bowel preparation increases or reactivates bleeding.

The injection of sclerosants and coagulation during colonoscopy can be used for the most common causes of bleeding [64, 65]. In diverticular disease, identifying a specific bleeding diverticulum can be difficult, as diverticula can be numerous, bleeding might be intermittent, and more than one diverticulum can bleed simultaneously. A submucosal injection of epinephrine in four quadrants can control active bleeding. Adherent clots can be addressed even in the absence of bleeding with a combination of epinephrine injection and electrocoagulation.

For angiodysplasia, electrosurgical energy is the preferred endoscopic modality. However, the selection of a specific approach is based on the anatomy and location of the lesion, the preference of the endoscopist, and the available resources. APC is the most common and successful method to treat bleeding vascular lesions such as angiodysplasia [66].

Bleeding polyps can be removed via colonoscopy if they exhibit no malignant characteristics. Malignancy can be temporized with surgical energy or clipping, but formal resection should be planned. Bleeding after removal of a polyp can be controlled with endoscopic techniques in most cases. Immediate bleeding can be addressed with direct pressure, epinephrine injection, electrocoagulation, and mechanical hemostasis with bands, clips, or loops. In patients with a delayed presentation, expectant management is an option if bleeding appears to have stopped. Urgent colonoscopy is reserved for those with frequent bloody stools or hemodynamic instability [67].

Angiographic Approach

An appropriate arteriography can isolate the site of bleeding, showing intraluminal extravasation of contrast. The ability to diagnose and treat bleeding makes it a suitable next step after negative colonoscopy in stable patients or after failed endoscopic therapy. Bleeding vessels can be embolized, but ischemic complications occur in approximately 5% of patients [68]; therefore, a surgical approach might be preferred in selected patients. The decision should be based on multidisciplinary discussions of patient presentation and comorbidities and resources and include interventional radiology, surgery, and gastroenterology teams.

Surgical Management

Indications for surgery include the unsuccessful localization of the bleeding source with continued or recurrent hemorrhage, hemodynamic instability despite resuscitation, a transfusion requirement greater than six units of packed red blood cells in 24 hours, findings that require surgical intervention, and peritonitis.

It is of utmost importance to determine the site of bleeding before surgical intervention [22] as mortality, recurrence, and adverse events increase significantly with "blind" resection. After appropriate localization of the bleeding, the most common surgical approach is segmental colectomy. The decision of a primary anastomosis depends on localization of the bleeding, hemodynamic stability, and patient comorbidities. An end ileostomy or colostomy can ease further exploration if bleeding recurs.

Some special situations include recurrent diverticular bleed. After a second bleeding episode, the risk for subsequent events approaches 50%; therefore, elective colectomy of the affected segment is recommended. Similarly, inflammatory bowel disease can manifest with massive bleeding that requires emergent surgery. In this situation, the recommended procedure is a total colectomy with or without proctectomy.

In cases with continued extreme colonic hemorrhage, subtotal colectomy represents an option but only after comprehensive efforts to localize the site of bleeding. An intraoperative small bowel endoscopy should be performed to exclude a small bowel source. In selected cases in which comorbidities limit the ability of the patient to undergo surgery, a high-dose barium enema has been used with promising results to achieve hemostasis in diverticular bleed [69, 70].

GI Bleeding of Obscure Source

In patients with an elusive source of bleeding, endoscopy of the small bowel can be useful and should be considered after negative bidirectional scopes. Approximately 1% of GIB originates from the small intestine. Common causes include Meckel's diverticula and arteriovenous malformations. The use of capsule endoscopy and push enteroscopy has allowed the diagnosis of bleeding originating from the small bowel, cases which in the past used to be labeled as obscure. In the presence of hemodynamic instability, emergent angiography is recommended [71]; in otherwise stable patients, the following modalities can be considered.

Capsule endoscopy is a minimally invasive option and is recommended as a first-line modality for the evaluation of the small bowel [71]. In this GIB population, capsule endoscopy has proven to be useful, with comparable results to angiography and less invasiveness [72]. Enteroscopy can be achieved with a pediatric colonoscope or a long-video enteroscope. A pediatric colonoscopy allows visualization of the proximal 60 cm of GI tract, while a long enteroscope can reach distances close to 100 cm [73, 74].

Double-balloon enteroscopy uses a long enteroscope and an overtube. Sequential advancement is made using balloons at the end of both enteroscope and overtube, creating traction on the mucosa. Longer distances can be covered with this technique [75]. The use of capsule endoscopy can increase the diagnostic yield in these patients [76]. If the patient has been taken to the operating room, an intraoperative enteroscopy can be achieved by mouth, per ostomy, per rectum, or via an enterotomy. The small bowel is manually advanced over the endoscope, and inspection is performed while the endoscope is withdrawn [77].

Conclusions

GIB is divided into two main groups: upper and lower GI bleeding. Upper GIB can be further divided into variceal and non-variceal bleeding. Initial management of upper GIBs includes assessment of the severity of the bleeding, PPI, lavage, and early (<24 hours) endoscopic localization of the bleeding. Recurrent or uncontrolled bleeding is next treated by repeat endoscopy and interventional angiography when available. Surgery is reserved for those who failed endoscopy and angiography interventions. Variceal bleeding also benefits from antibiotics, vasoactive medications, and the use of transjugular intrahepatic portosystemic shunting.

Lower GIB also requires assessment of the severity of the bleeding and early endoscopic localization. Failure to control the bleeding by endoscopic means is then treated by angiography when available leaving surgery as the last means of hemorrhage control. Fortunately, most GIBs resolve without surgical intervention, but this also means that the only ones who have to undergo surgery are the hemodynamically unstable patients or possibly the sickest patients. As such, a multidisciplinary approach with good communication is paramount for patient success.

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Chapter 8
Emergency Hernia Surgery: What to Know When Evaluating a Patient with an Incarcerated Hernia

Brent D. Matthews and Caroline E. Reinke

Introduction

Management of patients with ventral and incisional hernias can range from straightforward suture repair to complex abdominal wall reconstruction. For elective repairs, surgeons have the opportunity to optimize patients, consult colleagues and recruit assistance as needed, and investigate adjunct options to optimize outcomes. However, for nonelective hernia repair, management decisions often need to be made quickly with limited information in complex patients who often have many comorbidities. In this chapter, we will review management of incarcerated hernias and discuss best practices.

B. D. Matthews · C. E. Reinke (✉)
Department of Surgery, Carolinas Medical Center, Atrium Health, Charlotte, NC, USA
e-mail: brent.matthews@carolinashealthcare.org

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Hernia formation may be related to embryologic development or precipitated by prior abdominal surgeries. Incisional hernias occur at an estimated rate of 3–29% and are thought to be influenced most significantly by patient characteristics, technical factors, and postoperative wound infections [1]. Hernias that are initially reducible remain at risk of becoming incarcerated, in which the hernia content cannot be reduced on physical exam. While reducible hernias initially managed nonoperatively have an almost 40% chance of eventually undergoing operative repair, only 5% require emergency operation [2]. The presenting symptoms of acute incarceration include pain, nausea, and vomiting. When patients present with an incarcerated hernia, emergency surgical consultation should be sought [3]. Approximately 10–25% of all ventral hernia repairs are performed emergently [3, 4]. The rate of emergency ventral hernia repair in the United States is on the rise, particularly in patients >65 years of age [5].

Management of an Incarcerated Hernia That Can Be Reduced

If the hernia can be reduced by the surgeon, a decision must be made about the timing of operative repair. While delaying intervention until the patient can be optimized is appealing, this must be weighed against the risks of repeat incarceration. In our practice, low-risk patients are often offered a surgical repair at admission or electively within the next week. Hernia repair at the time of diagnosis has been shown to be cost-effective for patients with a low risk of operative mortality and recurrence [2]. Both race and socioeconomic status have been associated with increased risk of presenting with an acute hernia complication requiring emergency surgery [6, 7]. For patients with barriers to outpatient follow-up, hernia repair at the time of presentation may have an impact on these disparities. High-risk patients are encouraged to take steps to decrease their perioperative risks around the time of surgery and follow-up in our outpatient clinic, but if they have repeated episodes of incarceration, they are typically considered for operative repair in a more expedited fashion, with an acceptance of increased risk due to their comorbidities in an attempt to avoid strangulation secondary to incarceration.

Management of an Incarcerated Hernia That Cannot Be Reduced

Incarcerated hernias may contain bowel, omentum, or both. Nonreducible hernias that contain bowel are considered surgical emergencies due to the risk of strangulation and bowel ischemia. While incarcerated hernias that contain only fat can be quite painful, and often require repair and admission for patient comfort, they are not life-threatening. In obese patients, almost one-third of incisional hernias were missed by physical exam [8]. Body habitus can make it difficult to appreciate hernias and confirm that they have been reduced. On rare occasions, we have utilized repeat imaging to assess for successful reduction of an incarcerated hernia.

Risk Factors for Needing Emergency Repair

It is difficult to predict the risk of any hernia eventually needing an emergency repair. Many of the patient characteristics associated with requiring emergency hernia repair are similar to those associated with poor outcomes after hernia repair including older age, morbid obesity, ascites, and a greater number of comorbidities (especially congestive heart failure) [4, 9–11, 7]. Other factors that have been associated with an increased risk of emergency repair include female gender, minority race, and payer status [7, 9, 4, 10].

While surgical tradition has held that hernias with wider defects are less likely to incarcerate, recent work has identified additional hernia characteristics associated with higher risk of requiring emergency repair based on computed tomography (CT) findings. These include hernias with 2–7 cm defects, hernias with smaller angles between the hernia sac and the abdominal wall, and taller hernias [11, 4]. The hernia angle was defined as the most acute angle between the facial plane and the hernia sac on transverse cuts at the level of the width measurement. An Odds of Emergent Repair (OER) score has been proposed which incorporates both patient characteristics and CT findings:

$$\begin{aligned} \text{OER} = {} & 2*\left(\text{BMI} \geq 40\text{kg}/\text{m}^2\right) + 7*\left(\text{Ascites}\right) \\ & +2*\left(\text{CT angle } 30^{"} - 70^{"}\right) + 5*\left(\text{CT angle} < 30^{"}\right) \\ & +0.4*\left(\text{CT sac Height,cm}\right) \end{aligned}$$

An OER score of <5 indicates low odds of needing emergent repair, while a score of >10 indicates 2.5 greater odds of having an emergent repair [11]. This score maybe used to inform decisions about timing of operative intervention for low- and moderate-risk patients for whom further preoperative optimization is also an acceptable course of option. While the OER score may be applied to patients to estimate the preoperative odds of emergent repair, this assessment is not meant to replace a patient-specific discussion of the likelihood of surgical complications. The OER is meant to assist in preoperative surgical risk assessment for patients in which elective surgery is already being seriously considered, meaning low or moderate risk, but for which further preoperative optimization is also an acceptable course of action.

Early elective repair should be considered for low- to moderate-risk patients with hernia features concerning for incarceration, strangulation, or obstruction of bowel, such as those with greater hernia sac height or small hernia angle. Factors that are associated with bowel strangulation in the acute setting include CT findings of reduced wall enhancement and lab findings of elevated lactate, CPK, and d-dimer [3].

Once the need for emergency surgery is identified, patients must be prepared for surgery. For patients with an incarcerated hernia resulting in a bowel obstruction, nasogastric tube decompression can decompress the stomach and small intestine. This can facilitate the surgical approach, especially laparoscopy where working space can be limited. Nasogastric decompression also reduces the risk of aspiration. Communication with the anesthesia team is important to inform them that the patient may benefit from rapid sequence induction (RSI) to reduce the risk of aspiration. If a laparoscopic approach is being considered, a brief period of preoperative resuscitation can help mitigate the decreased venous return associated with pneumoperitoneum.

Laparoscopic Versus Open Approach

Both laparoscopic and open approaches are reasonable for most incarcerated hernias. There is a lack of consensus regarding the best approach for incarcerated ventral and incisional hernias [12]. Surgical technique will be influenced by surgeon expertise, patient habitus, previous surgical history of the patient, and hernia characteristics. For elective ventral hernia repairs, the only randomized control trial comparing surgical approach found that the laparoscopic technique had lower rates of short-term postoperative complications, 50% decreased odds overall complications at 8 weeks, and decreased pain at 1-year follow-up. While the laparoscopic cohort had higher rates of more severe complications, particularly bowel injury, this was not statistically significant [13].

The World Society of Emergency Surgery (WSES) outlined guidelines in 2017 for emergency repair of complicated abdominal wall hernias. They recommended that the laparoscopic approach to repair of incarcerated hernias may be performed in cases without bowel strangulation or the need for bowel resection (grade 2C) [3]. Laparoscopy creates traction between the bowel and the abdominal wall with the assistance of the pneumoperitoneum, allowing for visualization of planes for dissection and identification of occult hernias [1, 14]. In open cases traction between the bowel and the abdominal wall is achieved with manual retraction and can be physically demanding. Three case series have reported their experience with the laparoscopic approach to incarcerated hernias and concluded that it is feasible and safe (Table 8.1) [15–17]. A randomized control trial is unlikely to be practical in incarcerated hernia, and ultimately the decision to pursue an open or laparoscopic approach will be at the discretion of the operating surgeon. Surgeons who are comfortable with laparoscopy should feel confident that the safety of this approach in the incarcerated hernia is supported by current literature. Technical guidelines for laparoscopy in the reoperative abdomen are reviewed in the "Previous Abdominal Surgery" chapter of the SAGES manual on Basic Laparoscopy and Endoscopy [18].

Use of Mesh

The use of mesh and what type of mesh to use remains an area of controversy in hernia repair, and even more so in incarcerated hernias. These decisions are influenced by wound class (as defined by the Centers for Disease Control [19], Table 8.2), mesh characteristics, and mesh placement. While permanent synthetic meshes offer decreased rate of long-term hernia formation, they are much more difficult to manage if they become infected. Mesh can be placed in many locations—onlay (above the fascia), retrorectus (above the posterior sheath but below the rectus muscle), preperitoneal, or intra-peritoneal—and this affects their susceptibility to infection and management options.

The WSES Guidelines recommend the use of synthetic mesh in cases without bowel strangulation or concurrent intestinal resection (Grade 1A) and state that synthetic mesh can also be used in cases with bowel strangulation or concurrent intestinal resection (Grade 1A) [3], but do not provide additional detail about the location of mesh placement or subtypes of permanent synthetic mesh.

Table 8.1 Reports of laparoscopic repair of incarcerated ventral hernias

Study	N	Repair	Hernia content	OR	LOS	Complications	Exclusion criteria
Olmi et al. [17]	48	All laparoscopic, with new-gen composite meshes (Parietex™)	66% bowel, 34% omentum	Mean OR time 62 min; 4% rate of enterotomies	Mean 4 days (range 3–6 days)	0% mesh infection, 0% hernia recurrence, 16% seroma rate (median f/u 38 months)	Need for bowel resection, loss of domain
Shah et al. [32]	112	103 laparoscopic, 7 primary repair, and 2 converted to open	62% bowel, 38% omentum	Mean OR time 96 min; 4% rate of enterotomies	Mean 2.8 days (range 1–6.5 days)	20.5% complication rate, 1% mesh infection, 3% hernia recurrence, 14% seroma rate (mean f/u 48 months)	Gross abdominal distention due to massively inflated bowel, peritonitis, general condition that contraindicated laparoscopy
Landau and Kyzer [15]	25	All laparoscopic with Gore-Tex Dual Mesh (ePTFE)	84% bowel, 72% with omentum	Mean OR time 63 minutes; 4% rate of enterotomies, 4% bleeding	Median LOS 3.2 days (range 2–7 days)	0% mesh infection, 0% hernia recurrence, 12% seroma rate (median f/u 23 months)	<4 prior laparotomies, <10 cm hernia, surgeon's judgment, conversion to open due to bowel necrosis

TABLE 8.2 Surgical wound classification by the Centers for Disease Control [19]

Wound Class	
Class I Clean	Uninfected operative wounds in which no inflammation is encountered and the respiratory, alimentary, genital, or uninfected urinary tracts are not entered. In addition, clean wounds are primarily closed, and if necessary, drained with closed drainage. Operative incisional wounds that follow nonpenetrating (blunt) trauma should be included in this category if they meet the criteria
Class II Clean-contaminated	Operative wounds in which the respiratory, alimentary, genital or urinary tract is entered under controlled conditions and without unusual contamination. Specifically, operations involving the biliary tract, appendix, vagina, and oropharynx are included in this category, provided no evidence of infection or major break in technique is encountered
Class III Contaminated	Open, fresh, accidental wounds. Also, operations with major breaks in sterile technique or gross spillage from the gastrointestinal tract. Incision in which acute, nonpurulent inflammation is encountered
Class IV Dirty or infected	Old traumatic wounds with retained devitalized tissues and wounds that involve existing clinical infection or perforated viscera

Placement of a synthetic mesh in the onlay position for patients undergoing open repair of incarcerated and strangulated hernias has been reported to result in decreased recurrent rates without an increase in the rate of surgical site infection (SSI) when compared to primary repair [20]. Synthetic mesh has also been reported to be safe in elective hernia repair when placed in the retrorectus position for patients with wound classes II and III [21]. In a retrospective analysis of 121 patients undergoing emergency hernia repair, synthetic mesh was felt to be safe in patients who did not undergo bowel resection, had a duration of symptoms <24 hours, and had clear fluid in the hernia sac [22]. This study was limited by a lack of detail regarding mesh location and fixation. Another study found that in patients with bowel resection, prosthetic mesh placement (primarily in the intraperitoneal position) was associated with increased rates of SSI [23]. Looking at the use of biologic mesh, the RICH Study concluded that the use of a non-cross-linked, porcine, acellular dermal matrix was successful for single-stage reconstruction in contaminated ventral incisional hernias [24]. The COBRA study, a prospective multicenter observational trial, reported that biosynthetic mesh was a safe alternative to biologic and permanent synthetic meshes in wound class II and III cases. However, they noted a higher risk of recurrence when these meshes were placed in the intra-peritoneal position and in cases with a postoperative SSI [25]. There is not a clear best practice regarding the use type of mesh in contaminated cases and additional studies are needed.

Incarcerated Inguinal Hernia

While the above concepts are generally applicable to incarcerated inguinal hernias, there is additional specific literature regarding this scenario. The WSES 2017 Guideline recommendations reviewed above are unaltered in regard to inguinal and femoral hernias [3]. A systematic review in 2009 concluded that a laparoscopic approach to the incarcerated or strangulated inguinal hernia was safe, with a 2% rate of conversion to open and a 5% rate of requiring a bowel resection [26]. For the open approach to an incarcerated inguinal hernia, most studies have reported it is safe to place synthetic mesh and that the need for bowel resection is not a contraindication to placement of synthetic mesh [27–29]. The placement of mesh in either the preperitoneal space (laparoscopic repairs) or external to the abdominal cavity (open repairs) makes permanent synthetic mesh placement safe except in cases of gross contamination of either of those spaces, which is rare.

Complications

The complications associated with emergency hernia repair are the same as those of an elective hernia repair: enterotomy, seroma, surgical site infection, and recurrence. The rate of death after emergency hernia repair is fortunately quite low [5]. Patients should be counseled preoperatively on these risks and we inform patients that the emergency nature of their operation increases all of these risks. The American College of Surgeons National Surgery Quality Improvement Program Risk Calculator uses CPT codes, patient characteristics (including BMI), and the emergency nature of the operation to provide an estimate of risk for nine individual postoperative complications as well as discharge to a nursing or rehab facility (available at https://riskcalculator.facs.org/RiskCalculator) [26]. While there are nuances of hernia repair that are not captured in this tool, it can be used to facilitate conversations with patients undergoing emergency surgeries and is immediately available.

Preoperative risk factors for SSI include fluid in hernia sac on CT, heart rate >90 beats/minute, and a BMI of >35 kg/m^2 [27]. Other risk factors include history of diabetes, prior hernia recurrence, concurrent intestinal resection, length of symptoms, postoperative ileus, bacteria or cloudy fluid in the hernia sac intraoperatively [20, 22].

Enterotomy is a risk for all patients undergoing hernia repair and may be higher in patients undergoing emergency repair due to inflammation of the involved bowel or dilation of the upstream bowel. The reported rate of enterotomy for laparoscopic repair of incarcerated hernias is 4% [17, 15, 28]. Enterotomy during general abdominal operations occurs in 10–19% of cases and is associated with more postoperative complications, urgent relaparotomies, increased mortality, and longer LOS [29–31]. Intraoperative recognition of any enterotomy is critical to minimizing further complication as missed enterotomies can lead to sepsis, resulting in patient morbidity and mortality. While emergency hernia repairs have been associated with higher risks of many short-term complications [4, 9, 10, 7], long-term complication rates and recurrence are not increased in this population [9, 32].

Conclusion

There are multiple factors that influence the management of incarcerated hernias. Both the laparoscopic and open approaches are safe, and in the hands of skilled minimally invasive surgeons, the laparoscopic approach may have some benefits when successful. The use of and type of mesh remains controversial in all but clean cases. Patient outcomes can be optimized when the surgeon is aware of the variety of options for management and how to choose the best strategy for each unique patient and situation.

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Chapter 9
Bariatrics

Bradley J. Needleman

Laparoscopic Roux-en-Y Gastric Bypass

While the treatment of obesity continues to evolve with new technology and innovation, the Roux-en-Y gastric bypass continues to be the gold standard for the surgical management of obesity. Because of this and the overall increase in bariatric surgery procedures worldwide, it is important for the general and acute care surgeon to be familiar with the potential complications and obstacles that this patient population may experience. Specifically, we will discuss the management of internal herniation, intussusception, marginal ulcer, and malnutrition issues as they relate to the care of the bariatric patient.

Internal Hernia

Background

The majority of Roux-en-Y gastric bypass (RNYGB) procedures are now performed with minimally invasive techniques [1]. With the increasing popularity of laparoscopic and robot-assisted laparoscopic surgery, the issues of wound complications and incisional hernias that used to occur fre-

B. J. Needleman (✉)
Center for Minimally Invasive Surgery, The Ohio State University, Wexner Medical Center, Columbus, OH, USA
e-mail: Bradley.needleman@osumc.edu

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quently during open Roux-en-Y gastric bypass procedures have now become much less common [2]. However, bowel obstruction and the potential for subsequent ischemia due to internal hernia has now become a significant concern. The reported incidence of small bowel obstruction following laparoscopic Roux-en-Y gastric bypass is between 1.5% and 3.5%, with the majority caused by internal hernias [3, 4]. The decrease in scarring and adhesions after minimally invasive surgery combined with the thinning of mesenteric fat after weight loss is thought to contribute to internal hernia formation [5–7]. Internal herniation after gastric bypass can occur at the mesenteric defect at the jejunojejunostomy or under an antecolic Roux limb between the mesentery of the small bowel and transverse mesocolon. In Roux limbs that are passed retrocolically, there is a potential hernia site in transverse mesocolon and in the Peterson's defect (between the mesentery of the Roux limb and the transverse mesocolon). Symptoms on presentation often include abdominal pain that may be vague, diffuse, and periumbilical, may radiate to back, may occur 15–20 minutes after eating, and may improve with lying on one side. On physical exam, the patient may have diffuse tenderness, fullness, and/or distension, but remember that obese patients often have an unreliable physical exam. Patients with ischemia may present with pain out of proportion to exam and have a soft, nontender abdomen.

Clinical Pearls

- An internal hernia should be considered in any patient with a history of RNYGB who presents with abdominal pain, persistent nausea, or vomiting, especially after the patient has achieved a significant amount of weight loss. The incidence of internal hernia seems to be highest 1–2 years after surgery, but patients can present at any time [3, 8].

- Internal hernias can develop despite closure of mesenteric defects at the original operation [5].
- There is a wide range in the surgical literature of the sensitivity and specificity of CT scans in detecting internal hernias, with trends toward low sensitivity of 28–94% and higher specificity between 54% and 100% [9–12]. Findings such as swirling of the mesenteric vessels, edematous mesentery, engorged or partially/completely occluded mesenteric vessels and lymph nodes, and the majority of the small bowel sequestered in one quadrant are concerning findings on imaging that should increase clinical suspicion [11, 12].
- Diagnostic laparoscopy or laparotomy is warranted if suspicious findings are noted on history and physical and/or imaging.

Pitfalls

- Delay in diagnosis leading to a delay in operative treatment can lead to bowel ischemia and even death. Early recognition and surgical treatment are critical.

Operative Management

- Current surgical literature suggests that closing mesenteric defects at the time of the initial operation likely decreases the rate of postoperative internal hernias [13, 14]. We routinely close Peterson's space and the defect at the jejunojejunostomy with nonabsorbable sutures during all gastric bypass procedures.
- With a suspected internal hernia, treatment is operative and begins with a diagnostic laparoscopy and running all three limbs of small bowel. If there is an internal hernia, it may be difficult to run the Roux limb back to the jejunojejunostomy and difficult to determine proper orientation of the anastomosis, although this gets easier with experience.

- Operative pearls:
  – Place the camera port lower in the midline (often infraumbilical) to improve visualization of the small bowel and defects.
  – It is often easiest to reduce the bowel and ensure proper orientation by beginning at the cecum with its peritoneal attachments and running the bowel back from the terminal ileum.
  – Explore Petersen's space by lifting the Roux limb and the transverse colon to visualize the space between the small bowel mesentery and transverse colon mesentery. If bowel is in this space, it is easier to reduce by "pushing" the bowel back through the defect versus "pulling" from the Roux limb.
  – Dilated, thin-walled bowel may make it difficult to reduce or manipulate bowel and may require conversion to laparotomy due to enterotomies.
  – If the bowel cannot safely be reduced, the proper anastomotic orientation cannot be ascertained, or there is urgency due to impending bowel necrosis, division of the jejunojejunostomy (separating the biliopancreatic limb from the Roux limb and common channel) allows immediate reduction and proper reorientating of the bowel.
- Any evidence of ischemia will require resection and anastomosis.
- All defects should be closed, regardless of whether or not a hernia was found, with nonabsorbable sutures.

Intussusception

Background

While intussusception is most commonly seen in the pediatric population, it can be seen in the adult population as well, especially in postoperative gastric bypass patients. Patients rarely present with the triad seen in the pediatric population, consisting of currant jelly stools, colicky abdominal pain, and a palpable mass. However, these patients may experience chronic, intermittent obstructive symptoms including abdominal distention, nausea, and emesis. They can also present more acutely with significant pain and tenderness, abdominal distention, and rebound tenderness. However, in many cases intussusception may be found incidentally on CT scans.

Clinical Pearls

- The etiology of intussusception is likely multifactorial and related to dysmotility secondary to disruption of the intestinal pacemakers. This likely occurs during division of the small bowel and creation of the Roux limb in the primary gastric bypass procedure. Other mechanisms may include thinning of the mesentery as well as new lead points including sutures and staples [15, 16].
- Intussusception may occur in the antegrade or retrograde direction, often close to or at the jejunojejunostomy [15].
- A CT scan of the abdomen and pelvis can be diagnostic in most cases, with the characteristic target sign being pathognomonic. Other findings may include a dilated gastric remnant secondary to an obstructed biliopancreatic limb [17].
- Proposed treatments include surgical reduction, resection and revision, or enteropexy.
- If it is not clear that intussusception is the cause of patient symptoms or it is found incidentally, it is generally recommended that intussusception and its location are confirmed by two studies performed on different days.

Pitfalls

- A delay in diagnosis can result in bowel ischemia, sepsis, or even mortality. If patients present acutely, emergent operative intervention is necessary.
- Surgical reduction alone of intussusception is associated with high recurrence rates [16, 18].

Operative Management

- We begin with diagnostic laparoscopy. The small bowel is inspected starting at the ileocecal valve and sequentially examining the bowel proximally. The jejunojejunostomy should be examined, and any intussusceptions should be reduced. Evaluate all three limbs including the Roux limb, biliopancreatic limb, and common channel. Any bowel ischemia will require resection and likely anastomotic revision. In the absence of bowel ischemia, proceed with enteropexy. This is performed with interrupted, permanent sutures, tacking the common channel to the biliopancreatic limb to prevent recurrent intussusception. We additionally examine the mesenteric defects of Peterson's space and the jejunojejunostomy and close with permanent sutures if necessary.

Marginal Ulcer

Background

Marginal ulcers remain one of the most commonly seen and problematic complications after Roux-en-Y gastric bypass. The incidence of marginal ulcers after RNYGB ranges from 0.6% to 16% [19–21]. Studies as early as 1977 revealed that in the majority of patients, gastric acid secretion decreases after gastric bypass due to antral exclusion and subsequent decrease in gastrin levels and acid secretion. However, in some patients, acid secretion is predominantly under vagal control and not antral influence, and these patients may continue to have poor regulation of acid secretion following gastric bypass procedures [22]. Marginal ulcers may present months to years after the initial operation. They often are located at or just distal to the gastrojejunostomy. Upper endoscopy can be both diagnostic and therapeutic; an upper GI series can also be used for diagnosis. Patients can present acutely with bleeding, obstruction, or perforation. A typical presentation of a patient with a marginal ulcer includes epigastric pain and back pain. The pain may be persistent and exacerbated by food immediately upon entering the pouch. Pain may or may not radiate to the back. If ulceration leads to anastomotic stenosis, this can also cause food intolerance.

Pearls

- The best therapy, we believe, is prevention by ensuring smoking cessation and elimination of all NSAID and steroid medications preoperatively. We additionally prescribe proton pump inhibitors to all patients postoperatively for a minimum of 3 months. Furthermore, there is a strong association with *Helicobacter pylori* infection and marginal ulceration, and treatment of *H. pylori* preoperatively may reduce the postoperative incidence of marginal ulcers [23, 24].
- Other potential causes of marginal ulcers may include gastrogastric fistulas and foreign bodies at the anastomotic site (i.e., permanent suture, staples, mesh, silicon, etc.).
- Medical management consists of proton pump inhibitors (PPIs), sucralfate, and misoprostol. Opened PPI capsules may facilitate quicker healing from marginal ulcers than standard PPI capsules [25]. Sucralfate should be given in liquid form or made into a slurry to be more effective. Therapy is usually continued for 6 weeks.
- Ensuring the elimination of all NSAID medications, steroids, alcohol, and tobacco use is essential for proper healing.
- The incidence of gastrogastric fistulas reported in the literature after gastric bypass ranges widely from 6% to 42% [26–28]. This may be due to incomplete division of the stomach at the original operation, opening of a transverse anastomosis staple line in nondivided gastric bypass procedures, or fistulization between the remnant stomach and pouch at any time [26, 27]. Closure of the fistula will be necessary, endoscopically or operatively, for successful eradication of ulcers.

- A number of technical aspects at the initial operation may be associated with the formation of marginal ulcers including pouch size, pouch orientation, and ischemia. Ensuring the gastrojejunostomy is not under any tension and preserving the blood supply to the pouch and jejunum is critical. A small-sized pouch that excludes the fundus is important to decrease the gastric acid secretion postoperatively. Complete division should be performed between the pouch and the remnant stomach to avoid a gastrogastric fistula.

Operative and Endoscopic Management

- Upper endoscopy can be used for diagnosis by examining the gastrojejunostomy for evidence of an ulcer, foreign body (suture or staples), stricture, and bleeding. Biopsies can be taken of the ulcer as well as for *H. pylori*, and inspecting the pouch for any evidence of a gastrogastric fistula is important. Endoscopic therapies to treat bleeding or to dilate strictures can be performed as necessary. Additionally, if a gastrogastric fistula is identified, this can be repaired endoscopically by experienced endoscopists; this has been performed with varying long-term success [29, 30], likely dependent on the size and chronicity of the fistula.
- For patients who do not respond to maximal medical management, revisional surgery may be required for ulcer eradication. Division of a gastrogastric fistula, if present, should be performed. Resection and revision of the gastrojejunostomy may be necessary. Other surgical options include laparoscopic or thoracoscopic vagotomy. Nonoperative management is usually preferable, if possible.
- Early marginal ulcers or uncomplicated refractory ulcers may respond well to thoracoscopic vagotomy alone and is often a good first line operative therapy that does not potentially complicate future abdominal approaches.

- In a more acute patient presentation with perforation, diagnostic laparoscopy or exploratory laparotomy is warranted. A Graham patch repair is often feasible and successful, but if not, revision of gastrojejunostomy may be required. Wide drainage and enteral feeding access should be considered via the gastric remnant or small bowel.
- In the case of a hemodynamically unstable patient bleeding from a marginal ulcer, the ulcer has likely eroded into a vessel along the lesser curve of the gastric remnant; this may include a small vessel or the left gastric or splenic arteries and will require exposure and oversewing. Subsequent intraoperative upper endoscopy can be helpful to evaluate the repairs, as well as to assess for any stenosis of the gastrojejunostomy after these operative maneuvers.

Acute Malnutrition Issues

Background

All bariatric patients postoperatively are at risk for nutritional deficiencies, thus it is extremely important for close perioperative nutritional monitoring, as well as lifelong nutritional assessments. It is especially imperative for those patients who have undergone a malabsorptive operation, such as the RNYGB, to have long-term follow-up.

Pearls

- The most common nutritional deficiencies after Roux-en-Y gastric bypass include iron, Vitamin B1, folate, Vitamin D, and calcium. The duodenum is the normal absorption site for iron, Vitamin B1, and calcium, therefore bypassing the duodenum alters the normal absorption of these vitamins and minerals. Vitamin D is liposoluble, and absorption can be decreased postoperatively with lipid malabsorption. A decrease in folates is usually due to a deficiency of dietary intake of fruits and vegetables and can lead to chronic anemia [31].

- Vitamin B12 is another important vitamin to monitor in the perioperative period as well as long term. With alteration in the secretion of intrinsic factor by the excluded stomach, B12 absorption can be adversely affected. The prevalence of this deficit postoperatively is estimated at 12–70%, most commonly occurring the first year following gastric bypass. Consequences of this deficiency could lead to megaloblastic anemia or neurological symptoms [31, 32].
- Protein malabsorption can occur after RNYGB secondary to intake deficiencies, decreased absorption, or altered enzymatic breakdown. This can lead to loss of muscle mass, deterioration of the skin and nails, edema, and even anasarca. Severe protein malabsorption has been more commonly described in biliopancreatic diversion and duodenal switch operations. For a postoperative RNYGB, 60–90 grams of protein intake is recommended daily. High-quality protein supplementation is often required to meet these protein intake goals, especially in the immediate postoperative period [31, 33].

Pitfalls

- Alterations of lipid absorption can affect other fat soluble vitamins including A, E, and K. Major lipid malabsorption may be manifested by chronic diarrhea and steatorrhea. These deficiencies are more common with biliopancreatic diversion procedures than RNYGB. However, patients taking Vitamin K antagonists for anticoagulation must be followed very closely after all of these operations. Warfarin dosages tend to decrease after RNYGB and increased monitoring is required perioperatively to ensure the correct therapeutic levels [34].
- Women who decide to become pregnant and breastfeed after RNYGB need special attention to their increased nutritional demands. Of particular importance is the prevention of iron, calcium, Vitamin D, and folate deficiencies.

Iron deficiency anemia can increase the risk of prematurity and low birth weights [33]. Calcium and Vitamin D deficiencies can cause infantile rickets and weak osseous mineralization, and folate deficiency can lead to neural tube malformations [31]. Therefore, a prepregnancy nutritional assessment is important as well as monitoring every trimester, with nutritional supplementations and adjustments as needed.

Perioperative Management

We perform a comprehensive nutritional assessment preoperatively, with specific laboratory values, vitamins, and minerals detailed below. Dieticians begin to educate our patients preoperatively and continue throughout the postoperative period. Postoperatively, a multivitamin supplement is provided to all bariatric surgery patients, regardless of their operation, that provides 100% of the recommended daily allowance. Many supplements may not completely meet daily iron requirements, therefore special attention to ensuring adequate iron supplementation is necessary. We continue nutritional assessments postoperatively at 3 months, 6 months, 1 year, and then annually.

- More specifically, the authors monitor and adjust as necessary:
  - Complete blood count
  - Liver function tests
  - Fat soluble vitamins A, D, E, K
  - Vitamin B1
  - Vitamin B6
  - Folate
  - Calcium and parathyroid hormone
  - Vitamin B12
  - Vitamin C
  - Niacin
  - Iron
  - Zinc

– Selenium
– Protein: albumin and prealbumin
– Lipid profile

Laparoscopic Sleeve Gastrectomy

Postoperative Leak and Stenosis

Background

With the incidence of obesity increasing at an alarming rate worldwide, there has been an associated increase in the number of bariatric surgeries performed each year. This is especially true of the laparoscopic sleeve gastrectomy (SG), often seen by both surgeons and patients as a less complex operation when compared to the RNYGB and other bariatric procedures. However, it is not without its risk of unique complications, in particular postoperative stenosis and leak. The incidence of a leak postoperatively from sleeve gastrectomy is estimated between 0.7% and 7%, and the risk of stenosis is estimated between 0.7% and 4% [35–37]. Both complications can lead to significant morbidity and mortality; therefore, early diagnosis and intervention is critical.

The most common site for a postoperative leak after sleeve gastrectomy is at the proximal staple line close to the gastroesophageal junction, and the most common site for stenosis is at the incisura angularis. A significant proportion of patients may present with combined leak and stenosis, with the stenosis causing increased intraluminal pressure and a resultant proximal leak [36].

Postoperative Leak

Pearls

- Leaks may be caused by mechanical or ischemic causes; mechanical causes include stapler misfiring or a distal stenosis. Thermal injury and overdissection near the posterior aspect of the upper gastric sleeve can cause devascularization and subsequent ischemia, resulting in a leak [38, 39].

- Patients may present with a wide range of symptoms including pain, fever, tachycardia, abdominal pain, nausea and emesis, or with peritonitis and sepsis. Tachycardia is often the earliest clinical finding [40]. For patients who present postoperatively with concerns for a leak, an abdominal CT scan or upper GI series can be diagnostic. An upper endoscopy may also be helpful for both diagnosis and management.
- A significant proportion of leaks present late, with 79% of leaks occurring more than 10 days postoperatively. Therefore, close patient follow-up is necessary for all of these patients. The majority of leaks can be managed with minimally invasive techniques [35].

Pitfalls

- Early detection of a postoperative leak is associated with improved patient outcomes, so a high index of suspicion and early intervention is imperative. A negative radiologic study should not prevent the surgeon from operating if the patient still appears clinically to have a leak.

Operative, Procedural, and Endoscopic Management

- Small, contained leaks may be able to treat with parenteral nutrition, broad-spectrum antibiotics, and image-guided percutaneous drainage. Endoscopic stents can also be used to manage similar, contained leaks. Complications of endoscopic stent placement consist mostly of stent migration or stent intolerance due to pain and reflux. Other novel endoscopic management options for management of leaks include fibrin glue injection, over the scope clips, and internal drainage procedures [41–43].
- Patients with more clinically severe leaks and/or present with abdominal sepsis may require laparoscopic or open exploration, with irrigation and wide drainage, with or without oversewing the area of the leak.

- In patients with a chronic leak, a stenosis may be the reason there continues to be high pressure in the upper stomach and consequently the leak will not close without surgical intervention, which must include management of the stenosis.
- If patients continue to leak chronically despite these interventions, conversion to RNYGB or even Roux-en-Y esophagojejunostomy with total gastrectomy may be necessary. Other described options may include Roux-en-Y anastomosis of the small bowel to the leak site, buttressing of the leak with small bowel, or segmental resection of the sleeve.

Stenosis

Pearls

- Postoperative stenosis can be classified as functional or mechanical. A functional stenosis can occur when the sleeve is twisted, and on endoscopy, the passage of the endoscope may still be possible with rotation. Even an upper GI series will appear normal. In contrast, a mechanical stenosis occurs most commonly at the incisura angularis, and passage of the endoscope may be difficult or impossible [37].
- Most patients present with obstructive symptoms including nausea, vomiting, and reflux, but they can progress to malnutrition and dehydration if not identified and treated early. The diagnosis can be made best with an upper GI series or on endoscopy but may be found on CT as well.
- Stenosis may occur both early and late, with most early stenoses becoming symptomatic in the first 6 weeks postoperatively [44].

Pitfalls

- Avoiding stricture, twisting, and kinking at the primary operation is essential with meticulous technique, ensuring the staple line is straight with symmetric traction on the stomach during stapler firing. It is also important to make certain that there is an adequate distance from the incisura angularis and the stapler with placement of an appropriately sized bougie.

Operative and Endoscopic Management

- Endoscopic balloon dilation is often the first line option for treatment of postoperative stenosis. Controlled radial expansion (CRE) balloons have been used with success, reaching a diameter of 20 mm. Achalasia balloon dilators with larger diameters up to 35 mm have also been used successfully. Self-expandable metal stents inserted under endoscopic and fluoroscopic guidance may also be utilized [37, 45]. Ideally, the stent would extend from the esophagus to the duodenum which may require ordering a longer stent.
- If endoscopic interventions are unsuccessful, surgical revision may be necessary. This may include revision of the sleeve gastrectomy, conversion to a Roux-en-Y gastric bypass, or Roux-en-Y esophagojejunostomy with total gastrectomy.
  - Revision of the sleeve for narrowing may include a Heineke-Mikulicz type strictureplasty, myotomy, and resection and reanastomosis across the area of narrowing.
  - Conversion to Roux-en-Y above the area of narrowing is the most definitive operative treatment.

Conclusions

There are an estimated 300,000 bariatric surgery performed annually in the United States. Often the surgery is performed in another city from where the patient will present acutely. Acute care surgeons must recognize the complications of bariatric surgery and be able to manage them. Often times this can be done with laparoscopic or endoscopic therapy. Because of the RNYGB anatomy, these patients are more at risk for bowel obstructions, marginal ulcers, and malnutrition. The sleeve gastrectomy, conversely, has a higher risk of a leak due to its high luminal pressure. This also makes sleeve leaks more challenging to treat. A persistent stenosis will cause a sleeve leak to persist and it must be corrected or bypassed in order for the leak to close.

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Chapter 10
Paraesophageal Hernia

H. Alejandro Rodriguez, Jennifer A. Minneman, Jin Sol Oh, and Brant K. Oelschlager

Introduction

A majority of patients who present for care of a paraesophageal hernia (PEH) will do so in a nonemergent setting. In this population, evaluation and workup can be carried out deliberately, with surgical intervention offered only after careful consideration. In contrast, acute PEH with gastric volvulus, obstruction, strangulation, or perforation is a surgical emergency which requires prompt diagnosis and intervention. This is underscored by the fact that most of these patients are elderly and present with multiple comorbidities [1–4]. In this chapter, we review the approach to these patients and provide a simplified management algorithm.

Clinical Presentation

Patients with acutely incarcerated paraesophageal hernia present with acute symptoms of epigastric or chest pain, inability to tolerate oral intake, nausea, vomiting, or retching.

H. A. Rodriguez · J. A. Minneman · J. S. Oh
Department of Surgery, University of Washington, Seattle, WA, USA

B. K. Oelschlager (✉)
Division of General Surgery, University of Washington, Seattle, WA, USA
e-mail: brant@uw.edu

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A careful review of the history may reveal chronic symptoms of heartburn, regurgitation, dysphagia, early satiety, or vomiting. Physical exam findings are often nonspecific. Patients may have epigastric tenderness or upper abdominal distention as the stomach becomes dilated in obstruction. In the case of a completely intrathoracic stomach, however, the abdominal exam may be normal, and acute PEH can be mistaken for acute coronary syndrome, delaying diagnosis [1, 5, 6].

Hemodynamically unstable patients with acute PEH classically have gastric volvulus, although there may be strangulation or perforation of other hollow organs (i.e., small bowel or colon) within the hernia, or in very rare cases splenic rupture from traction on splenic vessels. In any case, patients with the above signs and symptoms and hemodynamic instability or peritonitis require a high index of suspicion for acute PEH and an expedited workup to allow for appropriate surgical intervention as soon as possible.

Workup

Labs may reveal elevated white blood count and lactate, electrolyte disturbances, and elevated amylase level. An acute PEH can be readily identified through a variety of diagnostic imaging studies. With the consistent clinical presentation as outlined above, a plain film of the chest with a large air-filled stomach in the mediastinum may suffice for the diagnosis of acute PEH.

An upper gastrointestinal (UGI) study provides excellent definition of foregut anatomy and can help to assess the presence of volvulus, as well as the degree of obstruction (Fig. 10.1) [7]. However, UGI is usually not practical for diagnosing acute PEH as it is not always available, its value is relative to the experience of the radiologist, and not all patients will tolerate the exam. If water soluble contrast is used for fear of perforation, aspiration pneumonitis is a risk. UGI is thus best reserved for stable patients who have been successfully decompressed.

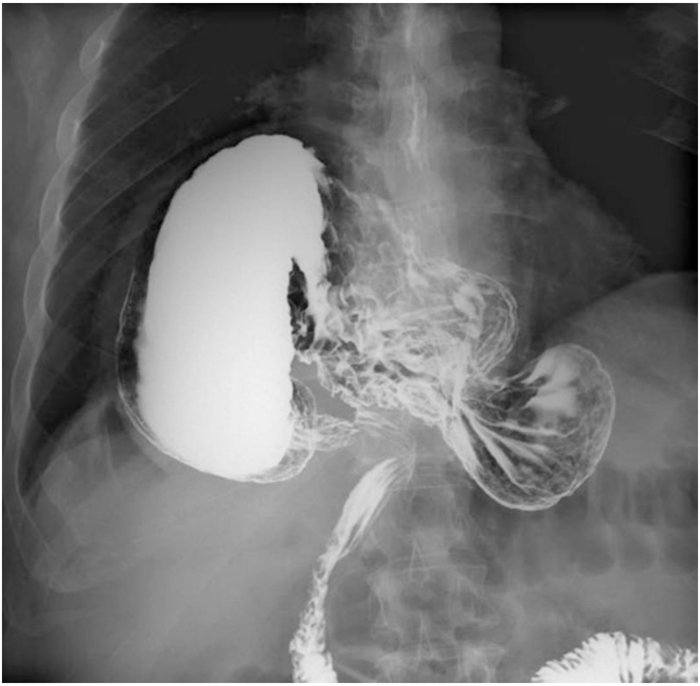

Figure 10.1 UGI showing paraesophageal hernia with gastric volvulus and partial obstruction

If not obvious on plain radiograph, CT of the chest and abdomen with intravenous contrast is usually the best study to establish the diagnosis of acute PEH, as it can be performed swiftly, is available in almost all hospitals, does not require the presence of a radiologist, has an excellent sensitivity, and can give information about gastric perfusion [8]. Radiologic features of an obstructed PEH on CT include position of the stomach above the diaphragm, gastric distension, perigastric fluid, and stenosis of a gastric segment as it traverses the hiatus. If gastric volvulus is present, an antropyloric transition point, reversed position of the lesser and greater curvatures, and the presence of the antrum at a level higher than the fundus can be observed [9].

Finally, upper endoscopy allows identification of a PEH, visual inspection of the mucosa, and decompression of the stomach. Unfortunately, obstruction can be easily missed, and volvulus can be inadvertently reduced by insufflation, which will decrease diagnostic accuracy [8]. As a result, this is rarely used for diagnosis of a PEH and is much more suitable for therapeutic decompression.

Management

Initial Approach

Emergent operative intervention was the primary therapeutic maneuver for acute PEH, but this is now only required for ischemia or perforation. Instead, prompt gastric decompression is the key initial step in the management of acute PEH (Fig. 10.2). In most cases, this can be achieved through placement of a nasogastric (NG) tube. After proper placement is confirmed, the NG tube is left on low intermittent suction. However, organoaxial volvulus with complete obstruction at the esophagogastric junction (from extrinsic compression)

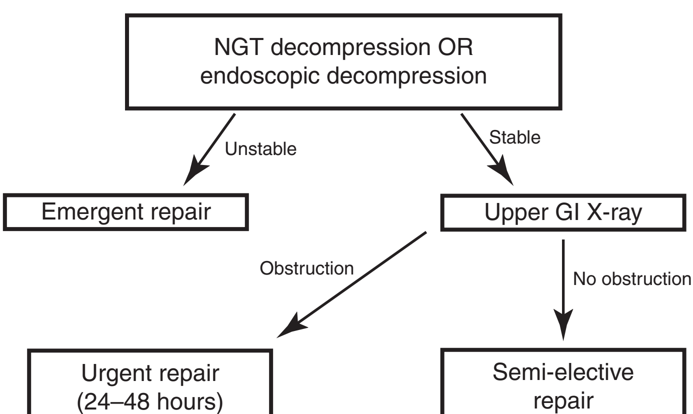

FIGURE 10.2 Simplified algorithm for the management of acute PEH

may preclude placement of the NG tube. In this subset of patients, upper endoscopy will allow for decompression, and in some cases, reduction of the volvulus [10, 11]. Once decompression is successful, the patient should have relief of pain and vomiting. The patient should be observed for signs of ischemia, and decompression should continue for 12–24 hours. If decompression fails, or if there is concern for ischemia with persistent pain, vomiting, or hemodynamic instability, the patient should go to the operating room immediately.

In hemodynamically stable patients who have undergone successful decompression, the next step is to rule out complete obstruction. After 12–24 hours an obstructing volvulus often de-torses, and a subsequent UGI study provides a clear assessment of the degree of obstruction. If complete obstruction is observed at the time of UGI, urgent repair (within 24–48 hours) should be undertaken. Patients without obstruction can be given a liquid diet and if tolerated may be managed with semielective repair. Only in the most high-risk patients would long-term nonoperative therapy be pursued.

Laparoscopic Paraesophageal Hernia Repair

Laparoscopic PEH repair is the gold standard in the treatment of PEH, by which the stomach can be returned to its intra-abdominal position and volvulus (if present) can be reduced. Reduction of the hernia contents, complete resection of the sac, hiatal closure, and mobilization of the esophagus to achieve an adequate intra-abdominal length will help prevent recurrence. Finally, the addition of an antireflux procedure will prevent symptoms associated with gastroesophageal reflux [12].

Surgical Technique

The patient is placed supine on either a split leg bed or in modified lithotomy position. The patient is secured to the table with straps around the thighs. The left arm is tucked to the patient's side while the right arm is extended on an arm board. The surgeon will stand between the patient's legs, with an assistant standing on the patient's left side (Fig. 10.3). The abdomen is insufflated with CO_2 via a Veress needle placed in the left upper quadrant. We use five incisions as depicted in Fig. 10.4. The left lobe of the liver is retracted anteriorly , exposing the hiatus. The stomach is carefully reduced into the abdomen and inspected for signs of ischemia. If present, volvulus is reduced at this time. Excessive traction of the stomach

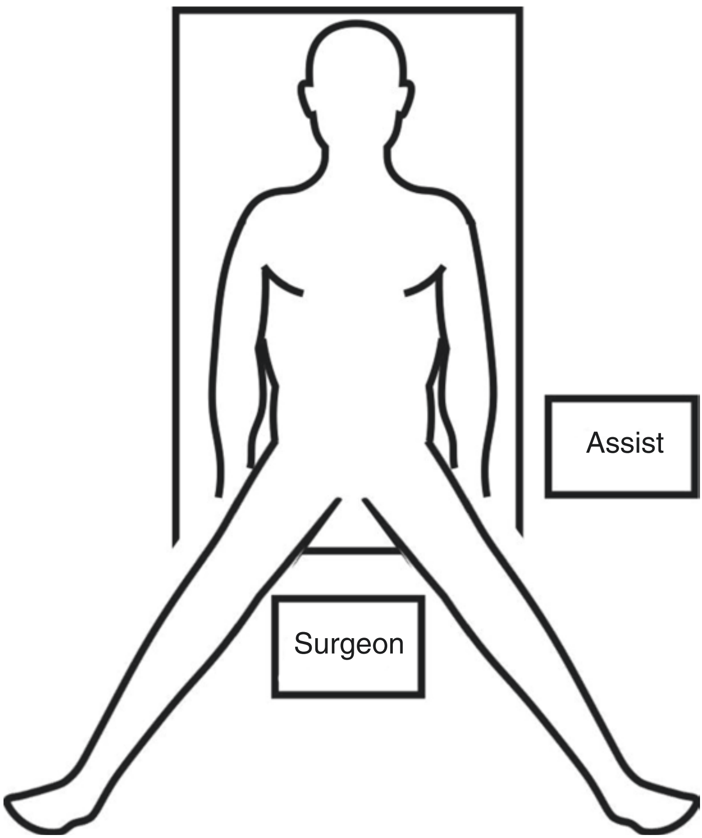

FIGURE 10.3 Patient and surgeon positioning

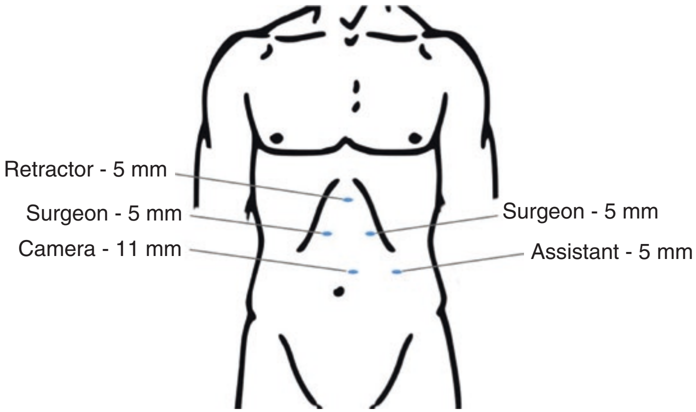

FIGURE 10.4 Diagram showing port placement for laparoscopic PEH repair. Ports for laparoscopic gastropexy are placed 5 cm caudal to those placed in PEH repair

is avoided; full reduction may only be achieved after resection of the hernia sac and esophageal mobilization.

The short gastric vessels are divided, and the greater curvature of the stomach is mobilized to the level of the left crus. The hernia sac is incised directly over the left crus. Mobilization of the hernia sac is performed through a combination of blunt and electrosurgical dissection. Correct identification of the areolar plane between the hernia sac and the mediastinum is crucial to allow full reduction. From the patient's left, dissection continues counterclockwise toward the right crus, staying anterior to the esophagus. The pars flaccida is then incised and the right crus is identified. The dissection of the hernia sac continues from the right crus. A retroesophageal window is made, and a Penrose drain is placed around the esophagus for traction. The hernia sac is then circumferentially reduced from the mediastinum. The hernia sac is resected to the left of and anterior to the anterior vagus, as circumferential removal of the sac from the gastroesophageal junction (GEJ) will result in vagotomy.

We have found that extensive esophageal mobilization precludes the need for an esophageal lengthening procedure, though the knowledge and ability to perform one is necessary when undertaking a PEH repair. With the stomach fully reduced, the crura are closed posteriorly with interrupted 2-0 silk (or other nonabsorbable) sutures. If excessive tension on the crura is present while closing the hiatus, reinforcement with biologic mesh or a relaxing incision may be necessary. Prosthetic mesh should not be used at the hiatus due to the risk of erosion into vital structures including the esophagus and aorta. Finally, either a 360° or 270° fundoplication, depending on patient characteristics and surgeon preference, is performed. The superior edge of the fundoplication is sutured to the hiatus to prevent recurrence. Upper endoscopy is performed to evaluate the stomach and the fundoplication.

Laparoscopic Gastropexy

While laparoscopic PEH repair is a safe and effective procedure, it may not be suited for some patients with acute PEH. This operation requires an intimate knowledge of the anatomy, advanced laparoscopic skills, extensive experience with elective PEH repairs, and several hours of general anesthesia. Surgeons without this skill and knowledge should perform a gastropexy if urgent surgery is required. In addition, high-risk patients with advanced age, severe comorbidities, poor nutritional status, extensive metabolic derangements from their obstruction, or those with an inflammatory process at the hiatus prohibiting an optimal PEH repair, may be best served by gastropexy which resolves the risk of incarceration. This is not a new concept; gastropexy was described as early as 1954 by Rudolph Nissen. At the time, most surgeons carried out PEH repairs via thoracotomy. However, Nissen cared for a physician with an incarcerated PEH whom he judged to be too infirm to tolerate a thoracotomy, so he performed an anterior gastropexy via a laparotomy , suturing the stomach to a pedicle flap of the anterior rectus sheath [13–15]. Currently, the literature supports a minimally invasive approach for gastropexy. This can be achieved by endoscopic, laparoscopic, or combined approaches [10, 16–19]. In an effort to prevent recurrent herniation or volvulus, we currently favor a laparoscopic approach that includes multiple fixation points along the greater curvature [17]. A gastropexy also does not preclude future repair. Reoperation with formal hernia repair can be performed after patient optimization and resolution of the acute inflammatory episode.

Surgical Technique

Patient and surgeon positioning for laparoscopic gastropexy are identical to that of laparoscopic PEH repair. The ports are also similarly placed; however, it is critical that they are placed 5 cm caudal to the site they would be placed in PEH repair. This allows access to the hiatus as well as the anterior abdominal wall, which is necessary for adequate fixation. The stomach is reduced to the fullest extent possible then gastropexy is performed with interrupted 2-0 silk sutures. The first suture secures the cardia (or the most proximal reduced portion of fundus) to the left crus. Additional sutures are placed 2–3 cm apart along the greater curvature, progressing from the diaphragm to the anterior abdominal wall (Fig. 10.5). Some authors have described adding a gastrostomy to aid gastric decompression. Our current practice, however, is not to routinely place a gastrostomy as our early experience showed little clinical benefit and an increased risk of complications [17].

Gastrectomy

On rare occasions, an obstructed portion of stomach will present with ischemia and/or perforation. This will necessitate a gastrectomy, the extent of which will vary depending on the affected site. Widespread or proximal necrosis will require a total gastrectomy with esophagojejunostomy, while necrosis

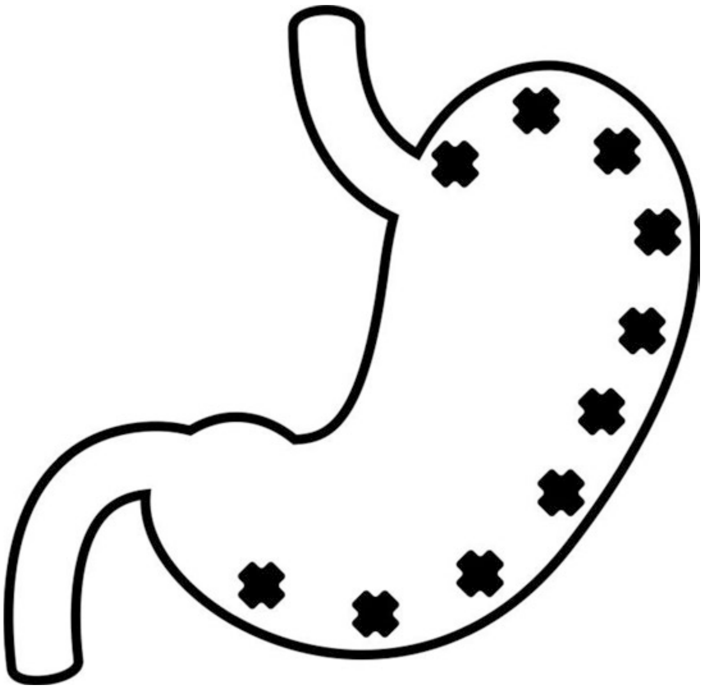

Figure 10.5 Diagram representing fixation points along the greater curvature to the diaphragm and anterior abdominal wall in laparoscopic gastropexy

in the antrum (rare) can be managed with a distal gastrectomy. Necrosis confined to the fundus or greater curvature can be addressed with a sleeve gastrectomy. Patient characteristics and surgeon experience dictate the choice between an open or laparoscopic approach for these operations. We favor the laparoscopic approach as it provides visualization of and access to the mediastinum, which is critical for esophageal mobilization. This is necessary to obtain the 3–4 cm intra-abdominal esophageal length to perform an esophagojejunostomy if a total gastrectomy is required. For patients who are in extremis or if the surgeon has limited foregut experience, the surgeon should consider resecting the ischemic portion of the stomach and, if necessary, leaving the GI tract in discontinuity. If resection is done at the level of the esophagogastric junction, it is important to place permanent stay sutures at the distal end of the esophagus, as the esophagus tends to recoil into the mediastinum. When appropriate, the patient should be transferred to a tertiary center for reestablishment of continuity. For surgeons who do not perform foregut surgery frequently, communication with anesthesia is key when resecting the stomach to assure no tube, probes, or other instruments placed by our colleagues are within the stomach when stapling is planned.

Open, Thoracic, or Laparoscopic?

Most techniques for PEH repair (including the Allison, Belsey Mark IV, and Nissen) were initially performed through a left thoracotomy. The benefits of this approach include ease of esophageal mobilization and wide drainage of the mediastinum in cases of gastric perforation. Over time, these procedures were adapted to laparotomy. An open abdominal approach allows a quick reduction of incarcerated contents and avoids the morbidity associated with a thoracotomy. With the advent of laparoscopy and the recognition of its excellent visualization of the hiatus and lower mediastinum, surgeons began to perform laparoscopic PEH repair, although the ideal approach remained the subject of some debate [20]. Hashemi et al. evaluated outcomes of 54 patients who underwent laparoscopic, open abdominal, and open thoracic repair of large PEH in 2000. Their recurrence rates were 42% in laparoscopic group and 15% in the open group. The authors reported abandoning the laparoscopic approach in favor of thoracotomy [21]. Eleven years later, the same group has modified their laparoscopic technique and reported no difference in recurrence rates between the laparoscopic and open groups (12 vs 24%, $p = 0.09$) [22].

A prospective, randomized trial comparing biologic mesh versus simple hiatal closure in laparoscopic PEH repair found that long-term recurrence rates can reach 50% with either approach, but most patients with recurrence are asymptomatic [23]. We therefore advocate for laparoscopic PEH repair as it offers the advantages of both laparotomy (decreased morbidity) and thoracotomy (access to the mediastinum), while adhering to the established tenets of repair: resection of the hernia sac, adequate esophageal length, hiatal closure, and intra-abdominal fixation.

Outcomes

Early reports on PEH repair noted that acute PEH was associated with high complication and mortality rates [24], which led many authors to advocate for routine PEH repair upon diagnosis [4, 25, 26]. This practice went mostly unchallenged for nearly half a century, despite being based on data from relatively small case series. In 2002, Stylopoulos et al. developed a decision-making model for PEH repair, using data from published studies as well as the National Inpatient Sample database. The authors estimated the mortality for elective laparoscopic PEH repair was 1.4%, while the annual probability of developing acute symptoms requiring emergent surgery was 1.1% [27]. Since then, watchful waiting has gained in popularity and is the preferred approach in asymptomatic or minimally symptomatic patients. In turn, this strategy has had some pushback, as many authors have noted that elective repair is associated with a much lower morbidity and mortality than emergent repair [28, 29]. In one such study, Kaplan et al. analyzed data from the National Surgical Quality Improvement (NSQIP) database. The authors found that more recently (2005–2012), the mortality associated with elective repair is 0.65%, in contrast to 5.5% in emergent repair. The mortality for elective laparoscopic PEH repair was 0.46% [30]. It must be noted that laparoscopic PEH repair was a relatively new procedure at the time of the Stylopoulos study, so it is possible that outcomes for elective repair have improved since the procedure has gained widespread adoption.

Conclusion

Acute paraesophageal hernia is a surgical emergency but rarely requires emergent repair. Prompt diagnosis requires a high index of suspicion, a careful history and a focused physical exam, followed by radiologic confirmation. In the absence of ischemia or perforation, gastric decompression allows surgical intervention to be pursued in an urgent or semielective fashion depending on the effectiveness of the decompression and presence of obstruction. Laparoscopic gastropexy should be considered for patients who are not able to tolerate prolonged anesthesia and for surgeons who are not practiced in complex laparoscopy or operating at the esophageal hiatus. If formal repair is pursued, it may be performed from the chest or the abdomen, although we prefer a laparoscopic approach for its decreased morbidity and excellent visualization of the hiatus.

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Chapter 11 Necrotizing Pancreatitis

Motokazu Sugimoto, David P. Sonntag, and L. William Traverso

Definitions

Necrotizing Pancreatitis

Necrosis of the pancreas is best defined by the revised Atlanta classification of acute pancreatitis in 2012 [1]. Simply described and important to realize is that necrotizing pancreatitis can include necrosis of pancreatic parenchyma, peripancreatic tissue, or both. About 5–10% of the acute pancreatitis patients develop necrosis. Necrosis is a *permanent* condition that will occur when a portion of the pancreas loses its blood supply secondary to severe inflammation. Therefore, contrast-enhanced computed tomography (CT) will show lack of enhancement of pancreatic parenchyma commonly with peripancreatic fluid collection (Fig. 11.1). According to the revised Atlanta classification, the term "acute necrotic collection" is a pancreatic and/or peripancreatic collection containing variable

M. Sugimoto (✉)
Department of Hepatobiliary and Pancreatic Surgery, National Cancer Center Hospital East, Kashiwa, Chiba, Japan

D. P. Sonntag
Department of Interventional Radiology, St. Luke's Health System, Boise, ID, USA

L. W. Traverso
Center for Pancreatic and Liver Disease, St. Luke's Health System, Boise, ID, USA

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amounts of both fluid and necrosis, whereas "walled-off necrosis" is a pancreatic or peripancreatic collection that has matured into an encapsulated collection with a well-defined inflammatory wall. Walled-off necrosis usually occurs more than 4–8 weeks after onset of necrotizing pancreatitis and is more uncommon.

Pancreatic Ductal Disruption

Pancreatic ductal disruption is a loss of ductal integrity anywhere in the pancreatic ductal system (i.e., the main pancreatic duct or secondary ductules). The disruption and its location are vitally important to demonstrate in each patient. The disruption can be observed by CT, sinogram through a percutaneous drain that reveals a pancreatic duct, endoscopic retrograde cholangiopancreatography (ERCP), or magnetic

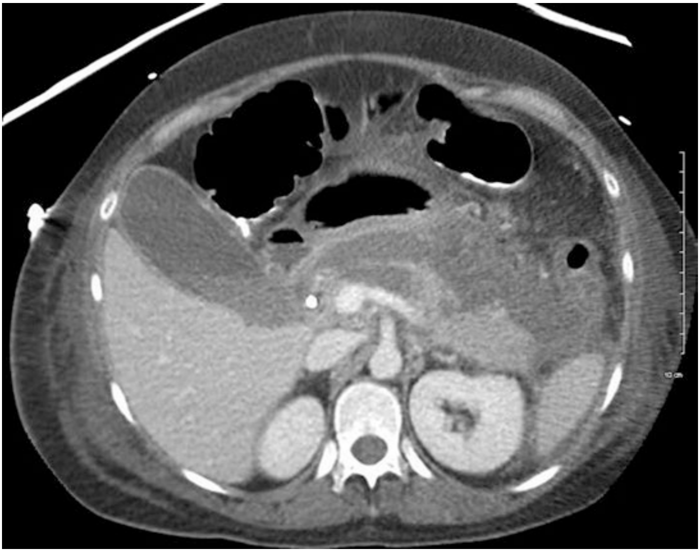

FIGURE 11.1 An abdominal computed tomography shows necrosis of pancreatic parenchyma and peripancreatic space

resonance cholangiopancreatography (MRCP). It is also suggested by a persistent finding of any amylase-rich drain fluid. Pancreatic ductal disruption is an important clinical finding suggesting the presence of pancreatic juice leakage that occurs as a consequence of necrotizing pancreatitis and implies the high likelihood that intervention will be required to prevent clinical deterioration. As described below, the intervention of minimally invasive percutaneous drainage works remarkably well.

Clinical Presentation and Diagnosis

Diagnostic Approach

In patients with suspected acute necrotizing pancreatitis, contrast-enhanced CT is used to identify presence, location, and size of pancreatic necrosis or peripancreatic fluid collection. Multiple, serial CTs during the entire clinical course should be carefully interpreted not to misread necrosis when the lack of enhancement may be due to inflammation or overlying fluid collections. Presence of pancreatic ductal disruption should also be sought in patients with necrosis. CT, ERCP, MRCP, and/or fluoroscopic drain studies when percutaneous catheter drainage was employed are the diagnostic modalities. Fluoroscopic drain studies or an ERCP may miss the leak site as sufficient volume of contrast may not be injected to clearly delineate the ductal anatomy at the site of disruption; therefore, evaluation of amylase activity in drainage fluid is useful to check for the presence of pancreatic leakage.

Pancreatic ductal anatomy has been successfully categorized in association with pseudocyst regardless of the presence of pancreatic necrosis [2] (Fig. 11.2). According to the types of pancreatic ductal injury after acute pancreatitis, consequences were predicted, and therapies were directed. A type III injury results in a clinical scenario known as the “disconnected pancreatic duct syndrome.” This scenario is associated with a

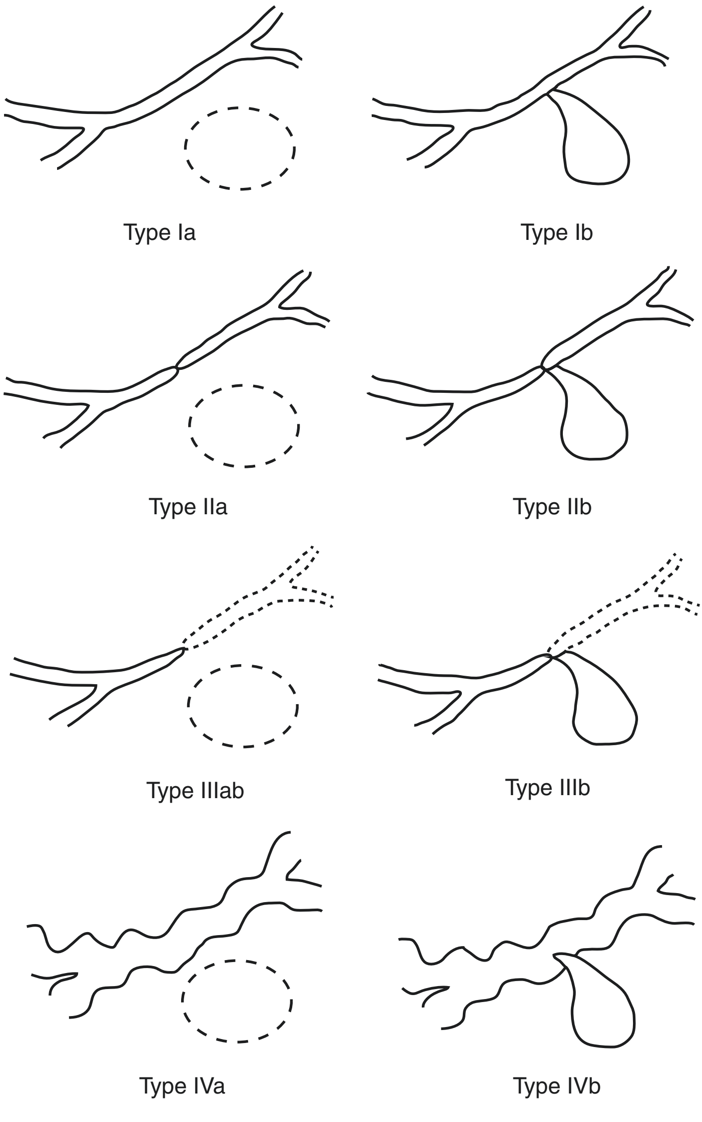

FIGURE 11.2 Schema of the type of pancreatic ductal disruption. (Sited from Nealon et al. [2])

more refractory clinical course with no spontaneous resolution, higher incidences of pancreatic fistula, recurrent pancreatitis, longer drainage time, and necessity of more aggressive treatment such as surgical debridement. In those patients with pancreatic ductal disruption proven in the pancreatic head/neck area, one should also be aware of the possible occurrence of biliary stenosis or gastric outlet obstruction developing later in their clinical course (2–3 months after the onset of acute pancreatitis) [3].

Indication and Rationale for Treatment

If a patient shows anatomic signs of persistent pancreatic leakage, such as persistent or enlarging peripancreatic collections, and the patient shows clinical deterioration with the signs, symptoms, and/or laboratory findings as listed in Table 11.1, then pancreatic collections (fluid or necrosis) should be drained. We have found that the likelihood of infection increases the longer the pancreatic leakage is uncontrolled which results in progressive peripancreatic

Table 11.1 Indications for percutaneous catheter drainage (PCD)

Presence of peripancreatic collections by computed tomography (CT) plus	
Symptoms	Refractory abdominal pain despite use of narcotics Inability to begin oral intake
Clinical signs	Persistent or enlarging fluid collection by CT Persistent abdominal distention/ileus Systemic inflammatory response syndrome and/or organ failure Persistent or increasing inflammatory data (C-reactive protein and/or white blood cell count) Persistent increase in serum amylase or lipase activity suggesting persistent pancreatic juice leakage

damage. All *symptomatic* fluid collections should be drained proactively with minimally invasive methods. If neglected a peripancreatic infection has been shown to result in systemic inflammatory response syndrome or isolated organ failure. The clinical process culminates in a higher mortality rate approximating 20–40%. Our premise is not to wait for infection but to halt the process.

Management and Treatment

Percutaneous Catheter Drainage

Percutaneous catheter drainage (PCD) is a minimally invasive drainage method to place a catheter with the shortest and safest route into the collections. The pioneering work [4] along with subsequent reports [5, 6, 7] popularized the significance of effective drainage of pancreatic necrosis with PCD. In 2010, a Dutch multicenter randomized controlled study (the PANTER trial) compared outcomes of primary open necrosectomy vs. minimally invasive "step-up" approach starting with PCD followed, if needed, by a surgical procedure such as video-assisted retroperitoneal debridement (VARD) or open necrosectomy. The study showed significant benefit of this minimally invasive step-up approach: 35% of the patients treated with a minimally invasive drainage procedure avoided any surgical procedure while experiencing similar mortality (19%) to the patients with primary open necrosectomy (16%) [8]. Since then, PCD has been used more frequently.

The CT-guided PCD began, in general, with placement of a 12Fr pigtail drainage catheter (Cook Inc., Bloomington, IN) which is attached to a low-pressure, closed suction drainage system (TRU-CLOSE, UreSil, Skokie, IL). The catheters are flushed with 10–20 ml of sterile saline three times daily. Contrast-enhanced CTs are obtained *every 3 days* after PCD to observe the status of the collection. Each CT is followed by a fluoroscopic drain study allowing cavity lavage and drain reposition, exchange, or upsize (up to 18Fr). Frequent imaging allows detection and treatment of new peripancreatic collections that can be drained using additional PCD sites. The frequency of CT/drain studies is decreased to *once a week* as the patient becomes clinically stable and the cavities decrease in size. Drainage fluid can be monitored for appearance and volume throughout the clinical course. Samples of the fluid are assessed for amylase activity, Gram stain, and microbiological culture at the time of PCD and anytime during the course. Drainage catheters are removed when the cavities are determined to be collapsed by CT and the output is minimal.

The goal of PCD is to achieve "*effective drainage*" with a low impact procedure. "*Effective drainage*" consists of two key elements to control pancreatic leakage—drain location and patency. Even though the drain may have been placed in the center of a fluid collection, subsequent CTs and serial fluoroscopic drain studies provide information regarding the presence and site of pancreatic ductal disruption; i.e., communication of contrast between the main pancreatic duct and peripancreatic space (Fig. 11.3a, b). Then, the drain can be maneuvered to the *site of leakage* from the pancreas (not necessarily the center of the original collection) (Fig. 11.3c). Drain patency can be maintained by frequent fluoroscopic drain studies, such as exchanging, upsizing, and lavage. By making use of a proactive protocol for PCD, our series of consecutive 39 patients with necrotizing pancreatitis did not require surgical necrosectomy and the patients had no pancreatitis-related mortality [9].

Endoscopic Treatment

The endoscopic approach includes transpapillary stenting to facilitate decompression of the main pancreatic duct using ERCP and endoscopic ultrasound (EUS)-guided transmural stenting (cyst-gastrostomy or cyst-duodenostomy) for pancreatic or peripancreatic fluid collection. In patients with a

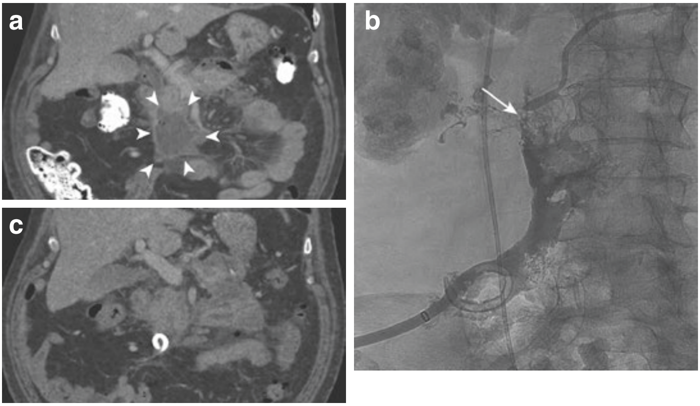

FIGURE 11.3 A 66-year-old male with severe acute necrotizing pancreatitis. (**a**) An abdominal computed tomography shows peripancreatic fluid collection localized inferiorly to pancreatic head. (**b**) A fistulogram drain study showed communication of contrast from peripancreatic fluid collection through main pancreatic duct *(arrow)*. (**c**) Tip of the drain was placed at the site of pancreatic duct disruption

disconnected pancreatic duct syndrome, it is desirable to place a transpapillary stent bridging from proximal (downstream) side of the pancreas to distal (upstream) side beyond the site of disruption. However, if not feasible, pancreatic juice leakage from the upstream side of a pancreatic ductal disruption requires percutaneous or endoscopic drainage. Endoscopists should also be cognizant of the risk of ERCP pancreatitis that might exacerbate the underlying inflammatory process.

EUS-guided transmural stenting can be performed as an alternative to PCD. Endoscopic necrosectomy can be done as an alternative to surgical necrosectomy [10]. Endoscopic drainage procedures allow patients to avoid external catheter placement and to establish internal drainage of leaked pancreatic juice to the gastrointestinal tract, especially for patients with a disconnected pancreatic duct syndrome. However, fluid collection must be located adjacent to the gastric wall or duodenum to be accessible for the endoscopic drainage procedure. Moreover, the endoscopic procedure may introduce infection into the peripancreatic space and, because no drainage can be collected, one cannot repetitively assess the appearance, volume, amylase activity, or microbiological culture of the drainage fluid. Particularly for direct endoscopic necrosectomy, the incidence of procedure-related adverse events is an issue to be overcome to include the potential for bleeding, perforation, or air embolism.

Efficacy of a combined percutaneous and endoscopic approach (dual-modality drainage) for symptomatic walled-off pancreatic necrosis has been advocated. By making use of dual-modality drainage, Ross et al.'s series of 117 patients with symptomatic walled-off necrosis demonstrated no need for surgical necrosectomy and no procedure-related mortality [11]. A recent multicenter randomized controlled trial comparing endoscopic step-up approach (endoscopic drainage followed, if necessary by endoscopic necrosectomy) vs. surgical step-up approach (PCD, if necessary followed by VARD) in patients with infected necrotizing pancreatitis showed that these treatment modalities were comparable in mortality (18% vs. 13%) or the occurrence of major complications [12]. They suggested the superiority of endoscopic approach because of the lower rate of pancreatic fistula (5% vs. 32%) or shorter length of hospital stay. However, we believe that the most compelling issue to save those patients from this highly lethal disease is not just a drainage method but *to control pancreatic juice leakage from the site of the pancreatic ductal disruption.* Success means immediate control with a low-impact drainage procedure.

Surgical Management

Traditionally, sick patients with infected pancreatic necrosis underwent open necrosectomy. An unacceptable mortality of 20–40% was observed. Although the "step-up" approach initiated with minimally invasive intervention is now primarily a standardized treatment for infected pancreatic necrosis, surgical debridement, including VARD or open necrosectomy, is always reserved as the last resort if less invasive treatment does not achieve *effective drainage*. However, failure of PCD is uncommon using a team effort and a monitoring protocol. VARD can be used to avert more invasive procedures or as a bridging therapy between PCD and open necrosectomy [13]. The technique of surgical necrosectomy removes just mature "necrosum" but the necrosectomy itself *does not control* pancreatic juice leakage. Once necrosectomy is completed, the surgeon still depends on the continued support of interventional radiology through regular exchange of percutaneous drains [14].

The current guidelines of the International Association of Pancreatology and the American Pancreatic Association stated that any intervention in necrotizing pancreatitis should be delayed more than 4–8 weeks after the onset of acute pancreatitis whenever possible in order to create walled-off necrosis. This recommendation is based on high mortality after primary open surgical necrosectomy from previous reports [15]. However, use of PCD as a less invasive approach done earlier, before development of infection in peripancreatic space, severe sepsis, or organ failure may preclude the need for these more invasive procedures. *Uncontrolled pancreatic leakage must be immediately and effectively controlled.* This hypothesis warrants a well-designed, prospective, randomized controlled trial to test the benefit of early minimally invasive intervention.

Multidisciplinary Team Approach

Patients with pancreatic ductal disruption should be managed during their entire clinical course in multidisciplinary fashion involving a team of interventional radiologists, hospitalists, nurses, dieticians, pharmacists, infectious disease specialists, intensive-care specialists, gastroenterologists, endoscopists, and pancreatobiliary surgeons. In the treatment modalities and strategies we mentioned above, we cannot always say which treatment is superior to others, because of the paucity of sufficient evidence and the variability in the patients' presentation. Two important prerequisites are necessary for a tailored approach for each patient. First is the assembly of a team, which requires years of recruitment using influence and leadership at centers of expertise in the treatment of these patients. Second, and possibly just as difficult as team assembly, is the design and use of a common algorithm that allows the reporting of data supported with the "power of n."

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Chapter 12
Acute Complications of Inflammatory Bowel Disease

Kenneth Bogenberger, Robert Conrad, and Suzanne Gillern

Inflammatory bowel disease (IBD) poses a challenging problem for the general surgeon. Despite advances in medical management, ulcerative colitis (UC) and Crohn's disease (CD) often present with acute and emergent surgical issues. Surgical intervention is generally reserved for failed medical therapy or complications of the disease. The complications that may require urgent surgical intervention include hemorrhage, acute severe colitis, perforation, obstruction, abscess, and fistula disease.

Medical Management

If at all possible, IBD patients should be admitted to the medicine service and a gastroenterologist consulted. Except for the few surgical emergencies described in this chapter, CD and UC should be treated medically until they become

K. Bogenberger · R. Conrad
General Surgery, Tripler Army Medical Center, Honolulu, HI, USA

S. Gillern (✉)
Department of Surgery, Tripler Army Medical Center, Honolulu, HI, USA
e-mail: Suzanne.m.gillern.mil@mail.mil

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refractory to such treatment. It is best to approach these complicated patients with a multidisciplinary team of specialists.

That being said, there are a few basic principles of medical management of both CD and UC that are important to understand. In the acute setting, corticosteroids and biologic therapy will be the first line of treatment. Corticosteroids induce remission in reported rates of between 67% and 92% [1, 2]. Typically, the starting dose is 60 mg methylprednisolone or an equivalent, followed by a slow taper down [3]. The downside of corticosteroids is there are significant side effects and they fail to maintain remission [4]. Corticosteroids will usually result in improvement of symptoms within 48–72 hours [3]. If this does not occur, or sometimes concurrently, patients will also get treated with a biologic agent. The most commonly used agents are infliximab (Remicade®, Inflectra®, Renflexis™), adalimumab (Humira®), and certolizumab pegol (Cimzia®), all of which are anti-TNF agents. Natalizumab (Tysabri®) and vedolizumab (Entyvio®) are integrin receptor antagonist and the newest biologic medications that may be used on IBD patients to induce remission. The addition of the biologic medications should lead to improvement in symptoms within 5–7 days. If clinical improvement is not seen at this point, surgery is often indicated [3].

Preoperative Considerations

When dealing with complications of IBD and faced with urgent or emergent surgery, there are several important factors to consider when developing the operative plan. Many IBD patients are chronically malnourished from insufficient dietary intake, malabsorption, systemic inflammation, and the side effects of medications [5]. One critical reason to avoid emergent surgery in this patient population, if possible, is to allow time to optimize their nutrition with the goal of decreasing postoperative morbidity [6]. Serum albumin of less than 3.5 g/dL has been shown to be a preoperative risk factor for anastomotic leak in elective colon surgery, and this data has been replicated for IBD patients as well [7, 8].

IBD patients are at a two- to threefold greater risk of suffering from venous thromboembolism. Patients with IBD undergoing surgery should therefore receive both mechanical and pharmacologic prophylaxis perioperatively [6].

Another factor to consider is that many of these patients will present to the surgeon already on immunosuppressive therapy. The use of steroids can lead to adrenal insufficiency (AI), which is critical to consider at the time of operation. Although there are no widely agreed upon patterns of steroid use that absolutely cause AI, patients who receive greater than 15 mg of prednisone or an equivalent dose daily for more than 3 weeks are likely to suffer from AI and should therefore be treated appropriately at the time of anesthesia induction [6].

There are many individual factors that should be considered when determining if diversion will be required in an operation for IBD. One of these critical factors is the patient's nutritional status as its importance was previously highlighted. In addition, although the impact of high-dose glucocorticoids and other immunomodulators such as the anti-TNF agents in the setting of sepsis or anastomotic leaks has yet to be universally agreed upon in the literature, they still likely play some role in the development of anastomotic leaks and need to be considered [6]. There are intra-operative factors that should also be evaluated to include the patient's hemodynamic stability, degree of abdominal contamination, and amount of bowel edema. Ultimately, the decision to perform diversion in IBD cases should be made on an individual basis for each patient, taking into account all of these factors as well as the surgeon's judgment [9].

Acute Hemorrhage

Acute lower gastrointestinal hemorrhage is a very rare complication of both UC and CD, occurring in 1–4% of patients [10, 11]. The bleeding from IBD is most often caused by inflammation and thus can often be successfully treated with corticosteroids and biologic therapy [10]. IBD patients with significant hemorrhage should immediately undergo resuscitation and diagnostic imaging. Stable patients may be treated by endoscopic or interventional radiologic techniques [9]. Operative exploration should be limited to those patients that are clinically unstable. In the case of both Crohn's colitis and UC, it is recommended that a total colectomy be performed in this setting. [9, 12]

Acute Severe Colitis

Acute severe colitis is not very common, occurring in approximately 5–8% of patients with UC and only 4–6% for CD [13, 14]. In both UC and CD, clinical evidence of acute severe colitis, noted by impending or actual perforation, are indications for urgent surgical intervention. Acute severe colitis is defined as greater than six bloody stools per day with signs of systemic toxicity, to include fever (>37.8 °C), tachycardia (>90), anemia (<10.5 g/dL), and elevated erythrocyte sedimentation rate (ESR >30 mm/h) [15]. Fulminant or toxic colitis is defined by the presence of systemic toxicity, greater than ten bloody stools per day, a transfusion requirement, colonic dilation on imaging, and abdominal distention and tenderness [15]. When the transverse colon is dilated >5.5–6 cm and the patient has associated signs of systemic toxicity, the diagnosis is toxic megacolon [16]. Patients with toxic colitis are at an especially high risk of perforation, and surgery is required 20–30% of the time [17]. Mortality in the setting of toxic colitis and IBD dramatically rises if perforation occurs, increasing from 2–8% up to 27–40% [18, 19]. For this reason, if there is concern for toxic colitis, early surgical intervention is preferred.

When initially consulted on the acute severe colitis patient, other causes of the colitis must be ruled out, specifically *Clostridium difficile* and cytomegalovirus. This may be done by performing both stool studies and endoscopic biopsy [20]. Initial management should include admission to a monitored setting, resuscitation, and early administration of maximal medical therapy. The use of antibiotics and nasogastric decompression may be considered but they have not been shown to consistently improve outcomes in severe colitis. Narcotics and antidiarrheal medications should be avoided [9, 12]. Imaging, preferably a computed tomography (CT) scan of the abdomen and pelvis with IV and oral contrast should be performed to evaluate for increasing dilation, evidence of pneumatosis, or free air, all of which are ominous signs. If the patient clinically deteriorates or does not medically improve after 5–7 days of corticosteroids and biologic agents, surgery is indicated [9, 12].

Whereas the goal of elective surgery is to remove all diseased colon, the goal in urgent/emergent surgery for IBD is to rescue the patient from life-threatening systemic toxicity by removing most of the inflamed intestine in the most efficient and safe manner that avoids a difficult pelvic dissection. Restorative procedures are not recommended in this operative setting for both UC and CD patients [21]. The preferred surgery is a total abdominal colectomy with end ileostomy [9, 12]. The distal extent of resection should be the sigmoid colon at or near the level of the inferior mesenteric artery as this will allow easier anatomic dissection for likely subsequent restorative operations. Due to the remaining inflammation of the distal bowel being left behind and the risk of perforation of this distal staple line, the surgeon should consider extrafascial closure of the closed rectosigmoid stump or abdominal drains with transanal drainage of the distal stump to decrease the risk of pelvic sepsis [9, 12, 21]. Restorative procedures can be considered 4–6 months later, based on the overall health status of the patient [21].

Bowel Obstruction

Bowel obstruction is a relatively common complication of IBD, being much more common in CD as it accounts for approximately 20% of the operations performed on these patients [22]. UC, unlike CD, is not a transmural process, with inflammation generally confined to the mucosa. The presence of obstruction in patients with previously diagnosed UC should prompt an evaluation to look for the etiology of the obstruction. A colonic stricture in the setting of UC harbors a malignancy approximately 25% of the time, regardless of negative biopsy results, and therefore an oncologic resection is indicated in these patients [12].

CD, in contrast to UC, is characterized histologically by transmural inflammation of the bowel and may present phenotypically in a fibrostenotic obstructing pattern or a penetrating fistulous pattern [23, 24]. When facing a Crohn's patient with obstructive symptoms, the most important thing to do is establish the source of obstruction. Symptoms may be a result of active inflammation, fibrotic stricture, or an anastomotic stricture. Although much more rare, patients may also present with obstruction secondary to adhesive disease from prior surgery, malignancy, or foreign bodies such as capsules or plant material. Any patient who presents with obstruction with either known or suspected Crohn's disease should have a thorough workup to include imaging and laboratory data. CT should be performed with IV and oral contrast. Consideration should also be given to obtaining CT or MRI enterography, as they both have a high sensitivity and specificity for identifying an obstruction from active inflammation or fibrostenosis [9].

CD patients with evidence of small bowel obstruction should be managed with nasogastric tube placement, fluid resuscitation, and a trial of IV corticosteroids. In the setting of inflammation, the obstruction will usually resolve with steroid treatment, and surgery can be avoided [25]. If the stricture is not responsive to steroid therapy or appears to be at the site of previous anastomosis, endoscopic evaluation, if anatomically feasible, is recommended [9]. Surgery is usually indicated if a fibrotic stricture is seen at the time of endoscopy. However, if the stricture is present at an anastomotic site, endoscopic dilation is the preferred treatment option, with over 80% success rate reported [26].

Once the decision has been made to proceed to the operating room, the primary tenet of surgery in this setting is to minimize the amount of bowel resected as recurrence rates are high and the patient may need future procedures. As many as 45% of patients require additional resections within 10 years [27]. With this in mind, patients should undergo a limited resection with gross negative margins of disease of approximately 2 cm. Recurrence rates do not increase with presence of microscopic CD at the margins [28]. One technique to determine healthy bowel is to use the thumb and index finger to palpate the mesenteric border of the bowel. A healthy target for resection will be where the thumb and index finger can be felt with minimal thickening and the bowel edges are soft [29]. When performing the bowel resection, it is important to be aware that the mesentery is likely very thick in the diseased area and may require suture ligation.

Stricturoplasty is a surgical option but should be reserved for patients who have non-inflamed strictures, diffuse involvement of the small bowel, short bowel syndrome, impending short bowel syndrome, or disease that recurs very rapidly [9]. Stricturoplasty allows for maximal preservation of bowel length while achieving the primary goal of relieving the obstruction; however it can lead to bacterial overgrowth and potential for malignant degeneration [30, 31]. The most commonly performed stricturoplasty is the Heineke-Mikulicz, which is performed by making a longitudinal incision on the antimesenteric side of the bowel followed by closure of the enterotomy transversely. This method is best utilized for strictures less than 10 cm. Other types of stricturoplasty include the Finney and Michelassi, or longitudinal isoperistaltic stricturoplasty, which are utilized for longer strictures [32].

Perforation

Perforation in the setting of active CD is a rare but potentially devastating indication for surgery that occurs in 1–3% of Crohn's patients [33]. The most common etiologies are an obstruction or toxic colitis. The presenting symptoms may be masked in the setting of immunomodulatory therapy, particularly high-dose steroids. A high clinical suspicion should be maintained in any patient with an active Crohn's flare who clinically deteriorates.

Immediate surgery is indicated when perforation is discovered. Perforations are usually solitary and most commonly occur in the ileum if severe colitis is not present [33]. Resection of the perforated segment is typically performed with primary anastomosis [34]. Diversion is indicated in the presence of hemodynamic instability, edematous bowel, technical challenges of the case as well as the aforementioned patient factors [9].

Colonic perforations can occur but are more commonly seen in the setting of UC and toxic colitis [35]. If a colonic perforation occurs at the cecum due to distal stricture or at the site of necrosis in the setting of toxic colitis, it is recommended to perform a total abdominal colectomy and end ileostomy [12].

Intra-abdominal Abscess

Intra-abdominal abscesses are not uncommon in the setting of CD and are often the result of perforation that is contained by the surrounding structures. Initial management in the setting of a hemodynamically stable patient consists of broad-spectrum antibiotics covering gram-positive, gram-negative, and anaerobic flora [36]. For larger abscesses (>3 cm), the treatment strategy of choice is parenteral antibiotics in addition to percutaneous drainage of the abscess performed by interventional radiology in order to avoid a potentially more morbid emergency surgery [37, 38]. It has been reported that up to 78% of the time, percutaneous drainage is successful in achieving resolution of the abscess and avoidance of urgent surgery [39]. Although nearly 30% of patients who undergo percutaneous drainage require surgery within a year, it serves as a bridge to definitive surgery resulting in decreased operative complications [38, 40]. If emergent surgery is required, a resection is preferred over operative drainage alone [9].

Enteric Fistulas

Fistulas in CD are fairly common and are responsible for up to 24% of surgeries performed on Crohn's patients [22, 41]. Enteroenteric fistulas are the most common fistulas that form in CD and the most common location is the terminal ileum [42]. Other types of fistulas include enterocutaneous fistulas and fistulas to other intra-abdominal organs such as the colon, bladder, stomach, or vagina.

Most fistulas do not require urgent or emergent surgical management. The first step in management is to determine if sepsis is present. If the patient is septic, he or she should be appropriately resuscitated and parenteral antibiotics initiated. A CT scan should be performed to look for uncontrolled source of sepsis such as an associated abscess, in which case a percutaneous drain should be considered. If the patient continues to be septic, operative intervention is required with resection of the diseased bowel [9].

In a patient without sepsis there is no urgent need for surgical intervention. Symptoms of fistula are malabsorption, diarrhea, and recurrent infections. If the patient is asymptomatic, which often occurs if only a short loop of bowel is bypassed by an enteroenteric fistula, no treatment is needed. If surgery is warranted due to symptoms, the patient should be medically optimized. The principle of surgery is to remove the diseased portion of bowel and the non-diseased bowel can be closed primarily. Other organs that may be involved such as the bladder or vagina may be closed primarily or left to heal by secondary intention [9].

Role of Laparoscopy in Acute Management of IBD

Laparoscopy is a safe option for the treatment of IBD. It has been found to be equivalent to open surgery in the well-chosen patient and setting [43]. A recent meta-analysis compared laparoscopic and open surgery in the treatment of CD and found the laparoscopic group had longer operative times, but faster recovery of bowel function and shorter hospital stay. In addition, the overall morbidity was lower in the laparoscopic group [44]. Even in the emergent setting of acute severe colitis and toxic megacolon, studies support that laparoscopic colectomy is safe and effective in experienced hands with appropriate patient selection [12, 45, 46]. The current data suggest that laparoscopy may allow for shorter time interval between each surgery of the three-stage surgical approach to UC [47].

Conclusion

IBD is a complicated disease process that is best treated initially with medical therapy with the assistance of medical specialist. At times, the clinicians can wait up to 7 days to see if medical management, biologic agents in particular, will be effective. However, in some circumstances, to include life-threatening hemorrhage, acute severe colitis, free perforation, or septic patients with intra-abdominal abscess or fistula, surgery may be emergently indicated. In cases involving the small bowel, every effort should be made to remove as little bowel as possible and individual consideration given to determine if diversion is required. For patients with colonic emergencies, an abdominal colectomy with end ileostomy is recommended. Laparoscopy can be safe and beneficial in IBD patients and should be considered in the emergency setting.

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Chapter 13
Minimally Invasive Techniques in Trauma: Above and Below the Diaphragm

Jarrett R. Santorelli, Daniel J. Bonville, Alexi Bloom, and Weidun Alan Guo

Introduction

Once thought to only be of use in elective general surgery specialties, minimally invasive surgery is gaining popularity in the fields of emergency general surgery and trauma. In this chapter we explore the uses of minimally invasive techniques in trauma surgery. Since its acceptance by general surgeons in the 1990s, laparoscopy has become the gold

J. R. Santorelli · W. A. Guo
Department of Surgery, Jacobs School of Medicine and Biomedical Sciences, University at Buffalo, Buffalo, NY, USA
e-mail: waguo@buffalo.edu

D. J. Bonville (✉)
Acute Care Surgery & Surgical Critical Care, Houston Methodist Hospital, Houston, TX, USA

Department of Surgery, Houston Methodist Specialty Physician Group, Houston, TX, USA
e-mail: djbonville@houstonmethodist.org

A. Bloom
Department of Surgery, Houston Methodist Hospital, Houston, TX, USA

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standard in several arenas. Its adoption in trauma patients, however, has been slow to gain traction. Major concerns surrounding laparoscopy in trauma address the increased expenses of laparoscopy, ineffectiveness at visualizing the entire abdomen, increased length of time in the operating room, and missed injuries. A 2016 meta-analysis of one randomized controlled trial (RCT) and eight observational studies found a missed injury rate of only 0.12% [1]. With the use of a standardized format in evaluating the abdomen for intraabdominal injuries, Koto et al. found a decrease in missed injury rate from 13% to less than 1% [2].

Advocates for the use of laparoscopy in trauma argue decreased length of stay with both diagnostic and therapeutic laparoscopy, decreased incidence of surgical site infections (SSI), pneumonia, decreased postoperative pain, and decreased rates of postoperative ileus [2, 3]. Laparoscopy in trauma can be broken down into three different categories: screening, diagnostic, and therapeutic. The original use of laparoscopy being a screening modality to rule out peritoneal penetration, which was found to significantly decrease the rate of negative laparotomies. Diagnostic laparoscopy has been described as a stepwise evaluation of the intra-abdominal cavity in order to identify injuries [2]. Finally, therapeutic laparoscopy delineates the actual management of these injuries laparoscopically.

At this time various diagnostic tests used to assess abdominal trauma include local wound exploration (LWE), diagnostic peritoneal lavage (DPL), abdominal US (FAST), and computed tomography (CT). Even with a positive LWE, the rate of nontherapeutic laparotomy is quoted at 43% [2]. Diagnostic laparoscopy offers an arguably equivalent assessment of abdominal injuries to these modalities with the added benefit of therapeutic options. Diagnostic laparoscopy offers nearly 100% sensitivity in detecting peritoneal penetration [4]. Important to note, however, is that the majority of studies assessing the use of diagnostic laparoscopy in comparison to exploratory laparotomy in trauma patients were performed in hemodynamically stable patients suffering penetrating abdominal trauma. Very little literature around laparoscopy in hemodynamically unstable patients with penetrating injuries and those who are victims of a blunt abdominal trauma. Stability, however, is very subjective with some studies using systolic blood pressure less than 90 mmHg and mean inspiratory pressure greater than 30 [2] and many others using surgeon judgment as their criteria.

The need for an alternative to laparotomy is highlighted by the risks involved in a nontherapeutic laparotomy. Postoperative complications including surgical site infections, pneumonia, increased length of stay, increased postoperative pain, delayed return of bowel function, and ventral hernias all add to the morbidity associated with a nontherapeutic laparotomy. Complication rates associated with nontherapeutic laparotomy range from 20% to 61% [2]. The avoidance of nontherapeutic laparotomy has been reported to be 45.6–63.0% with the use of diagnostic laparoscopy even with blunt injuries [1, 4, 5].

Exploratory laparotomy has traditionally and currently remained the gold standard for the exploration of penetrating abdominal trauma due to its accuracy and effectiveness in diagnosing abdominal trauma [6]. Laparotomy, though, is associated with well-documented risks including complications rates up to 41% and a mortality rate of up to 5%, a 20% morbidity rate, and a 3% long-term risk of bowel obstruction [6–8].

In an attempt to decrease the number of negative laparotomies performed and to avoid its complications, many advances have been made in the algorithm for nonoperative management. These techniques have included local wound exploration, CT scanning, observation with serial exams, and more recently diagnostic laparoscopy [9–12].

In this chapter we will discuss the use of laparoscopy in various clinical scenarios in trauma patients. We will also discuss the use of minimally invasive techniques for foreign body ingestion and the use of video-assisted thoracoscopic surgery (VATS) in the management of thoracic trauma.

Specific Clinical Scenarios for Laparoscopy in Trauma

Free Peritoneal Fluid Without Solid Organ Injury (Especially in TBI Patients)

The generally accepted method of investigation for the stable blunt abdominal trauma patient includes CT scan. However the false-negative rate and low sensitivity for hollow viscous injury diagnosed by CT remains a concern. A recent study showed that laparoscopy reduced the nondiagnostic laparotomy rate and was effective for the treatment of patients with blunt abdominal trauma and hemoperitoneum, with an overall failure rate as low as 4% [13]. Retrospective analysis by Lee et al. demonstrates that patients with blunt abdominal trauma underwent a 12.8% nontherapeutic laparotomy rate, mainly from intraperitoneal fluid accumulation caused by a retroperitoneal hematoma. After the adaptation of laparoscopy to the treatment algorithm, there was a statistically significant reduction in this rate [13, 14].

Essential to the avoidance of missed injuries is implementing a systematic approach. Lee et al. developed a protocol as can be seen in Fig. 13.1 in order to ensure the same approach was taken in each case to ensure complete exploration was performed. These procedures can be performed using either a totally laparoscopic or laparoscopically assisted technique. The diagnostic and therapeutic techniques have been described by different authors [13, 15, 16]. Briefly, the patient should be placed in the right lateral semidecubitus position with the left arm placed above the head. The figuration of trocar placement is shown in Fig. 13.2. Once pneumoperitoneum is established, the intra-abdominal organs should be explored systematically in two different compartments: the supramesocolic and inframesocolic compartments. For thoroughly exploring the supramesocolic compartment organs (the liver, spleen, stomach, omentum, transverse colon, and diaphragm), the patient was placed in reverse Trendelenburg position. The pancreas and the posterior gastric wall should be

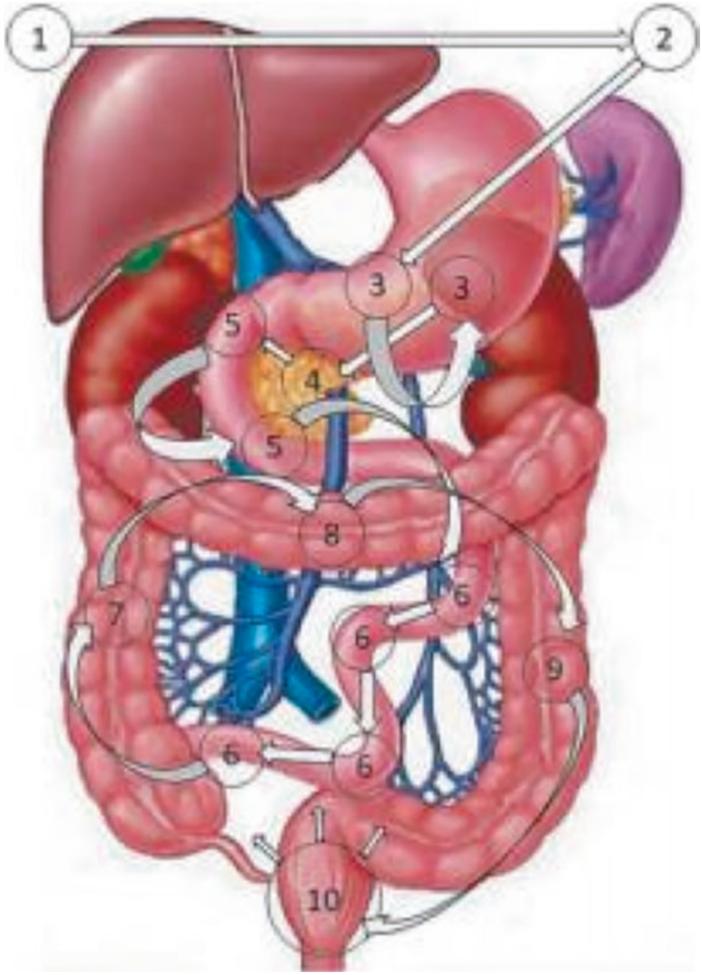

FIGURE 13.1 Memory aid. (Koto et al. [36])

inspected through the gastrocolic ligament. To inspect the organs in the inframesocolic compartment (rectosigmoid colon, urinary bladder, and the iliac regions and the female reproductive organs), the patient should be placed in the steep Trendelenburg position. The ascending colon and the small

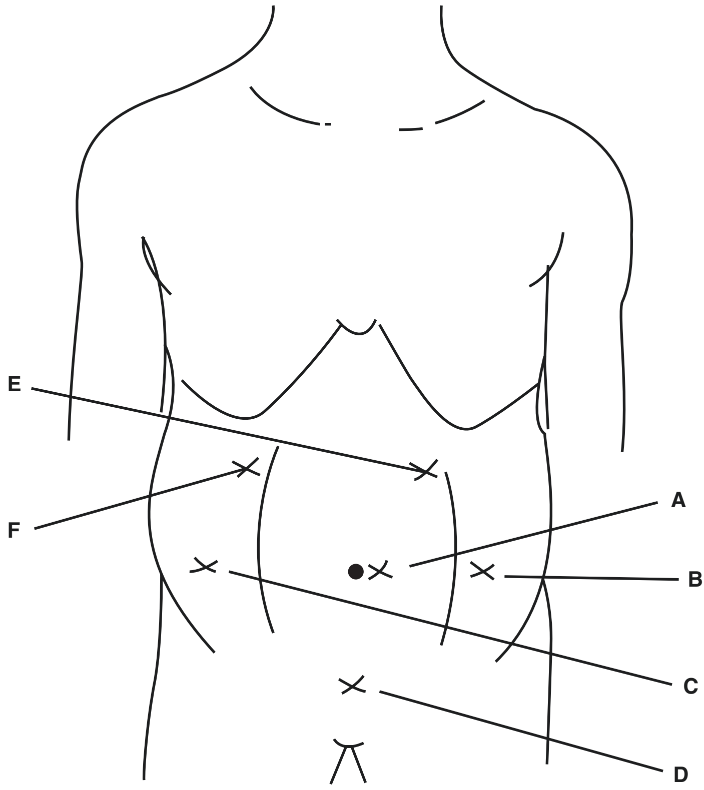

FIGURE 13.2 Steps for diagnostic laparoscopy for blunt abdominal trauma. (1) Port placement and establishment of pneumoperitoneum as seen in A–D. (2) Examination of solid organs, stomach, omentum, transverse colon, and diaphragm in the reverse Trendelenburg position. (3) Entry into lesser sac with examination of the pancreas and posterior stomach. (4) Place patient in steep Trendelenburg, and perform inspection of the pelvic structures, including the rectosigmoid colon, urinary bladder, and the iliac regions. (5) Evaluation of the ascending colon and the small bowel, a hand-to-hand technique was performed. (6) Placement of additional ports as needed for diagnosed pathology

bowel should be run in a "hand-to-hand" technique. The systematic exploration of the peritoneal cavity during laparoscopy requires the surgeon to maintain a linear sequence that covers the entire contents of both compartments.

Once the diagnostic mission is completed and an intra-abdominal injury is identified, the surgeons should embark on the therapeutic endeavor [17]. For hemoperitoneum due to omentum or mesenteric injuries, electrosurgical energy (Bovie, bipolar devices, etc.), electrocautery, or sutures can be used. If solid organ laceration with bleeding could not be controlled using electrosurgical energy, electrocautery should be attempted first. If this is not successful, a hemostatic agent can be used to gently pack into the laceration wound and held in place with or without intracorporeal sutures. For viscus perforation, repair or resection and anastomosis of perforated with laparoscopic or laparoscopically assisted procedures. The resection and anastomosis can often be performed with a 3–5 cm minilaparotomy incision. It should be emphasized that if the surgeon is not comfortable with the procedures, the injury is extensive, or the patients become unstable during the procedure, the procedure should be converted to open based on the extent of injury, patient's condition intraoperatively, and surgeon's experience.

46.5% of patients with blunt abdominal trauma have associated traumatic brain injury (TBI) [18]. At first glance this population group appears to be a population amenable to diagnostic and therapeutic laparoscopy due to the association with having an unreliable physical examination. However this is a common pitfall to be avoided. TBI constitutes an additional risk especially in the face of elevated intracranial pressure (ICP). Studies have demonstrated abdominal insufflation and elevated intra-abdominal pressure have been shown to further increase ICP, leading to potentially worsening outcome [19–21]. Because of these findings, we recommend extreme caution in considering laparoscopy in the treatment algorithm for patients with blunt abdominal trauma and TBI without the use of invasive ICP monitoring. A lower insufflation pressure may be used for TBI patients with intraperitoneal free fluid [6].

Abdominal Wall Contusion and Abdominal Pain

Hollow viscus injury (HVI) occurs in approximately 1% of blunt trauma patients and 3–5% of patients with abdominal trauma [7, 8]. While laparoscopy is emerging as both a diagnostic and therapeutic modality, patient selection remains of the utmost importance. The well-known abdominal "seatbelt" sign, ecchymosis of the abdominal wall, occurs secondary to the three mechanisms: direct injury resulting in compression and contusion, acceleration/deceleration injury causing shearing, and burst injuries. The seatbelt sign, increasing abdominal pain, and distension are all associated with HVI, lumbar spine injury, and chest injuries [7, 9]. While multidetector CT has become more sensitive in detecting intra-abdominal injury, there are few pathognomonic signs of hollow viscus injury, and abdominal exam can be unreliable. In the case of absence of the radiologic signs with increasing abdominal pain with an associated seatbelt sign, patients have often undergone laparotomy to rule out missed injury. In meta-analysis performed by Li et al. including 4 RCTs and 15 cohort studies, there was a statistically significant shorter hospital and ICU stay in patient's undergoing laparoscopy. Additional conclusions in this review include that laparoscopy could significantly reduce the risk of postoperative complications, perioperative mortality, intraoperative blood loss, and duration of postoperative pain and time to regular diet were significantly shorter when compared to laparotomy [10].

Patients eligible for laparoscopy should be hemodynamically stable with systolic blood pressure >90 mm Hg. In this patient population, the use of diagnostic laparoscopy may significantly reduce the morbidity associated with laparotomy as well as the morbidity associated with missed hollow viscus injury in nonoperative management.

Omental Evisceration

Exploratory laparotomy has traditionally and currently remained the gold standard for the exploration of penetrating abdominal trauma due to its accuracy and effectiveness in diagnosing abdominal trauma [12]. Laparotomy is associated with well-documented risks including complications rates up to 41% and a mortality rate of up to 5%, a 20% morbidity rate, and a 3% long-term risk of bowel obstruction [12, 22, 23].

In an attempt to decrease the number of negative laparotomies performed and to avoid its complications, many advances have been made in the algorithm for nonoperative management. These techniques have included local wound exploration, CT scanning, observation with serial exams, and more recently diagnostic laparoscopy [23–36].

In the setting of a patient presenting with a penetrating abdominal wound, either high or low velocity, with organ or omental evisceration, the question of peritoneal involvement has been answered. Studies have demonstrated that the overall incidence of significant injuries among the asymptomatic patients who had penetrating abdominal stab wounds with organ or omentum evisceration was 36.5–64% despite the normal hemodynamic status and lack of peritonitis [27, 28]. Therefore, an abdominal exploration is warranted. There has been much hesitation in the trauma community due to studies from early era of laparoscopy which reported missed injury rates as high as 77% [24], perceived inability of detailed exploration of all areas of the abdomen [5], and prolonged operative time. However, recently, data has revealed substantially lower missed overall injury rates ranging from 0% to 3.2% [15, 30–35]. The use of therapeutic laparoscopy has recently been demonstrated to be a safe and effective treatment modality [15, 35]. In surgeons with an experienced hand, the sensitivity of laparoscopy in penetrating abdominal trauma ranged from 66.7% to 100%, with specificity of 33.3–100%, and accuracy of 50–100% [36].

Evaluation and Repair of Diaphragmatic Injury

Diaphragmatic injuries are not uncommon with rates as high as 5% for patients hospitalized after motor vehicle accidents, and 15% for patients after penetrating injuries to the lower chest and upper abdomen [37–39]. About 75% of all acute diaphragmatic hernias are encountered in the left chest. In 1984, Adamthwaite suggested laparoscopy as a valuable tool for identifying a traumatic diaphragmatic injury [40]. In Fabian et al.'s report in 1993, patients identified as having a diaphragmatic injury on laparoscopy generally underwent conversion to laparotomy for repair [34]. More recently with the adaptation of diagnostic and therapeutic laparoscopy in the evaluation of trauma patients, surgeons have applied minimally invasive surgical techniques for the repair of acute diaphragmatic lacerations and chronic traumatic diaphragmatic hernias [41–44].

Techniques for repair are governed by the presence or absence of concomitant injuries. The standard repair involves the placement of simple, mattress, or figure of eight nonabsorbable sutures. In the setting of associated lung injury chest tube placement should be considered. In cases of associated perforation of abdominal viscera, it is essential to consider irrigation of the chest cavity to prevent occurrence of empyema which has been documented to be three times as prevalent with an associated hollow viscous injury [45]. In the setting of delayed presentation of traumatic diaphragmatic injury without other associated injuries, prosthetic repair has been described with the use of PTFE graft and/or nonabsorbable suture [46, 47]. During either route of repair, it is important not to injure the phrenic nerve, which can be found running through the left hemidiaphragm after passing over the pericardium of the left ventricle as this can cause the hemidiaphragm to become ineffective [45].

At this time, diagnosis of diaphragmatic injury using noninvasive measures remains with low sensitivity unless associated with large blow out injuries seen on imaging. However, with the advent of diagnostic laparoscopy, multiple studies including Murray et al. have reported increasing number of injuries up to 42% incidence [48]. As with other traumatic blunt and penetrating abdominal injuries laparoscopy has been demonstrated to represent a safe and effective diagnostic and treatment modality.

Laparoscopy in Foreign Body Ingestions

Foreign body ingestion remains a common problem in both the pediatric and adult population. In the management algorithm, surgical intervention is rarely indicated as the vast majority of foreign bodies pass through the GI tract uneventfully or are successfully removed via endoscopy [49, 50]. While the mainstay of surgical management has traditionally been celiotomy, the implementation of laparoscopic management of foreign body ingestion is slowly gaining popularity [51, 52].

Between 1% and 14% of FB ingestions will eventually require surgery with indications including failure of retrieval, contraindication to retrieval, and complications associated with retained foreign body. The most common complications include intestinal perforation, bleeding, and obstruction with perforation being the most common and occurring in <1% [50, 51]. Chia et al. describe the largest case series to date including five cases of incidental fish bone ingestion in which all foreign bodies were successfully removed via laparoscopic approach with no associated morbidity or mortality [53]. Other reports include removal of sewing needles [51, 54], toothpicks [55], and bezoar [56].

Laparoscopic approach has varied based on the size, location, and indication for surgical removal. For all foreign objects, the procedure should start with systematic exploration of the abdomen in a manner similar to diagnostic laparoscopy for trauma (see protocol and port placement above in Fig. 13.1). For large sharp gastric foreign bodies unamenable to endoscopic retrieval, the approach commonly consists of a combined laparoscopic and endoscopic approach. During this procedure it is often helpful to have an endoscope in place to provide insufflation and intragastric manipulation of the foreign object. A laparoscopic gastrotomy is made and the object removed from the stomach. Depending on the size and the shape, the objects can often be removed from one of the port sites or via endocatch device with laparoscopic closure of the gastrotomy [56]. For intestinal foreign bodies it seems that a totally minimally invasive approach has not been described and may not be possible. However a laparoscopic hand-assisted approach with minilaparotomy may be beneficial in reducing patient morbidity compared to traditional laparotomy.

For patient presenting with perforation and intra-abdominal infection, the laparoscopic approach should be strongly considered. Multiple case reports have documented successful foreign body removal with diagnostic laparoscopy including abscess drainage, closure of enterotomy or gastrotomy, and omental patching with great success [51–54, 57].

Using a laparoscopic approach for removal of complicated foreign bodies appears to be a safe and effective treatment modality. Advantages to this technique include well-documented benefits of laparoscopic vs open surgery including a shorter LOS, less postop pain, decreased postop hernia formation, and decreased incidence of wound infection [52, 53, 57].

Laparoscopic Washout of Peritoneum After Hepatic Trauma

Over the last century, the management of blunt hepatic trauma has evolved from observation, to mainly operative intervention, to the current practice of selective operative and nonoperative management. Nonoperative management of blunt hepatic injuries currently is the treatment modality of choice in hemodynamically stable patients, irrespective of the grade of injury or patient age [58, 59]. The advantages of this nonoperative technique have been well documented [60]. Despite its advantages, complications related to nonoperative management, including ongoing or delayed bleeding, hemobilia, biloma, biliary fistula, bile peritonitis, and peritoneal inflammatory syndrome (fever, leukocytosis, discomfort, and tachycardia), are not uncommon [60, 61].

The combination of bile and blood in the peritoneal cavity is suspected to lead to a chemical peritonitis and systemic inflammatory response syndrome (SIRS) as described by Carrillo et al. [62–65]. Additionally, bile leak and peritonitis has been identified as a risk factor for increased morbidity in hepatic injury [62, 66].

While the conventional treatment of bile peritonitis has been laparotomy, recent advances in surgical technology have created additional treatment options [61, 67]. Multiple studies have showed that about a quarter of the patients treated non-operatively required a delayed surgery for complications [60, 64, 68]. Percutaneous drainage has been used in many large series however is insufficient in the case of large diffuse bile collections within the peritoneal cavity [62]. Multiple small case series have now been published reporting the use of laparoscopy with peritoneal irrigation and evacuation to lead to resolution of peritoneal sirs with an improvement in morbidity and mortality associated with laparotomy. These interventions were commonly necessary and performed 3–5 days postinjury [60–62, 64, 69]. This technique is often used in conjunction with endoscopic intervention with biliary prosthesis to further control ongoing bile leak.

While the data is currently limited with no large prospective studies, it appears that laparoscopic management of peritoneal inflammatory syndrome due to large retained hemoperitoneum, infective perihepatic collections, and bile peritonitis after severe hepatic trauma initially treated by NOM is safe and is recommended by several guidelines [58–60, 66, 70].

Is There a Role for Laparoscopy in Hemodynamically Unstable Patients?

On review, the majority of reported series emphasize the importance of hemodynamic stability when considering the use of laparoscopy for traumatic injuries [15, 39, 71, 72].

Furthermore it has also been recommended to use extreme caution when using laparoscopy in the patient with severe blunt abdominal trauma with a low threshold for conversion to an open procedure if hemodynamic status deteriorates [72]. Many of the concerns for the use of laparoscopy stem from the side effects of pneumoperitoneum: reduction of lung volumes, reduction of cardiac index, increased systemic vascular resistance, and systemic hypercapnia. Despite this commonly held belief, Cherkasov et al. sought to demonstrate the potential of laparoscopy in hemodynamically unstable patients [73]. In this study retrospective analysis was performed over a 6-year period with the laparoscopic group in which the intra-abdominal insufflation of 9–12 mmHg demonstrates a 73% reduction in laparotomy, 4.7% reduction in mortality, and 7.9% reduction in postoperative complications. According to the authors, most of the victims presented with shock, 50.7%, 24.7%, and 15.9% in mild, moderate, and severe shock, respectively. However, they did not specify the criteria in the diagnosis of shock, neither did they report how to treat intraoperative hemodynamical instability.

Despite these encouraging results it remains our opinion that patient selection is essential for the use of both therapeutic and diagnostic laparoscopy. Until further prospective studies can demonstrate its safety, in alignment with most published series and literature review [31, 74, 75], we recommend the use of laparoscopy to be restricted to hemodynamically stable patients.

The Use of Video-Assisted Thoracic Surgery (VATS) Techniques in Trauma

Retained Hemothorax or Ongoing Hemorrhage

Several authors have shown the utility of VATS for retained hemothorax (HTX) [76–82] in trauma patients. Placing a second chest tube to treat persistent HTX in these patients often leads to delay of definitive management and a higher chance of empyema and the need for open thoracotomy. Early VATS, instead of a second chest tube, has now become the standard management for retained HTX [76, 78]. Early VATS has also led to better outcomes even in brain-injured patients who did not require craniotomy [83]. Another recent study showed that irrigation when placing the initial chest tube may avoid further intervention for retained HTX as well [84].

For ongoing intrathoracic or chest wall hemorrhage in a hemodynamically stable patient, VATS is an excellent diagnostic and therapeutic option. The two most common sites of hemorrhage in this patient group are the ones bleeding from lung parenchyma or intercostal vessels. For repairing intercostal vessels, locate the injury with the use of a finder needle, make a small incision on the skin superficial to the injury, and use a suture passing device (Carter-Thomson, PMI, etc.) to ligate the injured vessel. This technique works very well in most cases.

Persistent Pneumothorax Including Repair of Lung Laceration

Chou et al. studied 88 patients who had VATS for HTX with lung laceration who were divided into two groups [78]. Group 1 had evacuation only, whereas Group 2 had evacuation with repair of resection of the laceration. Group 2 had significantly better outcomes including length of stay (LOS) and infectious complications as well as shorter duration of chest tube.

Ahmed and Jones reviewed the indications and subsequent outcomes for VATS. Early VATS has a high success rate and reduces risk of empyema and trapped lung. Mortality ranges from far less 1% for patients who have early evacuation to almost 10% if they develop empyema [79].

VATS for persistent pneumothorax should be considered if the injured patient has a persistent air leak despite treatment with a chest tube for >72 h. Those that take longer than 72 h may persist for weeks despite chest tube and should be considered for further treatment using VATS.

Repairing parenchymal injuries are often best accomplished with endoscopic stapler devices. Stay sutures placed along the laceration can help ensure that the entire injury is included in the stapled repair. Intracorporeal suturing may be an option as well. Some advocate the use of a biologic "glue" over the staple or suture line to reduce the chances of bronchopleural fistula.

Empyema

Chest trauma is the third most common cause of empyema after pneumonia and recent thoracic surgery. The incidence of empyema in patients requiring a chest tube for trauma ranges from 2% to 25% but is most often cited at 10% [79, 85]. The timing after the start of pleural space infection (empyema) is divided into three stages. The exudative or acute phase is between 1 and 5 days, the fibrinopurulent or transitional phase (5 and 14 days), and the organized or chronic phase (2–4 weeks).

As mentioned above VATS for retained HTX often prevents empyema. VATS is highly successful at clearing pleural space infection in the exudative (nearly 100%) and fibrinopurulent (75–85%) phases [85]. In the chronic phase, there is a high conversion to open given the adhesions, locations, etc. associated with this late stage of disease. The surgeon should always be prepared for the possibility of open thoracotomy in these cases. In selected cases CT or ultrasound-guided drainage of remote collections can be used as an adjunct to VATS used to treat the main area of pleural space infection. Sending tissue and fluid for culture is important to avoid treatment failures.

Rule Out and Repair Diaphragm Injury or Lung Hernia or Other Injury

Diaphragm injury can be assessed by VATS or by laparoscopy [79]. Often when diaphragm injury is diagnosed by VATS it is in blunt trauma with multiple rib fractures after

CT scan has ruled out operative injuries in the abdomen. This can be repaired by intracorporeal suturing or by a minithoracotomy incisional at the corresponding location on the chest wall. The authors recommend permanent sutures placed using fairly close bites in a running fashion. Occasionally patients may require both procedures in the same setting to ensure all potential injuries above and below the diaphragm have been ruled out. This is mostly when the patient is taking to the OR urgently or emergently soon after injury.

Adjunct During Open Reduction and Internal Fixation (ORIF) of the Rib Fractures

ORIF of rib fractures for flail chest or other fracture patterns that compromise pulmonary function and/or the patient's functional status (mobility, pain, etc.) has gained significant notoriety over the last decade. Many surgeons who perform this procedure use VATS to clear the pleural space from HTX, remove lung adherent to the fracture sites, and better assess the fracture pattern to minimize the chest wall incision required for placement of the titanium plates used for fracture reduction and fixation. One of the authors has discovered several diaphragms and even a few lung hernias that were not seen on preoperative imaging (unpublished data). During VATS we use a spinal needle into the chest cavity and marking pen on the corresponding skin to minimize our incisions. This was particularly helpful in morbidly obese patients where identifying the precise location of the flail segments can be more difficult, despite the use of three-dimensional (3-D) reconstructions of the postinjury chest CT scan.

Technical Considerations and Other Thoughts on VATS

The patient should be positioned in the lateral decubitus position on a bean bag with the affected side up. All joints and bony prominences should be padded, and the use of an arm holder is recommended. The body must be well secured to the OR table. The OR table can be flexed to widen the intercostal spaces (ICS). The first port is usually the existing chest tube site often the fifth ICS. The subsequent ports will be dependent on the location of injury within the thoracic cavity or on the chest wall.

The authors use low-pressure (8–10 mmHg) CO_2 to aid with intrathoracic visualization for some time. This is infused through a short laparoscopic port and can be especially helpful in the start of the VATS procedure when the lung may be adherent to the injured chest wall despite proper single lung isolation by placement of the double lumen endotracheal tube or bronchial blocker. It is important to inform our anesthesia colleagues of this as their end-tidal CO_2 (ETCO2) readings will likely be elevated especially in the setting of a lung injury.

Less common indications for VATS in thoracic trauma include diagnosis and treatment of thoracic duct injury that presents as chylothorax, evaluation of mediastinal structures for injury, and removal of symptomatic foreign bodies [79]. One can also use this technique to assess transmediastinal gunshot or missile wounds in hemodynamically stable patients.

Contraindications are mainly related to hemodynamic instability or if the surgeon suspects a cardiac injury. Conversion to open thoracotomy, when appropriate, can avoid complications of failure to achieve the goals of surgery (i.e., ongoing bleeding, infection, missed injury, etc.)

Conclusion

Throughout this chapter we have highlighted the growing role of minimally invasive surgery for the trauma patient. The use of laparoscopy or thoracoscopy, originally emerging as a useful diagnostic adjunct, has now solidified its role as diagnostic and therapeutic treatment modalities in the management of the injured patient. The decision to convert to open procedures should be quickly made after initial exploration and is not a sign of surgeon's weakness. Intraoperative findings prompting an immediate conversion to an open approach include, but not limited to, hemodynamic instability, expanding hematoma, major vascular injury, or obvious destructive injuries not amenable to laparoscopic repair. Using the above principles, minimally invasive techniques are safe, expedient, and sensitive for the evaluation of both blunt and penetrating trauma as well as a statistically significant reduction in wound infection, pneumonia, and other complications associated with laparotomy or thoracotomy.

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Chapter 14
The Difficult Patient

Alberto S. Gallo and Courtney Collins

Cirrhosis

One in every ten patients with chronic liver disease will require surgery within the last 2 years of their life [1]. A systematic review found overall risk of perioperative morbidity and mortality for patients with chronic liver disease to be 30.1% and 11.6% with portal hypertension conferring a twofold increase in mortality [2]. Although medical management has made elective surgery on patients with hepatic dysfunction more feasible, emergency surgery patients often do not have the luxury of preoperative optimization. However, appropriate workup and modification of risk factors whenever possible will increase the chance of positive outcomes.

Pathophysiology

It is important to understand the degree of hepatic dysfunction present in a patient and what sequelae they have. Chronic hepatocyte dysfunction alone will translate to an increased risk of infection, hemorrhage, and thrombosis, as well as a prolonged half-life of numerous drugs. The inflammatory process

A. S. Gallo (✉)
Baptist Surgical Associates, Baptist Health Louisville, Louisville, KY, USA

C. Collins
Department of Surgery, The Ohio State University Wexler Medical Center, Columbus, OH, USA

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that results from chronic hepatocyte injury can further lead to cirrhosis which can then cause increased resistance to portal venous inflow. With sufficient obstruction in the portal venous system, portal venous hypertension can develop. This increased pressure in the portal system causes sequelae such as varices and ascites [3].

There are two widely utilized scoring systems for cirrhosis: the Child-Pugh classification [4, 5] and the Model for End-Stage Liver Disease (MELD) score [6]. The Child-Pugh system relies on three objective data points (albumin, bilirubin, and prothrombin time) and two subjective clinical assessments (severity of ascites and encephalopathy) to divide patients into A, B, and C classes with C being the most and A the least severe. Predicted surgical mortality varies from 10% for Child A patients to 80% for Child C patients [7, 8]. The Child-Pugh system, although relatively simple, is somewhat hindered by the fact that its subjective components make it subject to interobserver variability. In contrast, the Model for End-Stage Liver Disease (MELD) score contains only objective variables (international normalized ratio, bilirubin, and creatinine). In general, elective surgery is considered "safe" for patients with a MELD <10 and discouraged in patients with a MELD >15 [9]. Because of its objectivity and the larger continuum of scores, the MELD system is often preferred to the Child-Pugh system; however it should be noted that the MELD score was developed primarily to evaluate patients for liver transplantation and is not specific to patients with surgical emergencies. Whatever system is utilized for preoperative assessment, it is important to note that the hepatic system is not the only system affected by chronic liver disease. As blood pools in the splanchnic system, the renin-angiotensin-aldosterone system is activated with subsequent hypersecretion of vasopressin. This results in increased uptake of water and sodium with subsequent dilutional hyponatremia. In advanced cases, this results in a rapid decline in renal function due to severe renal vasoconstriction, a condition called hepatorenal syndrome which confers a poor prognosis [10]. Abdominal ascites and pleural effusions can also result in restrictive lung disease and secondary hypoxia [11]. Impaired hepatocellular function can also cause a buildup of ammonia which can cause cerebral edema and encephalopathy [11, 12]. Preoperative evaluation of surgical patients should consider their global physiology rather than just their degree of hepatic compromise.

Preoperative Considerations

The major immediate preoperative considerations in cirrhotic patients should be their volume status, the presence of thrombocytopenia, and their coagulation status. Fluid and blood product administration should be guided by hemodynamic monitoring rather than urine output as oliguria can result from hormonal and inflammatory changes associated with altered hepatic function [13]. Excessive use of crystalloid and blood products can lead to volume overload which in turn can precipitate respiratory issues and variceal hemorrhage. While correcting volume status, electrolyte abnormalities should be monitored and corrected where possible. Coagulation abnormalities should be corrected with the appropriate blood products although it should be noted that traditional coagulation assays may not entirely accurately reflect the overall clotting ability of a cirrhotic patient [14]. The use of thromboelastography has been increasingly used in liver transplantation, but more studies are needed to validate its use in other settings [15, 16].

Operative Approach to the Cirrhotic Patient

Laparoscopy was initially considered dangerous in this population due to the concern over inadvertent injury to vessels during abdominal entry, the potential pathophysiologic effect of pneumoperitoneum, and difficulty in controlling hemorrhage. However, when compared to open procedures, laparoscopy has been shown to confer improved outcomes in the form of reduced length of stay, blood loss, postoperative pain, and complications for patients undergoing both cholecystectomy [17, 18] and appendectomy [19].

It is important to keep the altered anatomy and physiology of cirrhotic patients in mind. For example, a Hasson entry is preferred over a Veress entry at Palmer's point to avoid vascular injury [17]. Midline ports should be avoided particularly in the umbilical and epigastric region due to the risk of injuring the umbilical vein or patent vessels in the falciform ligament [18, 19]. Although there have been no reported cases of hepatic failure linked to the physiologic effects of pneumoperitoneum, a lower intra-abdominal pressure can be used if desired. In general, surgeons should keep in mind that although less invasive approaches are beneficial, expeditiousness is also important. Conversion to an open procedure in the face of laparoscopic difficulty is preferred if it will significantly decrease a patient's time under anesthesia. Regardless of operative approach, meticulous attention to hemostasis is paramount as cirrhotic patients are likely to become increasingly coagulopathic in the postoperative period making even small areas of bleeding potentially dangerous.

The Postoperative Period

The resuscitative efforts initiated preoperatively must be continued postoperatively with attention paid to volume status, electrolyte abnormalities, and coagulopathy. In addition, surgical teams should be attuned to signs of hepatic decompensation and its sequelae so that aggressive and early management can be instituted. Neurologic decline can be a sign of elevated blood ammonia, although other causes should also be investigated [11]. Elevated ammonia levels can be treated with lactulose titrated to two to three bowel movements per day [20]. Rifaximin has similar effects on blood ammonia levels and can also be used, particularly in patients who are unable to tolerate lactulose [21]. Signs of acute kidney injury in the absence of nephrotoxic drugs or significant hemodynamic compromise should immediately raise suspicion for hepatorenal syndrome.

Abdominal ascites can increase the risk of herniation and wound complications in the postoperative period [22]. Where possible, postoperative ascites should be managed with sodium restrictions and diuretics with careful monitoring of electrolytes. Therapeutic paracentesis can be considered for refractory cases [11]. The utilization of intra-abdominal drains for the postoperative management of ascites has been increasingly described in the literature. Although the potential for decreasing postoperative wound complications is compelling, this must be balanced against the risk of contamination of ascites and the potentially deleterious effects of increased postoperative fluid shifts.

Pregnancy

About 1 in 635 pregnant women will require surgery for non-obstetrical indications during gestation [23]. The pregnant patient with abdominal pain represents a distinct challenge for emergency room physicians, obstetricians, and acute care surgeons. The unique characteristics of this patient population's anatomical and hormonal changes that occur during the different trimesters of pregnancy can make accurate differentiation of signs and symptoms of disease very challenging. Furthermore, commonly used diagnostic modalities such as computed tomography (CT) can potentially be harmful to the fetus and any delay or inaccurate diagnosis may result in errors that could be devastating to the mother, fetus, or both.

A multidisciplinary approach to diagnosis and treatment should be considered when evaluating pregnant patients with abdominal pain. The evaluation and treatment decisions should involve emergency room physicians, obstetricians, radiologists, and surgeons as well as the patient.

The history and physical examination should be detailed and focused, taking into consideration the different anatomic changes that occur at each trimester of pregnancy. Symptom overlap that may normally be expected at different stages of pregnancy such as abdominal pain, nausea, vomiting, and acid reflux should be carefully considered. Examining physicians should also remember that pregnant patients' abdominal anatomy can be significantly altered during the later trimesters making physical examination more difficult to interpret. For example, the appendix can be displaced to the right upper quadrant from the right lower quadrant.

Imaging modalities are often needed for diagnosis. The use of ultrasound (US) and magnetic resonance imaging (MRI) without contrast has been shown to be safe in pregnancy during all trimesters. However, the greatest pitfall of US in pregnancy is its low sensitivity for the diagnosis of acute appendicitis. This can be further complicated by the altered anatomy of the pregnant abdomen. On the other hand, while MRI is sensitive for intra-abdominal pathology, the use of this study may be limited by availability of the machine and/or staff to interpret these images. Furthermore, this test may be difficult to complete for pregnant patients as they are to lie supine and still for a lengthy period of time. Given the sensitivity of this test, however, MRI should be the first modality used for diagnosis when available [24]. However, if obtaining an MRI will represent a significant time delay, surgeons should carefully weigh the benefit of the scan vs. the risk of treatment initiation.

Computed tomography is a quick, sensitive, and relatively inexpensive imaging modality commonly used to diagnose suspected intra-abdominal pathology. This study, however, exposes the mother and fetus to ionizing radiation. If the use of ionizing radiation is necessary for diagnosis, the gestational age of the fetus and radiation dose should be considered in order to provide patients with accurate information about the possible risks associated with fetal radiation exposure. These radiation risks include potential for fetal death, growth and mental retardation, microcephaly, malformations, and childhood cancers. These risks are directly related to the level of radiation exposure. The risk of teratogenesis varies with gestational age, and this risk is increased in a fetus less than 16 weeks. Fetal mortality is known to increase when exposure occurs during the first week of conception. CT scan is less risky in the later phases of pregnancy but still poses risks to the developing fetus.

The recommended cumulative radiation dose during pregnancy should not exceed 50–100 milligrays (mGy) [25]. A CT of the abdomen can expose the fetus to as much as 30 mGy and a CT of the pelvis, as much as 46 mGy [26]. Although the risks of fetal complications are low after limited ionizing radiation, CT scan should be reserved for emergency cases or situations where MRI and US are unavailable or inconclusive. When CT is used, discussion should be had with the radiologist so as to minimize radiation dosing wherever possible.

In patients that require surgical intervention, fetal monitoring should be utilized in the pre- and postoperative setting if the fetus is considered viable (around weeks 22 to 24 of pregnancy) to help identify fetal problems and institute appropriate therapies [27]. The goal of surgical treatment in the pregnant patient should always be to safely treat the mother while protecting the fetus when possible. However, the mother's health should always take priority.

Available data of non-obstetrical surgical interventions on pregnant patients is scarce, and most reports focus on outcomes after appendectomy and cholecystectomy as acute appendicitis (44%) and gallbladder disease (22%) are the most common indications for surgery during pregnancy [28].

The overall rate of maternal death during non-obstetrical surgery is very low, reported to be between 0.006% and 0.4% [29, 30]. Preterm-induced labor occurs in approximately 3.5% of non-obstetric surgeries in pregnancy, and this rate is higher among patients undergoing appendectomy [30–32]. Fetal death occurs in approximately 2.5–4% of cases. This number rises significantly when peritonitis with perforation is present, with reports varying between 6% and 20% [31–33].

Acute Appendicitis

The incidence of acute appendicitis in pregnancy is calculated to occur at a rate between 1 in 1000–1500 pregnancies a year [34]. Laparoscopic appendectomy is the most common surgical procedure performed in the pregnant patient and has been shown to be safe and effective. The Society of American Gastrointestinal and Endoscopic Surgeons guidelines favor laparoscopic over open appendectomy for pregnant patients, citing lower rates of premature deliveries and fetal demise [35].

The rate of fetal loss and preterm labor is reported to be around 2–4% following a simple uncomplicated appendectomy, 6–11% following a complicated appendectomy, and 4–10% following an exploration resulting in a negative appendectomy [31]. Due to the difficulty in diagnosis, the rate of negative appendectomies is higher in pregnant patients (23–50%) when compared with non-pregnant patients (18%) [23, 36]. It is unclear why the rate of complications after negative appendectomy is higher than in uncomplicated appendectomy, but it is likely that concomitant medical and obstetrical processes that were not previously considered important may play a key role [31, 37]. This underscores the importance of establishing an accurate diagnosis before the decision for surgery is made.

The stage of pregnancy does not seem to play a role in the rate of complications, suggesting that surgery should be performed at any stage if medically necessary [32, 38]. There is no evidence to support non-operative management for acute appendicitis with antibiotics alone in pregnancy.

Gallbladder Disease

Gallbladder disease is the second most common non-obstetric indication for surgery during pregnancy. In the past, a conservative non-operative approach was advocated. Studies have shown that 55% of patients who develop biliary symptoms early in pregnancy will have recurrence of their symptoms later during pregnancy [39]. Up to 23% of patients with recurrent symptoms may develop complications such as acute cholecystitis, cholangitis, or gallstone pancreatitis, which significantly increase the risk of miscarriages, premature rupture of membranes, and preterm birth [39, 40]. As such, early cholecystectomy should be performed in any trimester of pregnancy for symptomatic gallbladder disease [40]. The laparoscopic approach seems to be associated with fewer complications, but there is no strong data comparing laparoscopic with open surgery. If indicated, intraoperative cholangiography can be used with appropriate shielding as this has been shown to result in minimal radiation exposure to the fetus.

Similar to the non-pregnant patient, cholangitis should be treated aggressively with intravenous fluid resuscitation, antibiotics, and early intervention with endoscopic retrograde cholangiopancreatography (ERCP). Cholecystectomy should be planned before the patient is discharged from the hospital due to high rate of recurrent symptoms associated with outpatient management.

Laparoscopic Surgery

Laparoscopy for solid organs during pregnancy has been shown to be safe, but elective surgery should always be delayed when possible until after parturition. As compared to an open approach, laparoscopy results in decreased hospital length of stay and a lower incidence of complications [37]. Adnexal masses should be only removed laparoscopically when concern for malignancy is present. Early diagnosis for ovarian torsion is imperative and should be performed through a laparoscopic approach [38].

When performing a laparoscopic operation, the patient should be placed in the partial left lateral decubitus when possible to remove the weight of the fetus on the inferior vena cava and to improve venous return to the heart. Trocar placement should be performed away from the fetus and most often in the subcostal areas, particularly during the second and third trimester. No specific recommendations can be made regarding the safest method of entry due to insufficient data, so the decision should be made based on an individual's prior surgical experience. The pressure of carbon dioxide (CO_2) insufflation should be adjusted to the patient's physiology. CO_2 insufflation pressures of 10–15 mmHg can safely be used in pregnancy and intraoperative CO_2 monitoring by capnography should be used to assess patient acid-base status and to prevent fetal acidosis [41]. Because of the increased risk of thrombosis, prophylaxis with pneumatic compression devices both intraoperatively and postoperatively and early postoperative ambulation are recommended. Pharmacological prophylaxis is recommended in patients with high Caprini scores [42]. Routine use of prophylactic tocolysis at the time of non-obstetric surgery in pregnancy is not indicated, but should be used preoperatively when signs of preterm labor are present [43].

Anticoagulation

More than six million people in the United States take oral anticoagulants and approximately one in ten will require some type of surgical procedure [44]. The most common indications for use of oral anticoagulants are non-valvular atrial fibrillation, venous thromboembolism (VTE), and mechanical heart valve (MHV).

Multiple different classes of anticoagulants are now available, including vitamin K antagonists (VKA), novel oral anticoagulants that are non-vitamin K antagonists (NOACs) and heparins. The most common VKA is warfarin (Coumadin®, Jantoven®). The NOACs include the direct thrombin inhibitor dabigatran (Pradaxa®) and Factor Xa inhibitors rivaroxaban (Xarelto®), edoxaban (Lixiana®/Savaysa®), and apixaban (Eliquis®). Heparins include unfractionated heparin, low-molecular-weight heparin enoxaparin (Lovenox®), dalteparin (Fragmin®), tinzaparin (Innohep®), and Factor Xa inhibitor fondaparinux (Arixtra®).

Frequently, surgeons are faced with patients who are fully anticoagulated and need acute or elective surgical intervention. Specific guidelines are available for discontinuation and anticoagulation bridging when necessary in the elective setting [45]. Scant data is available to guide anticoagulation management in the acute emergent setting. It is important to assess each patient's individual bleeding risk, especially those with a history of prior bleeding after surgery or trauma, as well as the use of antiplatelet therapy drugs.

In the acute setting, discontinuation of anticoagulation, delaying semi-urgent procedures, and the administration of oral activated charcoal can be useful measures. These measures, however, may not be practical in surgical emergencies.

Oral Anticoagulants

Recommendations for reversal of VKAs are based on a 2016 integrated analysis of two-phase 3b randomized clinical trials where administration of 4-factor prothrombin complex concentrate (4F-PCC, Kcentra®) or fresh frozen plasma showed similar rates of minor and serious adverse events. However, events due to fluid overload were more frequent in the plasma group (12.7%) than in the 4F-PCC group (4.7%). Therefore, 4F-PCC should be considered the first line of therapy over plasma when available, both in conjunction with 1–10 mg of intravenous vitamin K [46].

There has been an increase in the use of newer oral anticoagulants in recent years due to their predictable effects at fixed doses, less drug and food interactions, the lack of monitoring required, as well as the rapid onset and offset of their effect. Their main limitation is the lack of readily available reversal agents. All have a relatively fast onset of action, usually within 1–3 hours after ingestion. In the elective setting, the timing for anticoagulation cessation should be based on elimination half-life of the drug, patient renal function, and planned surgery (Table 14.1).

In general, stopping NOACs 2 days before low-risk surgical procedures and 3 days before high-risk procedures is rec-

Table 14.1 NOACs summary

NOAC	Target for activity	Half-life (hours)	Dosing frequency	Dialyzable
Dabigatran (Pradaxa®)	Factor IIa (thrombin)	12–17	Once or twice daily	Yes
Rivaroxaban (Xarelto®)	Factor Xa	5–9 (11–13 elderly)	Once or twice daily	No
Apixaban (Eliquis®)	Factor Xa	12	Twice daily	No
Edoxaban (Lixiana®/ Savaysa®)	Factor Xa	10–14	Once daily	No

ommended. Restarting NOACs should be based on protocols similar to low-molecular-weight heparin (LMWH) bridging, since both have onset of action that produce a full anticoagulant effect within hours. There are, however, no specific guidelines available for resumption of NOACs, and timing should be left to the discretion of the treating physician who must assess the potential risk for bleeding.

Perioperative levels can be measured for NOACs to determine residual anticoagulant effect, but this practice is usually not necessary. Dabigatran activity can be measured with activated partial thromboplastin time (aPTT) and dilute thrombin time (dTT) assay. Normal aPTT is indicative of no effective drug in the system, but importantly the level of aPTT prolongation does not correlate with the amount of effective drug activity. Residual anticoagulant effect of rivaroxaban and apixaban can be measured with antifactor Xa activity assay.

In the acute setting, several therapeutic interventions for reversal of factor Xa agents are available. Specific protocols with activated charcoal, hemodialysis (only for dabigatran), 4F-PCC (4-factor prothrombin complex concentrate), PCC3 (3-factor prothrombin complex concentrate), and aPCC (activated prothrombin complex concentrate) in combination with drug-specific antidotes when available can be used depending on the urgency needed for reversal [47, 48].

A specific antidote is available for the reversal of the anticoagulant effect of dabigatran. Idarucizumab (Praxbind®), a humanized monoclonal antibody fragment, was approved by the FDA in 2015 for use when reversal of dabigatran is needed for emergent or urgent surgery and life-threatening or uncontrolled bleeding. In the RE-VERSE AD trial, the use of 5 g of intravenous idarucizumab showed adequate periprocedural hemostasis in 93.4% of patients who required urgent procedures, with no patient having severely abnormal hemostasis [49]. The median time to the initiation of the procedure was 1.6 hours after idarucizumab administration. Thrombotic events were seen in only 4.6% and 7.6% of patients in the surgical group at 30 and 90 days, respectively, and mortality was 12.6% and 18.9% at 30 and 90 days, respectively, most commonly due to the underlying pathology and not from major bleeding or thrombosis.

Andexanet alfa (Andexxa®) is a recombinant modified human factor Xa decoy protein approved by the FDA on May 2018 that has been shown to reverse the effects of apixaban, rivaroxaban, edoxaban, and enoxaparin; this drug is currently not readily available. Preliminary results from studies in patients with non-surgical bleeding showed reduced anti-factor Xa activity with effective hemostasis in 79% of patients [50].

Another drug currently in early clinical development, ciraparantag, may act as a universal agent by binding to heparin, rivaroxaban, apixaban, edoxaban, and LMWH. To date, this effect has been shown only in healthy volunteers [51].

Heparin and LMWH have very short half-lives, and most often simple discontinuation of the drug is sufficient. Protamine sulfate can be used when urgent reversal is needed and its effect can be monitored by aPTT.

Antiplatelet Agents

Antiplatelet agent use is widespread for primary and secondary prevention of ischemic heart and cerebrovascular disease. The most common agents used are COX-1 inhibitors, aspirin, aspirin/dipyridamole (Aggrenox®), dipyridamole (Persantine®); P2Y12 inhibitors, clopidogrel (Plavix®), ticlopidine (Ticlid®), prasugrel (Effient®), ticagrelor (Brilinta®); and GP IIbIIIa inhibitors, eptifibatide (Integrilin®) and tirofiban (Aggrastat®).

Aspirin, clopidogrel, ticlopidine, and prasugrel inhibit platelet function for the platelet lifetime. Inhibition takes 7–10 days to resolve as new platelets are generated. Ticagrelor is a reversible inhibitor, so platelet function normalizes after the drug's clearance. The half-life of ticagrelor and its active metabolites is 7–9 hours.

Reversal of aspirin and aspirin/dipyridamole is usually not necessary for most surgical interventions. Both clopidogrel and prasugrel are irreversible antiplatelet agents; however, their antiplatelet effects may be decreased by transfusion of platelets [52]. Platelet function testing is expensive and inaccurate in assessing in vivo platelet clotting capacity and there is not enough data to recommend its use prior to any emergent, non-cardiac invasive procedure in patients taking antiplatelet agents.

The available data regarding perioperative management of antiplatelet agents is controversial. A large study on outcomes after laparoscopic abdominal surgery in patients taking antiplatelet drugs showed significantly increased risk of bleeding with dual antiplatelet agents [53] in contrast to two other large reviews that showed no difference in the rate of bleeding, ischemic events, or mortality between patients with or without discontinuation of antiplatelet agents before non-cardiac surgery [54, 55]. There is no strong clinical data to support the prophylactic transfusion of platelets before non-cardiac emergency surgery, and this should be reserved for situations where the risk of bleeding outweighs the risk of thrombotic complications or when there is evidence of active bleeding [56].

The reversal for GP IIb/IIIa inhibitors (eptifibatide and tirofiban) is usually not necessary since the drug has a short half-life of 2–4 hours. In emergent situations, transfusion of platelets is the most commonly used strategy in critical neurosurgery and eye surgery [57].

Obesity

Obese and overweight patients represent approximately 70% of the US population [58].The impact of obesity on outcomes after emergent and elective surgery has been studied, but no definitive conclusions have been drawn due to the paucity of large population prospective randomized trials. A large prospective study on outcomes after elective surgery showed that only morbidly obese patients with a body mass index (BMI; calculated as weight in kilograms divided by height in meters squared) >40 have an increased rate of complications but similar mortality to normal weight patients. Interestingly, most of the complications described were superficial wound infections [59].

An "obesity paradox" has been described in patients undergoing elective, non-bariatric general surgery procedures and confirmed by other authors [59, 60]. They described a "protective effect" for complications after surgery in overweight (BMI, 25.1–30 kg/m^2) and class 1 (BMI, 30–35 kg/m^2) and class 2 (BMI, 35–40 kg/m^2) obese patients in comparison to morbidly obese (BMI, >40 kg/m^2) and underweight (BMI, ≤18.5 kg/m^2) patients. There is lack of data on outcomes after emergent surgery in obese patients, and most studies are retrospective analyses of very small sample sizes. BMI does not seem to affect mortality but can increase morbidity [61]. The laparoscopic approach in this patient population, however, seems to be associated with improved outcomes [62, 63]. A single study evaluating open versus laparoscopic appendectomy in obese patients showed a decreased incidence of deep vein thrombosis (DVT) for non-perforated appendectomy and decreased rate of almost all complications with perforated appendicitis for laparoscopy over open surgery. There was also decreased overall rate of complications, lower mortality, shorter length of stay, and less hospital charges with laparoscopy [64].

Obese patients present both a diagnostic and therapeutic dilemma for clinicians. Diagnoses in obese patients can be delayed for several reasons including inaccurate physical examination, unreliability of ultrasound, and inability to obtain CT scans in centers not equipped to handle the morbidly obese. Furthermore, physicians should be aware that obese patients are often the victims of significant implicit bias with studies showing physicians overall spend less time hearing their concerns and are less likely to order diagnostic tests. A high degree of suspicion should be maintained for all obese patients with significant abdominal complaints.

Due to disparity of outcomes and lack of data, emphasis should be focused on improving preoperative comorbidities if possible and aggressively treating in the postoperative period to avoid preventable complications. Early mobilization, institution of aggressive deep vein thrombosis prevention, use of incentive spirometer, and perioperative protocols that aid in decreasing wound-related complications should be instituted. Laparoscopy should be used whenever feasible since this approach reduces the incidence of wound-related complications without compromising overall outcomes.

Hostile Abdomen

The definition of “hostile abdomen” is broad. Most surgeons would agree that a hostile abdomen is one that has undergone multiple prior abdominal operations where the intra-abdominal contents form a block within the visceral compartment with loss of planes and natural free spaces for dissection.

Accessing the abdomen in patients with one or more prior abdominal operations can be challenging; careful preoperative consideration for incision location and trocar placement should be made. As a general rule, access should be established as far away as possible from prior incisions to help avoid the risk of visceral injuries related to adhesions. Although multiple abdominal entry techniques in laparoscopy have been described with analysis of complications, there is insufficient evidence to recommend one entry technique over another [65]. Open-entry technique is associated with a reduction in failed entry when compared with closed technique; however no difference in the incidence of vascular or visceral injuries could be demonstrated [65]. Surgeons should choose whichever entry technique they feel most comfortable with and be prepared to change their approach pending operative course.

Patients with abdominal sepsis and hostile abdomen should be approached in a systematic manner. The initial step should include infection source control, which may include exploratory surgery with bowel resection, bowel diversion, external biliary drainage, and abdominal drain placement. Many cases will require closing the abdomen with temporary abdominal wall closure devices for planned "second look" operations. The second step includes aggressive resuscitation and patient stabilization. This may be accomplished in the intensive care unit by a multidisciplinary team focusing on the correction of coagulopathy, acidosis, hypothermia, and improving nutrition to create an optimal environment for healing and recovery. This stage may include return trips to the operating room for continuous infectious source control. The last step will include definitive GI restoration if possible, potential control of enterocutaneous fistulas, and abdominal wall closure. Abdominal wall closure may be achieved by gradual primary fascia closure or with a "planned ventral hernia approach" when primary closure is not possible [66, 67]. This may include different techniques such as skin grafts or the placement of absorbable mesh with plans to come back in the future.

Definitive abdominal wall closure and fistula treatment should be delayed for 6–12 months depending on patient overall health and nutritional status. This should be performed by physicians with surgical expertise in gastrointestinal surgery and abdominal wall reconstruction due to potential need for component separation with or without mesh placement and the potential requirement for musculocutaneous flaps.

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Chapter 15
Incorporating ACS into Your Practice

Holly B. Weis, Joshua J. Weis, Luis R. Taveras, and Michael W. Cripps

Introduction

Halsted believed that each major hospital in the United States should employ a surgeon who would be ready and able to manage any emergency [1]. Modern surgical practices, however, are becoming increasingly specialized [2], and fewer surgeons are equipped or willing to handle any surgical emergency which may arise, especially in rural areas [3]. In addition to the worsening shortage of general surgeons [3], the burden of busy emergency room calls on elective general surgery practices and a generation of trainees demanding a broader case mix within the subspecialty of trauma [4] have led to a novel practice model known as acute care surgery (ACS).

While the label of "acute care surgery" has been largely decided upon [5], a precise definition of ACS and the responsibilities which fall under its umbrella are still being discussed in the literature and among surgical societies. Initially, the addition of emergency general surgery (EGS) to trauma was introduced [6]. Since that time, L.D. Britt has written extensively on the topic and argued that ACS surgeons should be

H. B. Weis · J. J. Weis · L. R. Taveras · M. W. Cripps (✉)
Department of Surgery, University of Texas Southwestern Medical Center, Dallas, TX, USA
e-mail: Michael.Cripps@utsouthwestern.edu

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proficient in orthopedic and neurosurgical emergency management to address delay in care for these patients which is related to a deficiency in specialist availability at smaller centers [7]. More recently, ACS has been conceptualized as having five "pillars," defined as trauma, emergency surgery, critical care, elective general surgery, and "surgical rescue," in an effort to formally include patients who develop complications from medical or surgical care and require "after-hours," surgical expertise and/or intervention [8, 9]. This is currently the most accepted definition and what will be referred to as ACS for the remainder of the current text. Standardization of the definition and roles of ACS surgeons will undoubtedly continue to evolve to address the changing needs of physicians and patients. In the meantime, incorporation of an ACS service into an existing practice will likely need to be tailored specific to the needs of the hospitals, surgeon specialists, and patient populations in that region.

Benefits of Implementing an ACS Service

Patients

A 2010 study investigating the extent of on-call specialist physician coverage surveyed a national sample of emergency department (ED) directors and found that 74% of respondents experienced inadequate surgeon coverage, and this shortage was worse at nonteaching hospitals relative to teaching facilities [10]. With regard to general surgeons, 37% of EDs noted incomplete coverage. Fifty-five percent of respondents reported problems with trauma coverage. These gaps in coverage have a direct impact on patients as well with 27% of hospitals that have coverage issues reporting an increase in patients leaving the ED before being seen by a medically needed specialist.

Patients may also benefit from a decreased time from presentation to an ED to surgical evaluation within an ACS system. A 2012 retrospective study analyzed 288 patients who underwent appendectomy or cholecystectomy at a single, academic, Level I Trauma institution before and after implementation of an ACS service [11]. The authors found significantly decreased time intervals from arrival to ED to surgical evaluation after the institution of ACS in both the appendectomy (6.6 to 4.4 hours; $p < 0.001$) and cholecystectomy groups (12 to 6 hours; $p = 0.03$). The application of this model at a community hospital which is not an ACS-verified trauma center also showed benefit to patients while in the ED with regard to ED length of stay (LOS) (9.7 to 6.6 hours; $p = 0.007$) [12].

Time from ED arrival to operating room (OR) can also be reduced within an ACS system [13]. A review of 152 patients at a tertiary, nontrauma center found a significant decrease in time interval from presentation to arrival in the OR from 35 hours in the pre-ACS group to 24.6 hours in the ACS group for patients undergoing cholecystectomy for acute cholecystitis ($p = 0.0276$) [14]. Another study looked at time from surgical consultation to OR and also found improvements for both appendectomies (16.4 hours versus 11 hours; $p = 0.006$) and cholecystectomies (60 hours versus 34 hours; $p = 0.002$) [11]. These results by themselves are striking, and there is significant potential to affect patient outcomes with reduced wait time when considering the impact that delays in surgical treatment can have on more urgent diagnoses [15].

While operative times seem to be similar before and after the introduction of an ACS model [14, 16], outcomes for more routine cases have been investigated in multiple diagnosis groups and overall are improved. Specifically, Lau et al. found no difference in conversion rates from laparoscopic to open cholecystectomy or operative estimated blood loss; however, the authors reported a significant decrease in the number of drains placed in the post-ACS group (30% versus 9%, $p = 0.0097$) as well as a reduction in overall complications rates (18.5% versus 7%; $p = 0.032$) [14].

Murphy et al. conducted a meta-analysis in 2017 which evaluated the outcomes for biliary disease and appendicitis after ACS implementation [17]. Twenty-five studies were included in the analyses. The rate of negative appendectomies was unchanged. For both appendicitis and biliary disease groups, complication rates were improved with the introduction of an ACS model (appendicitis, OR 0.65; CI 0.49–0.86, and biliary disease, OR 0.50; CI 0.38–0.65). Decreased complication rates have also been demonstrated after implementation of an ACS model outside of the United States. Lehane et al. described the outcomes of acute cholecystitis patients at a public hospital in Australia and found a reduction in complication rates from 17.2% to 8.7% [18].

Surgeons

There are also benefits for surgeons who practice in an ACS model. The number of urgent and emergent cases performed during daytime hours increases significantly, and after-hours cases can decrease in an ACS system as much as 15% [14, 19]. The number of cases also increases significantly with the addition of an EGS service to a trauma practice [6, 20]. Furthermore, this increase in volume does not negatively impact outcomes for trauma patients. Britt et al. discussed the implementation of an ACS model at an academic center and noted that participating surgeons experienced a much broader range of consultative and operative experiences [19]. Additionally, the authors stated that non-acute care surgery staff reported high level of satisfaction due to a perceived improvement in their ability to maintain their elective practices. In terms of case mix, the addition of EGS cases to a trauma practice can result in a range of operations similar in complexity and diversity with that of an elective general surgery practice [6].

Productivity is another area of practice affected by transition to an ACS model. A retrospective review was conducted in 2011 at a university Level 1 trauma center to determine departmental productivity and provider satisfaction after institution of an ACS style model [21]. After transition from a trauma and surgical critical care division to an ACS division, total work relative value unit (wRVU) production increased by 94%. Operative volume within the ACS group increased by 66% with emergent cases increased by 129% and elective caseload increased by 44%. Of note, nontrauma general surgery experienced a net increase in total wRVUs of 8%, with an increase in elective cases of 3%, and while these findings did not meet statistical significance, they do warrant clinical consideration particularly from general surgeons who are working to incorporate an EGS aspect to their practice with or without a trauma component. The significant increases seen in both emergency and elective cases are related to a new patient population exposure from EGS coverage which would likely apply to other practice models such as an elective general surgery practice with the addition of EGS. In the aforementioned study, faculty from both divisions were surveyed regarding satisfaction and the impact of division reorganization on their individual practices. Both groups reported higher job satisfaction at 1 year after establishment of an ACS division ($p > 0.05$ in the nontrauma general surgery group). One hundred percent of respondents answered that they would prefer to practice in a department with an ACS system and that ACS had a positive impact on their practice. In accordance with the significant increase in wRVUs, ACS physicians reported a positive financial impact after ACS implementation, while nontrauma general surgeons reported no financial impact.

Hospitals/Established Practices

With the increasing subspecialization of the surgical workforce [22], decreasing comfort with management of emergencies, and an aging population requiring more resources, hospitals will likely continue to suffer from staffing difficulties in the coming years [2]. As a result, attracting qualified individuals willing to cover this gap is a significant concern. According to a survey study conducted by the American College of Surgeons, unfavorable changes in surgical practice are the most commonly cited reason for a surgeon to retire [23]. With regard to recruiting trainees entering practice, it is important to note that ACS fellowship has been considered by 46% of residents [22]. In fact, most residents when asked to compare general surgery to ACS believed that ACS offers better or equivalent case complexity, scope of practice, case volume, and level of reimbursement. Among the reasons surgeons considered pursuing ACS was a perceived potential for shift work/controlled lifestyle as an attending physician.

Hospitals and practices should consider the financial implications of establishing an ACS service as well. Several studies have demonstrated significantly lower lengths of stay (LOS) for appendectomy and cholecystectomy patient populations by as much as 1.9 days [11, 14, 17], and these findings translate to cost savings. When comparing mean cost per appendectomy patient in a traditional and ACS model, Cubas et al. found a $1924 advantage in favor of ACS [11]. Kalina et al. evaluated the implementation of an ACS service at a nontrauma community hospital with inclusion of all critically ill surgical, elective general surgery, and EGS patients. The authors reported a decrease in both hospital and SICU LOS by 6.3 and 7.6 days ($p < 0.001$; $p = 0.001$), respectively, in the post-ACS group [12], and these findings were associated with a decrease in total in hospital charges.

In a 2009 study, Parasyn et al. sought to address OR utilization and a discontented surgical workforce at an Australian facility [24]. With the institution of an ACS model at their institution, OR utilization, as defined by the amount of time the patient spent in the OR, was improved from 57.2% to 68.5% ($p < 0.0001$). Of note, the percentage of emergency cases conducted “in-hours” increased from 64.5% to 71.7% ($p < 0.0001$), while the “after-hours,” operating time and number of cases significantly decreased. Additionally, ACS and registrar estimates were examined, and approximately 40% of patients who were evaluated in the ED and discharged would have been admitted had the consultant not been on site and reviewing patients resulting in 20.5 bed days saved over 1 week. Staff morale was monitored during this study with a vast majority (19/21) of those surveyed reporting "better" or "much better" efficiency of managing acute surgical cases. Twenty-one out of twenty-two respondents preferred continuation of the ACS model.

In the United States, a 2013 investigation hypothesized that an ACS service at an appropriately staffed hospital would generate a positive contribution margin (CM) [25]. The authors reviewed fiscal data for a Level 1 trauma center with an ACS program. CM was defined as net revenue minus direct cost and was measured for all patients admitted to the service. Trauma and EGS were associated with increased CM when compared to elective general surgery. The data ultimately suggested that hospital subsidization of ACS providers is financially feasible and could help alleviate the strain on the emergency surgical workforce.

What Are the Potential Pitfalls?

Kaplan et al. sought to define the pitfalls encountered when building an ACS practice through a MEDLINE literature search [26]. The review found that the implementation of ACS varies greatly between institutions and can have many unintended consequences including increased complexity for resident scheduling and coverage, decreased ICU exposure for the surgeon due to increased patient volume and workload, and difficulties with OR availability. Ultimately, there is no firm recommendation on how to ideally construct an ACS service which is applicable to both academic and community practices, and the pitfalls in each of these settings will likely be multiple and result in an evolution of the practice over the coming years.

Literature specifically discussing the potential pitfalls of an ACS service is limited. A 2005 study by Kaplan et al. examined the effects of incorporating a full EGS arm to an existing trauma/critical care construct at a Level I trauma center and found that billing patterns were enhanced. However, time spent on clinical duties by the surgeons was increased, and an additional faculty member was required leading to investments of time in recruitment and money for compensation [27]. More specifically, the addition of an EGS arm to the trauma/critical care service was associated with a decrease in the case to consult ratio translating to an increased time investment per case. The number of emergent and elective general surgery cases doubled during the post-EGS period with an unanticipated effect of increased post-call operative requirements, increased time demands on the staff during off-service time for elective cases, and outpatient clinic responsibilities.

These findings lend themselves to a discussion of one of the most important topics in surgery today: physician burnout. Surgeon burnout is a significant issue in the United States with rates as high as 40% and an association with major medical errors [28, 29]. Interestingly, burnout differs between private and academic practices, and while academic surgeons experience less burnout, a career in trauma surgery has been found to be a risk factor along with nights on call and hours worked [30]. Of note, burnout is not a phenomenon isolated to the United States. A Canadian study investigated surgeon burnout after the establishment of an ACS model and found a rate of 41% despite an overwhelming majority of respondents rating the change to ACS as having a positive effect [29]. Given these findings, a reasonable concern would be the ability to work with an adequate number of partners to share the increased workload. There is also a feeling among practicing surgeons that both trauma and EGS are "young persons' sports," with lengthy calls, abnormal schedules, and sometimes exhausting responsibilities. As discussed above, these realities should be taken into account before incorporating this model into a practice.

Considering This Role

Patient Population and Reimbursement

When considering incorporation of ACS into an existing practice, an alteration of patient mix can be anticipated.

Bandy et al. reviewed the Virginia Health Information database for adults discharged with diverticulitis and compared patients between an ACS model and a traditional practice model. After reviewing nearly 24,000 patients, the authors found that ACS patients were more likely to be uninsured or covered by Medicaid which translates into reimbursement considerations [31]. Whether this structure change results in a positive or negative financial impact is complicated and may be situation specific.

One study which collected financial data on six trauma and critical care surgeons who incorporated EGS into their practice found that the inclusion or exclusion of an elective general surgery component may influence the financial viability of an ACS model [32]. In this study, financial data was prospectively collected in a single group whose practice included an urban, Level I trauma center and two private healthcare facilities over a 24-month period. Two groups were compared. Three surgeons were included in Group 1, which were defined by the exclusion of an elective general surgery practice. Group II also consisted of three surgeons, but this group maintained a private, elective practice in addition to their ACS responsibilities. Payor source, charges, reimbursement, total RVUs, and physician cost were among the variables recorded.

In Group 1, RVUs generated from commercially insured patients decreased from year 1 to year 2 by 30%. RVUs generated from patients who were unfunded increased by 30%. Concurrently, a decrease in work volume was seen ultimately resulting in a reduction of charges by 5% and reimbursement by 25%. The authors concluded that ACS surgeons practicing in this setting without a private general surgery component are dependent on factors beyond their control for reimbursement. These factors include work volume, high reimbursement for insured patients per RVU, and a financially advantageous payor mix and may require subsidization by partners or a decrease in personal compensation to account for the change.

For Group II, increases in RVUs generated were seen across all payor types (government funded 14%, commercially insured 11%, unfunded patients 11%) owing to the maintenance of a private practice. The outcome for this model was an increase in both total RVUs generated (12%), charges (18%), and reimbursement (3%). Of note, in this study setting, there was no funding source for physicians caring for uninsured patients.

Service Structure

Prior to establishment of an ACS model, consideration for practice structure is warranted. There is no data on transition to an ACS service from a private, elective general surgery practice. The addition of trauma/critical care responsibilities certainly has its own benefits and drawbacks; however the literature in this arena is lacking, and as previously discussed, there is no agreed upon or "best practice" guideline for how to most effectively create an ACS practice either de novo or from an existing practice. A review of various ACS structures is provided here for reference; however, there is no one size fits all approach to incorporation of ACS into a practice given that each practice has its own surgeon, hospital, and community needs and priorities.

The variation in implementation of an ACS service is highlighted in a 2014 qualitative study which interviewed ACS leaders from 18 programs across the country in diverse practice settings to ascertain how the model is structured in these settings [33]. All respondents described ACS as encompassing trauma, critical care, and EGS, and 9/18 included elective general surgery in their practice. All programs included covered surgical critical care separately from trauma and EGS with a majority sharing critical care responsibilities with non-surgical intensivists. At 15/18 programs, overnight critical care was covered by the on-call/in-house trauma surgeon. The combination of trauma and EGS into a single team was employed at ten programs. At programs with combined trauma/EGS teams, seven had separate rounding and new consult or activation staff. Another program chose to have four attending surgeons on-service at a time to cover patients based on clinical location such as clinic, floor, step-down unit, and ICU. The step-down attending was designated to respond to all new consults and activations. Eight programs had separate service for trauma and EGS with a concern for high patient volumes with a combined service.

Programs were split between an on-service model with 5–7 consecutive days of daytime care responsibilities and a shift model which varied in length from 12 to 24 hours. For night and weekend coverage, most often call was shared with other general surgeons (13/18), and most programs had an in-house surgeon for EGS consults. A few programs would allow non-ACS surgeons to take night and weekend EGS call from home. One program employed a single surgeon who covered 51 weekends per year, and another program instituted a night float system. Of note, the mean number of monthly night/weekend calls was 4.7 days. Nine programs incorporated an elective general surgery component to their practice model.

In terms of OR designation, seven programs had block time for elective surgery cases from 1 to 3 days per week which could be booked in advance. Eight programs had an OR reserved for EGS cases; however, the time it was set aside ranged from half a day at seven programs to 24/7 coverage at a single institution. Twelve programs conducted daily sign-out rounds, but just six included attending surgeons at these meetings.

Challenges most often cited by the ACS leaders included "lack of manpower," "poor continuity," and "lack of dedicated OR." The significance of a dedicated OR for an ACS service has not yet been determined in the literature. Murphy et al. noted less after-hours operating in the setting of a dedicated OR (OR 0.49, CI 0.33–0.73) [17]. In 2011, a brief report surveyed surgeons after the addition of an ACS OR and found that 60% of respondents felt they performed fewer cases after 5:30 p.m., and 69% felt they had more control over their urgent cases with a dedicated OR despite a lack of statistical difference in objective measures [34]. Table 15.1 discusses some of the pros and cons of various ACS structure options.

Table 15.1 Pros and cons of ACS structures

Pros		Cons
General structure considerations		
Shared call coverage, fewer demands on ACS staff time, increased time for non-ACS practice aspects	SCC[a] responsibilities shared with nonsurgeons	Nonsurgeons may manage patients differently, may be easier to comanage with ACS partners
Efficiencies of scale, may allow for fewer staff needed to cover at once	EGS/trauma combined team	Burdensome patient volume, logistical issues for hospital staff and clinic visit referrals
More “regular” hours for staff, better continuity of care, less potential for “post-call” responsibilities	Daytime on-service model	Potential for more frequent hand offs and sign outs
Fewer hand offs and sign outs	Shift schedules	Lengthy shifts for staff, more potential for “post-call” responsibilities
May be more financially beneficial, attractive aspect for potential partners	Inclusion of elective general surgery component	Additional non-ACS responsibilities for surgeons, more potential for “post-call” obligations, i.e., clinic, elective cases
Night/weekend coverage		
All surgeons in the call pool are invested in the ACS group and outcomes, increased RVU potential for the group	Core group only (versus shared coverage with other general surgeons)	Potential for volume/manpower imbalance or competition from other general surgeons for EGS call

(continued)

Table 15.1 (continued)

Pros		Cons
Speedier patient evaluation and management	In-house EGS coverage	Potential for better lifestyle and may be more of an incentive for non-ACS surgeons to take call
Other considerations		
Helpful tracking for quality improvement and outcomes comparisons	Nontrauma surgical emergency database	May require additional staff for data collection and maintenance as well as time for review process

[a]*SCC* Surgical critical care

Nuts and Bolts of Gastrointestinal Surgical Practice: Coding, Billing, and Metrics

Coding and billing are topics which are rarely formally taught, however are some of the most important aspects of a surgeon's practice. With the incorporation of an ACS service, a thorough knowledge of documentation requirements is essential. The following is a review of coding and billing guidelines meant to clarify and simplify a sometimes anxiety producing topic.

First, the importance of documentation cannot be overstated, and it should be clear and concise the first time. This is to say that documentation does not require length to be sufficient for billing. Instead, understand that the best chance at appropriate reimbursement is when a bill is approved on the first submission. The emphasis should be on learning the criteria for coding and billing components.

There are two major sources for billing: evaluation and management (E/M) and current procedural terminology (CPT). The E/M component represents work associated with a face to face encounter. Surgeons often regard billing for E/M as “little money.” CPT codes translate to procedural work or “big money.” This belief, along with the fear of being accused of or committing fraud, can result in inadequate documentation, billing and ultimately compensation for work performed. For example, a laparoscopic cholecystectomy is assigned 10.47 RVUs, while the wRVUs designated to an initial hospital encounter of the highest level is 3.86. The take home here is that “little money,” can add up over time.

While it is important to note that the goal ultimately is accurate coding, it is worth noting that a majority of EGS patients meet the highest level of E/M by nature of their acuity and severity of disease process. Level of E/M is determined by history, exam, medical decision-making (MDM), and time. History is divided into problem focused, expanded problem focused, detailed, and comprehensive based on the intensity of documentation of its components (history of present illness, review of systems, past history). Determination of history type is displayed in Table 15.2. A brief history of present illness (HPI) includes one to three elements such as location, quality, severity, and so on. To meet requirement for an extended HPI, four or more elements must be documented. Problem pertinent review of systems (ROS) includes just one system, while extended includes two to nine, and complete includes ten or more. Past history (PFSH) may include a past medical history,

Table 15.2 History coding designation guidelines

History	**Problem focused**	**Expanded problem focused**	**Detailed**	**Comprehensive**
HPI	Brief	Brief	Extended	Extended
ROS	None	Problem pertinent	Extended	Complete
PFSH	None	None	Pertinent	Complete

If all three intensities circled are in one column, designate the corresponding level of history in the first row. If no column has all three intensities circled, choose the type of history which has a circled intensity farthest to the left family history, or social history to meet requirements for a pertinent designation. At least one specific item from any of the three history areas must be documented for a pertinent past history, and two or three elements must be included to be considered a complete past history.

For the physical exam, there are 10 body areas and 12 organ systems recognized by the coding guidelines. To meet a problem focused designation, only a limited exam of the affected body area or organ system must be documented. For expanded problem focused exams, a limited exam of two to seven systems must be documented. To meet the requirements for a detailed exam, two to seven systems must undergo an extended examination. Finally, for a comprehensive designation, a general multisystem exam of eight or more organ systems or a complete exam of a single organ system must be performed and documented.

MDM is a section with an often-underestimated level of complexity which is based on three components: number of diagnoses or management options, amount and complexity of data, and overall risk of the patient. Table 15.3 provides a template for MDM type determination. Number of diagnoses/management options and amount/complexity of data

Table 15.3 Medical decision-making type determination

Medical decision-making	**Straight forward**	**Low complexity**	**Moderate complexity**	**High complexity**
Number of diagnoses or management options	Minimal	Limited	Multiple	Extensive
Amount and complexity of data	Minimal or none	Limited	Moderate	Extensive
Overall risk	Minimal	Low	Moderate	High

If two or three circles appear in one column, look at the top of that column for the MDM type. If there is only one circled per column, choose the type of MDM with the second circle from the left types are point based, and point assignments are represented in Tables 15.4 and 15.5. Overall risk is divided into minimal, low, moderate and high risk based on presenting problem, diagnostics ordered, and management options selected. Of note, any patient with an acute illness with systemic symptoms qualifies for moderate risk, and any patient requiring emergency major surgery will automatically be classified as high risk. A noteworthy fact, MDM requires just two of three circles in a column for determination of complexity. Therefore, a patient with a stable problem and a new problem, i.e., a patient with history of well-controlled hypertension and new onset cholecystitis, would meet requirements for high complexity MDM even if the risk category was moderate. However, a patient with acute cho-

Table 15.4 Point designations for number of diagnoses/management options

Number of diagnoses/management options	Points
Self-limited or minor problem	1
Established problem, stable or improving	1
Established problem worsening	2
New problem, no additional work-up planned	3
New problem, additional work-up planned	4

Table 15.5 Point designations for amount/complexity of data

Amount/complexity of data	Points
Review and/or order of clinical lab tests	1
Review and/or order of radiology tests	1
Review and/or order of tests from medicine section	1
Discussion of test results with performing physician	1
Review/summarization of old records/history from someone other than patient	2
Independent review of imaging, tracing, specimen	2

lecystitis is appropriate for the high-risk category if they are planned for surgical intervention emergently.

Specific code choices can also be overwhelming at times. The following are codes which warrant special mention. For an initial visit for a patient being admitted, use the code 99223. This translates to 3.86 wRVUs. For cases of Medicare patients only, this code may be used for inpatient consults as well. ED consults which are not admitted, including those patients brought straight from ED to OR and then discharged from the post-anesthesia care unit, 99285 is appropriate and results in 3.8 wRVUs. For patients admitted for observation, 99220 is associated with 3.56 wRVUs. For critical care, 99291 results in 6.4 RVUs; however, the physician must document that the patient is critically ill. This means that without the interventions being provided for that day, the patient would die. This can include management of a ventilator or vasopressors or any other nonsurgical support. This code does not usually apply for EGS patients as the care they are receiving is considered a bridge to the ultimate therapy of an operation.

Resident involvement does require consideration with regard to documentation. A teaching physician (TP) must personally document that they performed the service being billed for or that they were physically present for the key or critical portions when service is performed by a resident. Documentation must also include that the TP participated in the management of the patient. For example, if a TP performs the E/M after the resident but without the presence of the resident, the following are acceptable documentation: "I performed a history and physical examination of the patient and discussed the management with the resident. I reviewed the resident's note and agree with the documented findings and plan of care," "I saw and evaluated the patient. I agree with the findings and the plan of care as documented in the resident's note unless otherwise noted," and "I saw and examined the patient. I agree with the resident's note except for…." In a case where the TP performs the E/M service in the presence of or jointly with the resident, the following are acceptable: "I was present with the resident during the history and exam. I discussed the case with the findings and plan as documented by the resident's note" and "I saw the patient with the resident and agree with the resident's findings and plan unless otherwise noted." It is unacceptable to document a signature or identity alone followed by "agree with above;" "rounded, reviewed, agree;" "discussed with resident. Agree;" "seen and agree;" or "patient seen and evaluated."

Conclusion

The ACS practice model was created in response to a number of challenges facing the US patient population and general surgery workforce. These included a shortage of surgeons capable of managing operative emergencies, a lack of interest in trauma/critical care among trainees due to the growing success and prevalence of nonoperative management, and an increasing burden of emergency calls on elective general surgery practices. The conceptualization of ACS has continued to evolve, and while the structure of its implementation differs across various practice settings, and there is not a one size fits all approach to its incorporation, outcomes seem to improve with its institution for patients, surgeons, and hospital systems. The transition to a new practice pattern can be difficult, and this chapter aimed to provide evidence and advice for those individuals considering an ACS model which the authors feel is a worthwhile endeavor.

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Chapter 16
The Future of Acute Care Surgery: From Divergence to Emergence and Convergence

The Evolution in General Surgery Continues

Steven D. Schwaitzberg

In the beginning, there were just surgeons who did it all. With all due respect to Ambrose Pare the sixteenth century giant of the battlefield, the dawn of modern surgery is the late 1700s and early 1800s. This era was witnessed by the challenges and struggles of the preanesthetic and preantibiotic era. Nearly all care was acute care. Elective surgery was less common. Surgeons were measured by their daring and moreover their speed. Our forebearers operated at such lightning speed that incisions were not only made in the patients, but also to the assistants and the

S. D. Schwaitzberg (✉)
Department of Surgery, University of Buffalo, Jacobs School of Medicine, Buffalo, NY, USA

Biomedical Sciences, The State University of New York, Buffalo, NY, USA
e-mail: schwaitz@buffalo.edu

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surgeons themselves. Infections were fatal unless the suppuration drained spontaneously or by the knife. Pus was laudable, actually a good sign in the eyes of many surgeons of the day.

Despite some early specialists like obstetricians William Hunter (brother of John Hunter who is often regarded as the father of modern surgery) in the Scotland and Meigs in Philadelphia, most surgeons did it all. They set fractures, removed bladder stones, repaired hernias, and performed a thyroidectomy. As anesthesia and sterile technique made abdominal procedures feasible, we entered the abdomen and the chest with vigor. The rise of institutions like the Johns Hopkins Hospital under the leadership of the visionary and sadly drug addicted, William S. Halsted, the splintering of surgery began to take hold. Still one trained to be a surgeon and then went off to study with giants such as Harvey Cushing (neurosurgery) or Hugh H. Young (urology) who themselves started as general surgeons and were either assigned or found their passion in a particular area.

All through the 1940s to the 1980s, many surgeons had crossover interests. I had the unique opportunity to have an extended conversation with Michael E. DeBakey, the legendary cardiac surgeon who spoke fondly of organizing care for the injured soldier in World War II and the management of amoebic abscess as a young attending at the Ochsner clinic where he wrote the seminal paper on the topic. John Border, one of the fathers of modern trauma surgery, is revered by general and orthopedic surgeons alike where his career is memorialized in the annual Border Lecture hosted by both surgery and orthopedics in alternating years at the University at Buffalo. Today it is a rare trauma surgeon who would pin his own patient's fracture.

Severe super specialization in surgery is a fairly recent phenomena and there are both good and other consequences of these forces. No one argues that best in class outcomes are associated with volume and repetition although sufficient outcomes can be achieved in many procedures without needing different surgeons to repair right versus left groin hernias.

This specialization has created silos and truly calls into question, how many general surgeons do we have and how many do we need? For my money, if you do not take at least acute care (but not necessarily trauma) call, then you are not a "general surgeon" for headcount and workforce assessment purposes regardless of holding an American Board of Surgery certificate. A hospital can stay open without a bariatric only, colorectal only, endocrine only, transplant only, or even a breast/surgical oncology only surgeon, but if these folks don't or won't take call and there is no one to do an appendectomy, the doors will close since the top seven surgical mortalities are all related to emergency general surgery. The diverging pathways of these surgeons has led to radical change in the last 20 years where many who hold ABS certificates simply state they will not take night call outside of their narrow vertical sliver of care.

This set the stage for two specialist groups laying claim to the title of *general surgeon* in addition to those who went directly from training into practice. They are the trauma surgeons creating a new moniker in the form of acute care surgery led through the efforts of groups like AAST or EAST and the MIS type surgeons who operate all over the body led by SAGES and others. There are both intended and unintended consequences of the emergence of these two groups that has led me to the conclusion that at least some convergence is needed among them.

The arrival of the acute care service was propelled by a number of forces. (1) Trauma and/or ICU surgeons (including me in my first iteration) were doing less and less operative surgery particularly as trauma care became increasing nonoperative. In 2005 the Denver group writing to inspire change, "To resurrect our discipline, we must reclaim and expand our operative potential and be relieved of our excessive night and weekend burden of serving as housestaff for the neurosurgeons, orthopedic surgeons, and interventional radiologists. The trauma surgeon can effectively manage trauma and acute care surgery emergencies including thoracic and vascular conditions. Education of the future trauma and acute care surgeon must include specialty training in thoracic and vascular surgery" [1]. (2) Subspecialists were refusing to take general call citing they were becoming increasingly "uncomfortable" managing patients coming through the emergency room. (3) The lack of surgeons to take call created a lever to motivate hospitals to pay for call coverage creating the financial headroom to create a sustainable service. No model is perfect and there are problems associated with this new type surgical care. The nature of the training in trauma and ICU did not leave much time to build expertise in MIS techniques in these acute cases. That expertise existed on other services. Questions arise such as who is best to do a difficult laparoscopic cholecystectomy? Is it the acute care trauma-based surgeon that night or the experienced MIS surgeon the next day? Answers vary; however if acute care surgeons are going to manage these patients, then the operative technical skills not common to trauma/ICU curriculums need to be taught after training or in settings where they congregate for education. Considerable scrutiny of the acute care model ensued after the initial push forward. In 2008 only 18% of Level 1 Trauma Center performed the full range of proposed procedures [2]. On the flip side, critically ill surgical patients are increasingly managed in closed ICUs staffed by their acute care colleagues. Surgeons taking general surgery call who accumulate patients late in the evening before a busy elective schedule benefit from an acute care service willing to take over their care. Hospitals see this as a benefit as well by maintaining an efficient OR schedule. Despite considerable rebranding of trauma surgeons to ACS surgeons in the subsequent years, diffusion is modest. A 2018 survey of more than 2800 hospitals in the United States noted that only 16% had an acute care service [3]. Further adoption may be facilitated by seeking out additional opportunities for convergence as seen in patients with small bowel obstruction, diverticulitis, acute cholecystitis, and non-ICU pancreatitis. These case types point out a potential continuity weakness in the ACS model in some sites where it is conceivable that difficult cases that are not quite sick enough to warrant an emergent operation are "passed on" to the next shift delaying care due to a lack of ownership. Surgeons in practice often have no one to pass the cases to and are motivated to intervene before the patient becomes too ill since they will have to deal with the problem either way.

In other words, acute care services need to hone their minimally invasive techniques, and surgeons in practice need to collaborate with these teams to lend their expertise and continuity of practice to optimize patient care. These conversations could be facilitated by intersociety collaboration at annual meeting or specific postgraduate courses bilaterally sponsored. A case in point could be seen in the performance of laparoscopic cholecystectomy. While this is a commonly performed procedure in general surgery training, it was demonstrated that younger surgeons have a threefold higher incidence of bile duct injury than their more experienced colleagues [4]. These data highlight the need for the safe cholecystectomy task force developed by SAGES. All surgeons performing cholecystectomy benefit from this education, and it would be a waste of resources for an ACS group to duplicate these efforts – these groups must collaborate. As early as 1995, trauma surgeons have been using portable ultrasound in the abdominal and thoracic evaluation of the injured patient [5]. Today it is a common modality used in most emergency departments. General surgeons in practice would be well served and learning these techniques, and are most likely to do so from their acute care colleagues.

One of the significant components of acute care and emergency services involves the use of endoscopy in the management of gastrointestinal bleeding, esophageal obstruction, and ICU services such as feeding access. In hospitals with full-service medical or surgical endoscopy teams, it is less likely that the ACS surgeon will be called upon to perform endoscopy for bleeding or obstruction scenarios. However, many of us notice an increasing movement of gastroenterologists from hospital-based endoscopy to privately owned ambulatory centers where many of the gastroenterologists have almost no hospital involvement and thus have avoided the emergency call schedule. Carried to an extreme the ACS surgeon of the future may need to add the skills to their ever-increasing armamentarium. Where will the management of a gastrointestinal bleeder be taught? There is not a preponderance of ACS surgeons with this skill set. Current graduates of surgical residences are required to pass the Fundamentals of Endoscopic Surgery Curriculum. Unfortunately, this curriculum does not create proficiency in the manage of gastrointestinal hemorrhage. Further training would be mandatory and will come from collaborative opportunities developed should the need arise. Groups like SAGES or ASGE or the American College of Surgeons will need to collaborate with ACS surgeons to assist in providing these skills.

As newer technologies come in to play such as robotics, the ACS surgeon will need to be selective as to which arrows to add to his or her quiver. Robotic surgery is such a case in point. The diffusion of robotics and to the general surgery practice has certainly exploded and in recent years on an elective basis. This technology is being used in diverticulitis, acute cholecystitis, bowel resection, hernia, and the like. Robotic technology has certainly been enabling for surgeons such as urologist to perform complex prostate resection without an extraordinary skill set in laparoscopy first. One must wonder if this evolution will be applicable to the acute care surgeon. It may in fact be a straighter line to skip attempts at laparoscopic colectomy and move straight to robotics. Significant competition for console-based and handheld robotic systems is approaching rapidly. This is a broad philosophic question for the leadership of acute care surgical services since most residents do not come out with qualification certificates at this point in history on any robotic system.

This ever-expanding skill set which already requires so many skills in general, vascular, neurosurgical, orthopedic surgery truly represents a training challenge for the future. Adding additional endoscopic or robotic skills may require the training period to expand or force those who want to go into the specialty to do an additional fellowship to function optimally in selected environments. Without a doubt it seems this group of surgeons may in fact follow the adage "everything old is new again" returning to our roots where general surgeons do it all.

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