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Isolated and Combined Duodenal and Pancreatic Injuries: A Review and Update

Rachel L. Choron[1,2] · David T. Efron[1]

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Abstract
Purpose of Review Duodenal and pancreatic injuries are challenging to diagnose and treat. Over the last several decades, appropriate and optimal surgical management of these injuries have been debated. This is a review of the latest literature regarding diagnosis and operative management of these injuries.
Recent Findings In duodenal injury, primary repair should be pursued for partial or complete transection with little tissue loss and no ampulla involvement. In more complex injuries, where tension-free repair is not possible, Roux-en-Y duodenojejunostomy or pyloric exclusion with diverting gastrojejunostomy can be utilized. Wide external closed suction drainage is recommended for grade I, II, and IV pancreatic injuries. Distal pancreatectomy with or without splenectomy is recommended for grade III injuries. Pancreatoduodenectomy in a staged procedure is safe for grade V combined injuries with ductal disruption.
Summary Delayed diagnosis contributes to increased mortality in pancreatic and duodenal trauma. Establishing early diagnosis and ductal involvement followed by appropriate surgical intervention improves outcomes.

This article is part of the Topical collection on *Trauma Surgery*.

✉ Rachel L. Choron
Rachel.Choron@gmail.com

David T. Efron
DEfron1@jhmi.edu

[1] Division of Acute Care Surgery, Department of Surgery, The Johns Hopkins Hospital, Baltimore, MD, USA

[2] 1800 Orleans Street, Suite 6107F, Baltimore, MD 21287, USA

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Introduction

Historically, both duodenal and pancreatic injuries have been challenging to identify and treat. The first description of a duodenal injury was not until 1814 in France by Larrey and it was years later in England when Travers described the first pancreatic injury in 1827 [1, 2]. While two centuries have passed, both isolated and combined duodenal and pancreatic injuries still provide diagnostic and surgical treatment challenges to providers.

Duodenal Injuries

Outcomes

While duodenal injuries are not necessarily common, they present an ongoing problem with high associated morbidity and mortality. Early deaths in patients with duodenal injuries are usually hemorrhagic in nature and often secondary to associated adjacent vascular injuries or concurrent liver and spleen injuries. Whereas, delayed deaths are due to septic complications and multi-system organ failure. Of those patients demonstrating delayed mortality, one-third are attributable to the duodenal injury itself. This accounts for a direct attributable mortality rate of 2–5%.

The overall mortality of patients with duodenal injuries has been described as ranging from 12 to 40% [3–5]. Mortality varies based on a number of factors. Patients who have a penetrating mechanism of injury have been shown to have a higher mortality in comparison to those injured

by blunt mechanisms (25% vs. 12–14%) [6]. Additionally, delayed diagnosis of duodenal injuries results in increased mortality; therefore, identifying injury early is paramount to patient outcome.

Lucas et al. found a delay in diagnosis greater than 24 h in 28% of patients with blunt duodenal injury; this resulted in a mortality rate of 40% of patients with a delayed diagnosis vs. 11% of patients who underwent surgery within the first 24 h [3]. Cuddington et al. echoed these findings and attributed 100% of the mortality in their study to delayed diagnoses [4]. Delayed diagnosis also contributes to increased morbidity. A study by Synder and colleagues reviewed 247 patients with duodenal injuries over an 18-year period. The factors they attributed to increasing morbidity of the duodenal wound included a missile or blunt injury as opposed to stab wounds, defect larger than 75% of the circumference, injury of the first or second portion, adjacent common bile duct injury, and a delay in operative intervention greater than 24 h [5].

Diagnosis

The priority in managing a duodenal injury is early and immediate recognition. A plain abdominal radiograph or upright chest X-ray can indicate a duodenal injury when there is obliteration of the right psoas muscle or retroperitoneal air. While this may be the most simplistic radiographic study to identify duodenal trauma, it is not the most reliable.

CT scan has been shown to be the best method for early diagnosis; however, it still carries the burden of a high missed injury rate. A study of 206 patients with blunt duodenal injury revealed 30 patients with full thickness rupture. Of those 30 patients, CT scan was the primary diagnostic investigation in 18 cases; however, extravasation of oral contrast was only noted in two patients and four of the studies were interpreted as normal. Overall, they found a 27% missed blunt duodenal injury rate with CT scan [7].

A study by Allen et al. identified 35 patients over 10 years with blunt duodenal injuries. They found that 83% of patients with a delay in diagnosis actually had subtle CT findings indicating the presence of duodenal injury. These findings included pneumoperitoneum, free fluid, or unusual bowel morphology [8] These studies emphasize the need for careful radiographic interpretation of CT scans with clinical correlation to avoid delayed diagnosis of duodenal injuries and, in turn, increased morbidity and mortality.

Classically, the use of oral and intravenous contrast has been labeled the best method for diagnosing duodenal injury; however, oral contrast is not standard trauma CT scan protocol. A study from 2004 examined the use of CT imaging without the use of oral contrast in blunt bowel and mesenteric injury. Five hundred consecutive trauma patients were confirmed to have blunt bowel injury by laparotomy, autopsy, or radiology read and discharge summary. They found CT imaging without oral contrast compared favorably for the detection of blunt bowel and mesenteric injury to CT imaging with oral contrast. Overall, they found CT scan without oral contrast solution to have 95% sensitivity and 99.6% specificity in diagnosing blunt bowel and mesenteric injury [9].

While CT scan is the best method for early diagnosis, other diagnostic tools are available. Upper gastrointestinal series using water soluble contrast, followed by barium contrast if the initial test is negative, is another adjunct that can be used for diagnosis. However, this is not a great first study to be used in the management of duodenal trauma. Diagnostic peritoneal lavage is another option for diagnosing duodenal injury. While this is not a great study at identifying isolated duodenal injuries, 40% of duodenal injuries have associated intra-abdominal injuries that could result in a positive diagnostic peritoneal lavage. Ultimately once in the operating room, if a retroperitoneal hematoma, bile staining, or air bubbles are noted during exploratory laparotomy, the duodenum should be investigated and examined.

Treatment

Priorities in the management of duodenal injuries first include immediate diagnosis of the injury followed by operative intervention. Once in the operating room, the order of importance regarding surgical intervention includes: hemorrhage control, limiting bacterial contamination, clearly identifying the duodenal injury, and determining the status of the pancreas. Typically, 70% of duodenal injuries can be repaired primarily whereas 30% require more complex repairs.

Primary Repair

Some studies in the past have advocated for primary repair of most duodenal injuries. Rickard et al. published a manuscript in 2005 entitled, “Pancreatic and duodenal injuries: keep it simple.” They suggested most duodenal injuries can be managed with debridement and primary repair and only recommended the use of temporary exclusion and reoperation in unstable patients [10]. In 2006, Talving et al. examined 75 patients with gunshot wounds causing duodenal injury. Primary repair was utilized in 87% of patients, resection and re-anastomosis were completed in 11%, and one pancreatoduodenectomy was performed. Overall, they reported a comparable complication rate (58%) between simple primary repair and more complex surgical procedures. They concluded that primary

repair could be applicable for pancreatic and duodenal gunshot injuries [11].

In 2008, Velmahos reviewed 193 consecutive patients with severe injuries including only patients with grade III, IV, or V duodenal injuries (Table 1). When comparing simple duodenorrhaphy or resection with primary anastomosis versus pyloric exclusion, there was no difference found in morbidity, mortality, intensive care unit length of stay, or hospital length of stay. They concluded that pyloric exclusion is, therefore, not necessary and duodenal injuries can be managed by simple primary repair [12].

Cogbill and colleagues examined 164 duodenal trauma patients at 8 different trauma centers. They identified 46% of patients with grade III, IV, or V duodenal injuries underwent complex repairs including: pyloric exclusion, duodenoduodenostomy, duodenojejunostomy, or pancreatoduodenectomy. Based on their outcomes, they concluded that tube duodenostomy was not mandatory, pancreatoduodenectomy is rarely needed, and the great majority of duodenal injuries can be managed with simple repair [13].

Overall, primary repair should be pursued, if there is partial or complete transection of the duodenum with little tissue loss, no ampulla involvement, and mucosal edges can be debrided and closed without tension. Either two layer closures or watertight serosa approximating single layer closures can be completed when repairing a duodenal injury primarily.

Complex Repair

While multiple papers recommend primary simple repair, this is not always feasible. If adequate mobilization for a tension-free repair is not possible, the injury is adjacent to the ampulla, or mobilization would risk injury to the common bile duct, a more complex repair may need to be performed.

Table 1 Duodenal injury scoring scale

Grade	Type of injury	Description of injury
I	Hematoma	Involving single portion of duodenum
	Laceration	Partial thickness, no perforation
II	Hematoma	Involving more than one portion
	Laceration	Disruption < 50% of circumference
III	Laceration	Disruption 50–75% of circumference of D2
		Disruption 50–100% of circumference of D1, D3, D4
IV	Laceration	Disruption > 75% of circumference of D2
		Involving ampulla or distal common bile duct
V	Laceration	Massive disruption of duodenopancreatic complex
	Vascular	Devascularization of duodenum

Duodenal Diverticulization In 1974, Berne et al. described "duodenal diverticulization" as a method of managing severe duodenal injury or combined duodenal and pancreatic injury. He reviewed 34 patients managed by gastric antrectomy with end–side gastrojejunostomy, t-tube drainage of the common bile duct, tube duodenostomy, closure of the duodenal injury, and drainage. They reported 16% mortality and described regional complications as well tolerated with spontaneous closure of all duodenal and pancreatic fistulas [14].

While duodenal diverticulization is an option for surgical management of duodenal injuries, we believe that performing an antrectomy and gastrojejunostomy in patients who are already critically ill and likely hemodynamically unstable causes unnecessary exposure to increased operating times and complications. Additionally, the authors do not favor placement of a t-tube or intraluminal duodenostomy tube, whereas wide extraluminal drainage remains paramount.

Pyloric Exclusion with Gastrojejunostomy As discussed above, true anatomic diversion includes primary closure of the duodenal injury, antrectomy, vagotomy, end–side gastrojejunostomy, T-tube drainage of the common bile duct, and lateral tube duodenostomy. This method completely diverts gastric and biliary contents from the duodenal injury and allows for enteral feeding via the gastrojejunostomy. A less aggressive surgical approach involves pyloric exclusion with diverting gastrojejunostomy. This was first described by Summers in 1904 in the Annals of Surgery [15]. He described a temporary method to divert gastric contents by suturing off the pylorus. Through a gastrotomy, the pylorus is sutured closed with absorbable suture and a loop gastrojejunostomy is completed. This temporary closure opens in several weeks–months while the duodenal injury heals.

While, some have advocated for the use of a truncal vagotomy alongside a pyloric exclusion, by the time a marginal ulcer would form, the pylorus would likely be open and, therefore, truncal vagotomy is not required [16].

Several studies review patients with severe grade III–V duodenal injuries; the pyloric exclusion technique has been historically utilized in 19–32% of cases [12, 17]. These patients had more pancreatic injuries and more injuries involving the first and second portions of the duodenum [12]. In a 2008 review of the national trauma data bank, patients who underwent pyloric exclusion had higher injury severity scores [17]. The use of pyloric exclusion has been recommended in the setting of complex duodenal injuries with an elevated PATI score greater than 40, duodenal

injury score greater than 12, or combined duodenal and pancreatic head injury [18].

In a small prospective study of 30 patients with duodenal injuries over 3 years, Jansen et al. concluded the selective liberal employment of pyloric exclusion can minimize duodenal related morbidity [19]. In more severely injured patients, when the pyloric exclusion technique is deployed in grade III–V duodenal injuries, no difference in morbidity or mortality has been noted when compared to primary repair [12, 17]. While some have suggested improved morbidity, the majority of studies have not shown a difference in morbidity or mortality when comparing primary repair and pyloric exclusion techniques in grade III–V injuries. Therefore, adjuncts to primary repair like pyloric exclusion are often thought to be unnecessary in these more severely injured patients since the exclusion strategy has shown similar outcomes.

Roux-en-Y Duodenojejunostomy When primary repair is not a feasible option anatomically, complex repair is required. Duodenal diverticulization requires anatomic resection, long operating times, and unnecessary t-tubes in an already sick patient population. Buttressing the duodenal injury using an omental patch or the serosa from a loop of jejunum is often associated with complications and has not been shown to improve outcomes. Ivatury et al. found increased mortality when using the serosal patch technique opposed to Roux-en-Y anastomotic repairs and therefore recommended against buttressing [6]. Additionally, the pyloric exclusion technique does not account for duodenal stricturing once the pyloric suture line opens up.

The authors, therefore, favor the use of Roux-en-Y duodenojejunostomy for the surgical reconstruction of complex duodenal injuries. Often in severe duodenal injuries, primary repair is not feasible because it would cause narrowing of the duodenal lumen by greater than 50% and result in stricturing. While liquids and bile can often pass through a narrow lumen, the passage of solid food is more difficult. We, therefore, suggest the creation of a Roux-en-Y duodenojejunostomy when primary repair would result in greater than 50% luminal stenosis.

We also favor duodenojejunostomy in the setting of a concomitant pancreatic injury. Because pancreatic leak is such a common complication following pancreatic injury and repair, a primary duodenoduodenal anastomosis would be at high risk for break down when exposed to pancreatic secretions. Therefore, the authors favor the use of duodenojejunostomy when pancreatic leak is a foreseen complication.

While the use of duodenojejunostomy is our preferred approach, we do not recommend it when the duodenal injury is located at the ligament of treitz. Alternatively, when the injury is peri-ampullary or peri-pancreatic, the duodenojejunostomy is favored because both the Roux limb and the duodenal limb will have a healthy blood supply with good perfusion.

Decompression Tubes: Retrograde Jejunostomy, Lateral Duodenostomy, and Moss Gastrojejunostomy Tubes One of the feared complications of duodenal injury repair is leakage from the duodenal suture line. Different operative strategies to minimize this morbid outcome have been described. Historically, the use of intra-luminal drainage tubes is one technique used to limit intra-abdominal septic morbidity. In 1979, Stone et al. published on 237 patients with routine duodenal decompression via gastrostomy and jejunostomy tubes. They reported a higher duodenal suture line leak rate when this strategy was not utilized [20]. While they found this an effective strategy, this technique is not part of routine management of duodenal injuries currently. The use of extra-luminal wide drainage is, however, a key management strategy in duodenal injury patients.

Later, Hasson and colleagues reviewed eight studies involving patients with penetrating duodenal trauma followed by repair and decompression of the suture line by gastrostomy tube, duodenostomy tube, or jejunostomy tube insertion. Overall, they found retrograde decompression with jejunostomy and feeding jejunostomy tubes a safe method for penetrating duodenal injuries [21]. While using jejunostomies was found to be safe, direct drainage through the duodenal stump suture line with a lateral duodenostomy tube has been associated with a dehiscence and fistula rate as high as 23% and is, therefore, not recommended.

The authors favor using a Moss gastrojejunostomy tube in the setting of severe duodenal injury when there is high suspicion for a post-operative course complicated by leak. The Moss gastrojejunostomy tube has drainage holes both above and below the pylorus which provide excellent decompression of both the stomach and duodenum. Additionally, it is advantageous because it has pro peristaltic positioning in comparison to retrograde jejunostomies which can move with peristalsis resulting in failure to drain the duodenal repair site. There is also a feeding port that lies several centimeters distal to the ligament of Trietz.

Pancreatoduodenectomy Massive injuries to the proximal duodenum and head of the pancreas with destruction of the ampulla and proximal pancreatic duct or distal common bile duct cannot be resolved with primary repair alone. Asensio et al. reports that the indications for traumatic pancreatoduodenectomy are massive uncontrollable retropancreatic hemorrhage or massive unreconstructable injury to the head of the pancreas when involving the main pancreatic duct and distal or intrapancreatic portion of the common bile duct. They found a mortality

rate of 33% in patients who underwent pancreatoduodenectomy for these indications [22]. Pancreatoduodenectomy in the injured patient is further discussed later in this review.

Duodenal Hematoma

While duodenal hematomas can occur in adults, it is also typically an injury seen in childhood. Unfortunately, 50% of childhood cases of duodenal hematoma are secondary to abuse. In this setting, it is mostly a non-surgical injury. About one-third of patients present 48 h after the initial injury; during that time period, fluid shifts result in more significant edema causing symptomatic duodenal hematomas.

Diagnosis is typically made with CT scan or upper gastrointestinal series. About 25% of patients have findings consistent with fold thickening, narrowed lumen, or displacement of the duodenum. Although the majority of duodenal hematomas do not require operative intervention, the exclusion of additional injuries is important, specifically pancreatic injuries. The literature describes a 20–42% rate concomitant pancreatic injury in pediatric and adult patients with duodenal hematoma [23, 24].

The treatment for duodenal hematomas without concomitant injuries requiring operative management is nasogastric tube placement and intravenous nutrition with re-evaluation of patency with upper gastrointestinal series 5–7 days later. If this conservative approach fails after 2 weeks, operative management is advised to rule out stricture or injury to the head of the pancreas that could be contributing to the obstruction.

If a duodenal hematoma is found intraoperatively, the duodenum should be thoroughly mobilized using an extending Kocher maneuver for exploration to rule out perforation. After careful inspection, if there does not appear to be any evidence of perforating injury, the hematoma is not unroofed and gastrojejunostomy or jejunostomy feeding tube placement should be considered.

Pancreatic Injuries

Outcomes

While uncommon, pancreatic injuries continue to present an on-going problem with morbidity rates as high as 30–60% and mortality rates of 9–34%. The high rate of mortality is typically related to concomitant injuries. In 2011, Krige et al. reviewed 110 patients with blunt pancreatic injury and concluded mortality was higher in patients with associated injuries. In this study, they found a mortality rate of 16.4%; however, they attributed only two deaths to pancreatic injury itself [25]. In a multicenter study reviewing penetrating pancreatic trauma, the majority of deaths were also from solid organ or vascular injuries [26].

Early mortality is also specifically attributed to uncontrolled or massive bleeding from associated vascular or adjacent organ injuries. Vasquez et al. found that 61 of 62 consecutive patients with penetrating pancreatic injury had associated injuries and the majority deaths were secondary to bleeding within one hour of admission. They attributed only 1 death to pancreatic injury itself [27].

Patient prognosis is related to the complexity of the injury, estimated blood loss, duration of shock, and the timing and nature of surgical intervention. In a 2012 study from Cape Town, South Africa, Chinnery et al. reviewed 326 patients with pancreatic injuries secondary to gunshot wounds. They found the highest mortality in patients presenting with shock and in patients with severe concomitant injuries requiring damage control laparotomy [28].

Diagnosis

Like duodenal injuries, delayed diagnosis and missed pancreatic injuries contribute to increased morbidity and mortality. It is critical to establish the diagnosis early and whether there is duct involvement or not. In patients with blunt pancreatic injury who underwent operative intervention within 24 h, Olah et al. found lower mortality than in patients with delayed intervention. They concluded higher pancreatic specific morbidity and mortality when operative intervention was delayed [29].

Physical Exam

In the trauma bay, contusions or bruising of the upper abdomen with epigastric pain out of proportion to physical exam maybe suggestive of pancreatic injury. This can be seen in motor vehicle collisions with impact from the steering wheel in adults or bicycle handle bar injuries to the epigastrium in children. Typically, a higher transfer of energy to the upper abdomen is required for blunt injury. Additionally, if associated injuries such as Chance fractures are identified, pancreatic injury should be considered part of the differential.

Amylase and Lipase

Amylase has not been found to be a good indicator of pancreatic injury; however, it can be used for negative predictive value as a screening tool. In 2014, Mahajan et al. performed a prospective cohort study in patients with blunt abdominal trauma. They found elevated amylase levels in patients with pancreatic and bowel injuries and elevated

lipase in pancreatic injuries with or without associated bowel injury. Overall, they found a combined amylase and lipase specificity of 100% and only 85% sensitivity in predicting pancreatic injury [30]. Importantly, this was found to be non-diagnostic when it was within 6 h or less of traumatic injury, which is the critical time to establish diagnosis to avoid increased morbidity and mortality.

CT Scan

CT scan is usually the image modality of choice in traumatically injured patients. Typical findings on CT scan consistent with pancreatic injury are parenchymal disruption, intrapancreatic hematoma, fluid in the lesser sac, separation of the splenic vein and body of the pancreas, peripancreatic edema, thickened left anterior renal fascia, and retroperitoneal fluid (Fig. 1). While the sensitivity and specificity of CT scan for diagnosing pancreatic injury is up to 80%, it does not have great sensitivity in diagnosing pancreatic duct injuries. In blunt pancreatic trauma patients, failure of CT scan to reveal the injury was found in 21% of patients resulting in a mean operative delay of 3.8 days [31]. The multicenter ReCONECT study from 2009 identified a 13% missed injury rate on initial CT scan in blunt pancreatic injury. While overall mortality was 15%, patients without a missed diagnosis on CT scan had a mortality of 8.8% [32].

ERCP, MRCP, and Intraoperative Cholangiopancreatography

Endoscopic retrograde cholangiopancreatography (ERCP) can be both diagnostic and therapeutic in evaluating and treating pancreatic duct injuries. In hemodynamically stable patients with equivocal CT scans without obvious indication for operative intervention, ERCP can be useful in the early post injury period [33]. However, ERCP is not always available and should not delay operative intervention. Currently, the luxury of ERCP depends on the hemodynamic stability of the patient and access to the resources needed for ERCP including availability of a trained gastroenterologist. Magnetic resonance cholangiopancreatography (MRCP) is an option for diagnosing pancreatic injury; however, it also is not used in the acute work-up after injury.

Fig. 1 CT Scan imaging of gunshot wound injuries to the pancreatic neck and tail

It is critical to determine the status of the pancreatic duct when evaluating a patient intraoperatively for pancreatic injury. Fifteen percent of pancreatic injuries involve the duct and most commonly are due to penetrating injury. Investigation for duct injury is mandated with a hematoma overlying the pancreas, a retroperitoneal hematoma abutting the pancreas, retroperitoneal saponification, or bile staining.

Intraoperative pancreatography can be used but is often not practical during the index operation. The following techniques are ways to evaluate the ductal system: needle cholecystocholangiogram, pancreatography via direct cannulation of the ampulla of vater via an existing duodenal injury, or pancreatography of an injured pancreatic tail. Ultimately, an uninjured duodenum should not be opened as a technique for duct investigation.

Treatment

The main goal of treating any injured patient includes control of hemorrhage followed by control of contamination and subsequently systemic abdominal exploration and evaluation. Proper and thorough evaluation of the abdomen includes exposure of the pancreas.

Surgical Exposure

Asensio et al. described a unified approach to pancreatic exposure. First, open the lesser sac by dividing the gastrocolic omentum inferior to the gastroepiploic vessels. The transverse colon is retracted inferiorly and the stomach superiorly (Fig. 2). A nasogastric tube can be used as a handle to the lift the greater curvature of the stomach. A Kocher maneuver should be performed by incising the lateral peritoneal attachments to the duodenum to mobilize the second and third portions of the duodenum to adequately assess the head of the pancreas and the uncinate process. This is completed once the left renal vein is visualized. [34]

If there is pancreatic tail injury, an Aird maneuver should be performed by mobilizing the splenic flexure of the colon and incising the splenocolic, splenorenal, and lienosplenic ligaments to medialize the spleen allowing visualization of the tail and distal body of the pancreas

Fig. 2 Surgical exposure depicting a pancreatic hematoma. Reproduced with permission of Lippincott Williams & Wilkins, from Efron et al. Operative Management of Pancreatic Trauma. In: Fischer JE, ed. *Mastery of Surgery 5th Edition*. Philadelphia, PA: Lippincott Williams & Wilkins; 2007: 1320–1323.

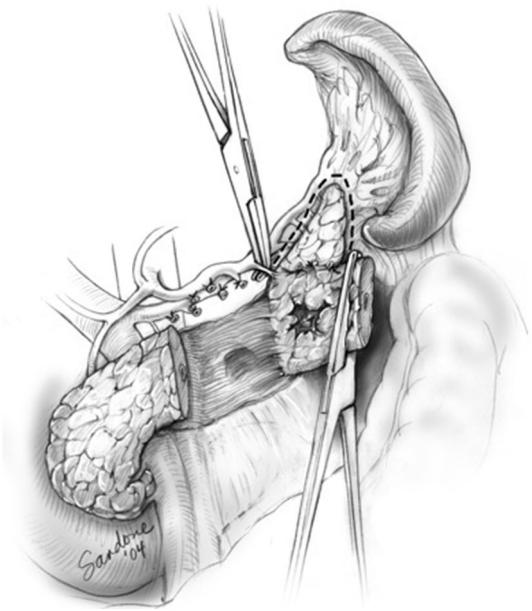

Fig. 3 Medialization of the spleen when performing distal pancreatectomy in the setting of pancreatic body injury. Reproduced with permission of Lippincott Williams & Wilkins, from Efron et al. Operative Management of Pancreatic Trauma. In: Fischer JE, ed. *Mastery of Surgery 5th Edition*. Philadelphia, PA: Lippincott Williams & Wilkins; 2007: 1320–1323.

(Fig. 3.) [34] Mobilizing the inferior border of the pancreas is the safest initial approach for exposure. This will allow for visualization of the posterior body and tail and possibly to identify if there is full thickness injury to the gland.

Injury Grade and Surgical Planning

In pancreatic trauma, the grade of injury dictates surgical decision-making. In a study of traumatic pancreatic injuries, Kao et al. concluded that the American Association for the Surgery of Trauma (AAST) organ injury score predicts the development of complications and mortality after pancreatic injury; it also identifies patients who require extensive resources and require a level I trauma center (Table 2) [35].

The practice management guideline from the Eastern Association for the Surgery of Trauma published in 2017 was a systematic review using 37 articles for guideline creation. They recommend for grade I or II pancreatic injuries, non-operative or non-resectional management. For grade III or IV pancreatic injuries identified on CT scan or during operation, they conditionally recommend pancreatic resection. Additionally, they recommended against the use of prophylactic octreotide for post-operative pancreatic fistula formation. Furthermore, they did not have conclusive recommendations for grade V injury management or for routine splenectomy with distal pancreatectomy [36•].

Grade I and II Injuries Patients with grade I and II injuries have minor or major lacerations or contusions to the pancreatic parenchyma, typically stab or gunshot wounds to the tail of the pancreas without ductal involvement or tissue loss. In this patient population, wide drainage is the ideal treatment strategy. Krige et al. found that 60% of all pancreatic injuries are consistent with contusions, hematomas, or capsular lacerations. And 20% of all pancreatic injuries are parenchymal lacerations without ductal injury. They recommended management with hemostasis and external drainage [37].

In a prospective analysis randomizing patients with pancreatic injury to receive sump versus closed suction

Table 2 Pancreas injury scoring scale

Grade	Type of injury	Description of injury
I	Hematoma	Minor contusion without duct injury
	Laceration	Superficial laceration without duct injury
II	Hematoma	Major contusion without duct injury or tissue loss
	Laceration	Major laceration without duct injury or tissue loss
III	Laceration	Distal transection or parenchymal injury with duct injury
IV	Laceration	Proximal transection or parenchymal injury involving ampulla
V	Laceration	Massive disruption of pancreatic head

drainage, septic complications post-operatively were significantly less in the closed suction drainage group [38].

Grade I and II pancreatic injuries are best managed by external drainage and controlled fistula formation. Solitary parenchymal injuries should not be repaired as there is no pancreatic capsule and sutures may lead to pseudocyst formation. While prolonged ileus and pancreatic complications may inhibit starting a diet, patients with low-grade pancreatic injuries should receive enteric nutrition as soon as possible. This should be consistent with elemental diets lower in fat and higher in pH to lessen the stimulatory effects on pancreatic exocrine function.

Grade III Injuries Grade III injuries are consistent with major lacerations typically from gunshot or stab wounds to the body or tail of the pancreas with visible duct involvement or have greater than half the width of the distal pancreas transected. For patients with distal parenchymal transection and disruption of the main pancreatic duct, distal pancreatectomy is the recommended management strategy [36•, 37].

Intraoperatively, the duct should be visualized and individually ligated. This can be accomplished with direct suture ligation using non-absorbable suture through the full thickness of the gland in an anterior–posterior direction with interlocking U sutures or figure of eight sutures to close the duct. A stapling device could also be utilized. A small omental patch can be placed over the area of resection to help buttress the stump closure. And closed suction drainage should be placed adjacent to the distal pancreatectomy site [39].

Distal pancreatectomy can be accomplished in grade III pancreatic injuries with or without splenectomy. However, splenic preservation can lead to increased time in the operating room with increased blood loss [39]. Splenic preservation should only be attempted after complete pancreatic mobilization with careful dissection of the splenic artery and vein in hemodynamically stable, normothermic patients.

Grade IV Injuries Proximal transection of parenchymal pancreatic tissue involving the ampulla or distal bile duct is consistent with a grade IV injury. If there is not massive disruption to the head of the pancreas and duodenum, external drainage with primary repair of an associated duodenal injury is an option for operative treatment [37]. If intra-operative exploration fails to exclude duct injury and intra-operative pancreatography cannot be accomplished, wide external drainage and post-operative ERCP are a management strategy.

Paton et al. identified 13.5% of all patients with proximal pancreatic injuries developed fistulas or abscesses [31]. The main treatment tenant in these patients is adequate external drainage with closed suction drains to minimize pancreatic fluid spillage in the abdomen to avoid future complications.

Grade V Injuries Grade V pancreatic injuries are described as massive disruption of the pancreatic head. This injury typically requires more than just external closed suction drainage to create adequate fluid spillage control, especially if there is a combined duodenal injury resulting in dual bile duct and pancreatic duct disruption involving the ampulla. Pancreatoduodenectomy may be required in these patients and can be the optimal operative treatment strategy for anatomic reconstruction [37].

Combined Duodenal and Pancreatic Injuries

Combined pancreatic head and duodenal injuries with disruption of the ampullary–biliary–pancreatic union or major devitalizing injuries to the pancreatic head and duodenum are rare. These are often seen in the setting of associated intra-abdominal injuries and are most likely secondary to penetrating trauma. The number one cause of mortality in these patients is associated major vascular injury.

Diagnosis of combined biliary and pancreatic ductal disruption is critical. Therefore, any stable patient with pancreatic and duodenal injury should have a cholangiogram performed. Surgical treatment strategy can then be determined by the integrity of the distal common bile duct, ampulla, and severity of the duodenal injury. If these anatomic structures are not intact, completion pancreatoduodenectomy is the procedure of choice [37]. The authors favor duct identification via transcystic placement of a Fogarty catheter also allowing for recognition of the ampulla opening within the duodenum.

Pancreatoduodenectomy in Trauma

While pancreatoduodenectomy is one method of repair, some recommend a more conservative approach. In 2014, Van der Wilden et al. evaluated the National Trauma Data Bank to determine whether or not pancreatoduodenectomies should be performed in the setting of traumatic injury. They compared 39 patients who had pancreatoduodenectomies versus 38 patients who did not in the setting of grade IV and V severe combined pancreatic and duodenal injury. They did not find a difference in outcomes, despite the pancreatoduodenectomy patients having a better systolic blood pressure and Glasgow Coma Score. They, therefore, recommended a more conservative approach to management [40].

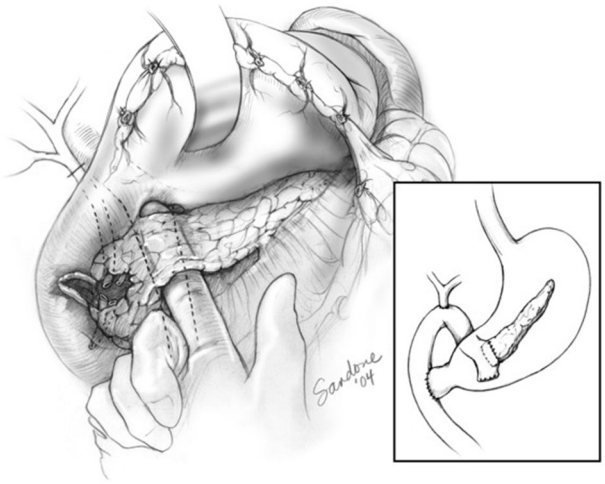

Fig. 4 Surgical exposure of ampulla, duct, and pancreatic head disruption for reconstruction. Reproduced with permission of Lippincott Williams & Wilkins, from Efron et al. Operative Management of Pancreatic Trauma. In: Fischer JE, ed. *Mastery of Surgery 5th Edition*. Philadelphia, PA: Lippincott Williams & Wilkins; 2007: 1320–1323.

Conversely, some have argued that pancreatoduodenectomies are life-saving in patients carefully selected with non-reconstructible pancreatic head injuries (Fig. 4) [41]. In 2016, Krige et al. published prospectively collected data on traumatic pancreatoduodenectomies in grade V injuries. He identified 75 patients with combined pancreatic and duodenal injuries, 19 of whom underwent pancreatoduodenectomy. These patients had an 84% complication rate and 16% mortality rate. They attributed mortality to associated vascular injuries; 9 of the 16 patients had associated portal vein or inferior vena cava injuries. They concluded their careful selection of patients resulted in an 84% survival rate [42•].

Damage Control Pancreatoduodenectomy

Once pancreatoduodenectomy becomes the treatment strategy of choice, timing becomes critical to management. In 2013, Thompson et al. reviewed patients who underwent pancreatoduodenectomy for trauma. They found that the majority of patients underwent a staged procedure using damage control laparotomy (DCL) during the index case. They found patients who underwent completed reconstruction in the first operation had an operative time of 460 min vs. 243 min in patients who underwent DCL. While 87% of patients were acidotic, hypothermic, and coagulopathic during the first operation, there was no difference in complications and overall mortality was 13%. They concluded that a staged approach with this injury pattern should be used to achieve a low mortality rate [43•]. Additionally, DCL prior to pancreatoduodenectomy has been reported as a salvage technique to save the most severely injured patients [41].

The authors favor a damage control approach to patients with combined duodenal and pancreatic injuries requiring pancreatoduodenectomy. The pancreatoduodenectomy specimen should be removed during the first operation whereas reconstruction should be completed in the second. During the index operation, hemostasis and contamination control should be obtained immediately. We then recommend performing a Kocher maneuver, mobilizing the duodenum, and taking down the ligament of Treitz. Unless involved in the injury, we favor leaving the gallbladder in place to avoid increased operative time and easier identification of anatomy during future operations. The common bile duct should be divided and proximally ligated leaving a generous suture tail for ease of later identification. An additional strategy to avoid excessive bleeding is to mobilize the ligament of Trietz and divided the short first few branches of the SMA/SMV early. Following ongoing high volume transfusion and resuscitation, these vessels become engorged, and their division later in the procedure can result in excessive blood loss.

After intra-operative and post-operative resuscitation, both the ligated pancreatic duct and common bile duct dilate several millimeters. The patient returns to the OR at 36–48 h, hopefully in a more stable condition. The pancreas is inspected and any additional damaged tissue not well identified initially (say due to GSW energy) is resected to "freshen up" the cut edge of the pancreas. The edematous gland also holds sutures better than normal gland tissue. We, therefore, favor reconstruction in the second operation when the pancreatic and common bile ducts are more easily identifiable to construct the pancreatojejunostomy and choledochojejunostomy. We find this especially important since the leading risk for pancreatic leak following resection is trauma as the indication for operation [44].

Conclusion

Duodenal and pancreatic injuries remain challenging to diagnose and treat. While rare, they are a significant cause of morbidity and mortality. Early recognition is critical in improving morbidity and mortality in these patients. Thorough evaluation in the operating room of ductal involvement and appropriate surgical management of these injuries are paramount to optimize patient outcome.

Compliance with Ethical Standard

Conflict of interest Rachel L. Choron and David T. Efron declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

Reference

Papers of particular interest, published recently, have been highlighted as:

- Of importance

1. Larrey Baron DJ. Memoirs of military surgery and campaigns [Translated from the French by R.W. Hall]. Vol. 3. Joseph Cushing, Baltimore. 1814;3:309–9.
2. Travers B. Rupture of the pancreas. Lancet. 1827;12:384.
3. Lucas CE, Ledgerwood AM. Factors influencing outcome after blunt duodenal injury. J Trauma. 1975;15(10):839–46.
4. Cuddington G, Rusnak CH, Cameron RD, Carter J. Management of duodenal injuries. Can J Surg. 1990;33(1):41–4.
5. Synder WH 3rd, Weigelt JA, Watkins WL, Bietz DS. The surgical management of duodenal trauma. Precepts based on a review of 247 cases. Arch Surg. 1980;115(4):422–9.
6. Ivatury RR, Nallathambi MA, Gaudino J, Rohman M, Stahl WM. Penetrating duodenal injuries. Analysis of 100 consecutive cases. Ann Surg. 1985;202(2):153–8.
7. Ballard RB, Badellino MM, Eynon CA, Spott MA, Staz CF, Buckman RF Jr. Blunt Duodenal rupture: a 6-year statewide experience. J Trauma. 1997;43(2):229–32.
8. Allen GS, Moore FA, Cox CS Jr, Mehall JR, Duke JH. Delayed diagnosis of blunt duodenal injury: an avoidable complication. J Am Coll Surg. 1998;187(4):393–9.
9. Allen TL, Mueller MT, Bonk RT, Harker CP, Duffy OH, Stevens MH. Computed tomographic scanning without oral contrast solution for blunt bowel and mesenteric injuries in abdominal trauma. J Trauma. 2004;56(2):314–22.
10. Rickard MJ, Brohi K, Bautz PC. Pancreatic and duodenal injuries: keep it simple. ANZ J Surg. 2005;75(7):581–6.
11. Talving P, Nicol AJ, Navsaria PH. Civilican duodenal gunshot wounds: surgical management made simpler. World J Surg. 2006;30(4):488–94.
12. Velmahos GC, Constantinou C, Kasotakis G. Safety of repair for severe duodenal injuries. World J Surg. 2008;32(1):7–12.
13. Cogbill TH, Moore EE, Feliciano DV, Hoyt DB, Jurkovich GJ, Morris JA, Mucha P Jr, Ross SE, Strutt PJ, Moore FA, et al. Conservative management of duodenal trauma: a multicenter perspective. J Trauma. 1990;30(12):1469–75.
14. Berne CJ, Donovan AJ, White EJ, Yellin AE. Duodenal "diverticulization" for duodenal and pancreatic injury. Am J Surg. 1974;127(5):503–7.
15. Summers JEIX. The treatment of posterior perforations of the fixed portions of the duodenum. Ann Surg. 1904;39(5):727–32.
16. Asensio JA, Feliciano DV, Britt LD, Kerstein MD. Management of duodenal injuries. Curr Probl Surg. 1993;30(11):1023–93.
17. Dubose JJ, Inaba K, Teixeira PG, Shiflett A, Putty B, Green DJ, Plurad D, Demetriades D. Pyloric exclusion in the treatment of severe duodenal injuries: results from the National Trauma Data Bank. Am Surg. 2008;74(10):925–9.
18. Nassoura ZE, Ivatury RR, Simon RJ, Kihtir T, Stahl WM. A prospective reappraisal of primary repair of penetrating duodenal injuries. Am Surg. 1994;60(1):35–9.
19. Jansen M, Du Toit DF, Warren BL. Duodenal injuries: surgical management adapted to circumstances. Injury. 2002;33(7):611–5.
20. Stone HH, Fabian TC. Management of duodenal wounds. J Trauma. 1979;19(5):334–9.
21. Hasson JE, Stern D, Moss GS. Penetrating duodenal trauma. J Trauma. 1984;24(6):471–4.
22. Asensio JA, Petrone P, Roldan G, Kuncir E, Demetriades D. Pancreaticoduodenectomy: a rare procedure for the management of complex pancreaticoduodenal injuries. J Am Coll Surg. 2003;197(6):937–42.
23. Desai KM, Dorward IG, Minkes RK, Dillon PA. Blunt duodenal injuries in children. J Trauma. 2003;54(4):640–5.
24. Jewett TC Jr, Caldarola V, Karp MP, Allen JE, Cooney DR. Intramural hematoma of the duodenum. Arch Surg. 1988;123(1):54–8.
25. Krige JE, Kotze UK, Hameed M, Nicol AJ, Navsaria PH. Pancreatic injuries after blunt abdominal trauma: an analysis of 110 patients treated at a level 1 trauma centre. S Afr J Surg. 2011;49:62–4.
26. Young PR, Meredith JW, Baker CC, Thomason MH, Chang MC. Pancreatic injuries resulting from penetrating trauma: a multi-institution review. Am Surg. 1998;64:838–43.
27. Vasquez JC, Coimbra R, Hoyt DB, Fortlage D. Management of penetrating pancreatic trauma: an 11-year experience of a level-1 trauma center. Injury. 2001;32:753–9.
28. Chinnery GE, Krige JE, Kotze UK, Navsaria P, Nicol A. Surgical management and outcome of civilian gunshot injuries to the pancreas. Br J Surg. 2012;99(Suppl. 1):140–8.
29. Olah A, Isselkutz A, Haulik L, Makay R. Pancreatic transection from blunt abdominal trauma: early versus delayed diagnosis and surgical management. Dig Surg. 2003;20:408–14.
30. Mahajan A, Kadavigere R, Sripathi S, Rodrigues GS, Rao VR, Koteshwar P. Utility of serum pancreatic enzyme levels in diagnosing blunt trauma to the pancreas: a prospective study with systematic review. Injury. 2014;45(9):1384–93.
31. Patton JH Jr, Lyden SP, Croce MA, Pritchard FE, Minard G, Kudsk KA, Fabian TC. Pancreatic Trauma: a simplified management guideline. J Trauma. 1997;43(2):234–9.
32. Velmahos GC, Tabbara M, Gross R, Willette P, Hirsch E, Burke P, Emhoff T, Gupta R, Winchell RJ, Patterson LA, Manon-Matos Y, Alam HB, Rosenblatt M, Hurst J, Brotman S, Crookes B, Sartorelli K, Chang Y. Blunt pancreatoduodenal injury: a multicenter study of the Research Consortium of New England Centers for Trauma (ReCONECT). Arch Surg. 2009;144(5):413–9.
33. Harrell DJ, Vitale GC, Larson GM. Selective role for endoscopic retrograde cholangiopancreatography in abdominal trauma. Surg Endosc. 1998;12(5):400–4.
34. Asensio JA, Demetriades D, Berne JD, Falabella A, Gomez H, Murray J, Cornwell EE 3rd, Velmahos G, Belzberg H, Shoemaker W, Berne TV. A unified approach to the surgical exposure of pancreatic and duodenal injuries. Am J Surg. 1997;174(1):54–60.
35. Kao LS, Bulger EM, Parks DL, Byrd GF, Jurkovich GJ. Predictors of morbidity after traumatic pancreatic injury. J Trauma. 2003;55:898–905.
36. • Ho VP, Patel NJ, Bokhari F, Madbak FG, Hambley JE, Yon JR, Robinson BR, Nagy K, Armen SB, Kingsley S, Gupta S, Starr FL, Moore HR 3rd, Oliphant UJ, Haut ER, Como JJ. Management of adult pancreatic injuries: A practice management guideline from the Eastern Association for the Surgery of Trauma. J Trauma. 2017; 82(1):185–99. Current guidelines by the national trauma society, EAST, for pancreatic injury management.

37. Krige JE, Beningeld SJ, Nicol AJ, et al. The management of complex pancreatic injuries. S Afr J Surg. 2005;43:92–102.
38. Fabian TC, Kudsk KA, Croce MA, Payne LW, Mangiante EC, Voeller GR, Britt LG. Superiority of closed suction drainage for pancreatic trauma A randomized, prospective study. Ann Surg. 1990;211:724–30.
39. Asensio JA, et al. Atlas and textbook of techniques in complex trauma surgery. Philadelphia: Saunders; 2005.
40. Van der Wilden GM, Yeh D, Hwabejire JO, Klein EN, Fagenholz PJ, King DR, de Moya MA, Change Y, Velmahos GC. Trauma whipple: do or don't after severe pancreaticoduodenal injuries? An analysis of the National Trauma Data Bank (NTBD). World J Surg. 2014;38(2):335–40.
41. Krige JE, Nicol AJ, Navsaria PH. Emergency pancreatoduodenectomy for complex injuries of the pancreas and duodenum. HPB. 2014;16(11):1043–9.
42. • Krige JE, Kotze UK, Setshedi M, Nicol AJ, Navsaria PH. Surgical management and outcomes of combined pancreaticoduodenal injuries: analysis of 75 consecutive cases. J Am Coll Surg. 2016; 222(5):737–49. A recent study, completed in 2016, of 75 consecutive combined duodenal and pancreatic injuries; one of the largest series to date.
43. • Thompson CM., Shalhub S, DeBoard ZM, Maier RV. Revisiting the pancreaticoduodenectomy for trauma: a single institution's experience. J. Trauma Acute Care Surg. 2013;75:225–28. A recent article reviewing their latest experience with pancreaticoduodenectomy in the traumatic setting.
44. Nathan H, Cameron JL, Goodwin CR, Seth AK, Edil BH, Wolfgang CL, Pawlik TM, Schulick RD, Choti MA. Risk factors for pancreatic leak after distal pancreatectomy. Ann Surg. 2009;250(2):277–81.