Diagnosis and management of pancreatic trauma: What you need to know

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ABSTRACT: The pancreas is an entirely retroperitoneal structure, and hence, the initial step of recognizing a pancreatic injury is at times difficult. This is particularly critical since delays in recognition and appropriate management dramatically increase morbidity. This review article discusses the important anatomical features of the pancreas, the large variety of diagnostic maneuvers and their pitfalls, and a management strategy for pancreatic injury that is largely based on the organ injury scale. Nuances in the operative management are highlighted, as they are the most challenging of management dilemmas, making this a review of "What you need to know" about pancreatic trauma. (*J Trauma Acute Care Surg.* 2025;00: 00–00. Copyright © 2025 Wolters Kluwer Health, Inc. All rights reserved.)

KEY WORDS: Pancreas; pancreatic trauma; pancreatic injury.

PANCREAS ANATOMY

The pancreas is a transversely oriented, retroperitoneal structure, which curves up from the midline toward the left upper quadrant. As an entirely retroperitoneal structure, the initial step of recognizing a pancreatic injury is at times difficult and made more crucial since delays in recognition and appropriate management dramatically increase morbidity. Important anatomical details for the trauma surgeon is that it is positioned anterior to the first and second lumbar vertebrae and is in proximity to a multitude of vascular structures. The head of the pancreas overlies inferior vena cava, right renal vessels, and left renal vein entering the inferior vena cava. The splenic vein is posterior and inferior to the gland and is joined at variable locations by the inferior mesenteric vein. A key anatomical junction is the splenic vein and superior mesenteric vein (SMV) joining to form the portal vein under the neck of the pancreatic gland.[1–4] The pancreas has a shared blood supply with the duodenum from the anterior and posterior branches of the superior and inferior pancreaticoduodenal arteries, making hemorrhage control particularly challenging.

The anatomy of the exiting pancreatic duct can have some variation. The most common anatomy is the main pancreatic duct of Wirsung and the common bile duct joining into the major duodenal papilla. A common variant is the duct of Wirsung sitting caudad to the minor duodenal papilla, which drains the smaller duct of Santorini.[2]

EPIDEMIOLOGY AND MECHANISMS OF PANCREATIC TRAUMA

In reports from large volume trauma centers, pancreatic injury occurs in less than 2% of traumatically injured patients. Common mechanisms leading to pancreatic injury including crush injury from the steering wheel leading to compression of upper abdominal organs against the spine, or penetrating trauma from stab and gunshot wounds, and the incidence of blunt or penetrating injuries are largely dependent on the institutional experience with blunt mechanism generally being more common and in the range of 56% to 89%.[5–9]

In a recent Western Trauma Association multicenter study of 1,240 patients with pancreatic injury, 44% were found to be due to penetrating mechanism.[6] In this cohort, patients with penetrating injury were found to be twice as likely both to undergo resection and to have pancreas-related complications compared with blunt injury mechanisms. Resection was performed in 45% of patients with penetrating mechanism and pancreatic injury versus 23% of those with blunt mechanism and pancreatic injury. Penetrating mechanism was also identified as an independent risk factor for pancreas-related complications (39% in those with penetrating injury vs. 20% in those with blunt injury; odds ratio, 1.99; 95% confidence interval, 1.33–3.05). There were concomitant colon (47% penetrating, 27% blunt), stomach (46% penetrating, 29% blunt), and duodenal (33% penetrating, 10% blunt) injuries, emphasizing the anatomical location of the pancreas and its contiguous structures. Figure 1 highlights key differences in penetrating and blunt force pancreatic injury management, complications, and associated injuries.

DIAGNOSTIC STRATEGIES

Clinical Examination

Given the pancreas is well protected in the retroperitoneum, the mechanism required to cause pancreatic injury is often significant and results in associated intra-abdominal injuries. The intimate proximity of major vessels and the duodenum also challenges good exposure and detracts attention from pancreas.

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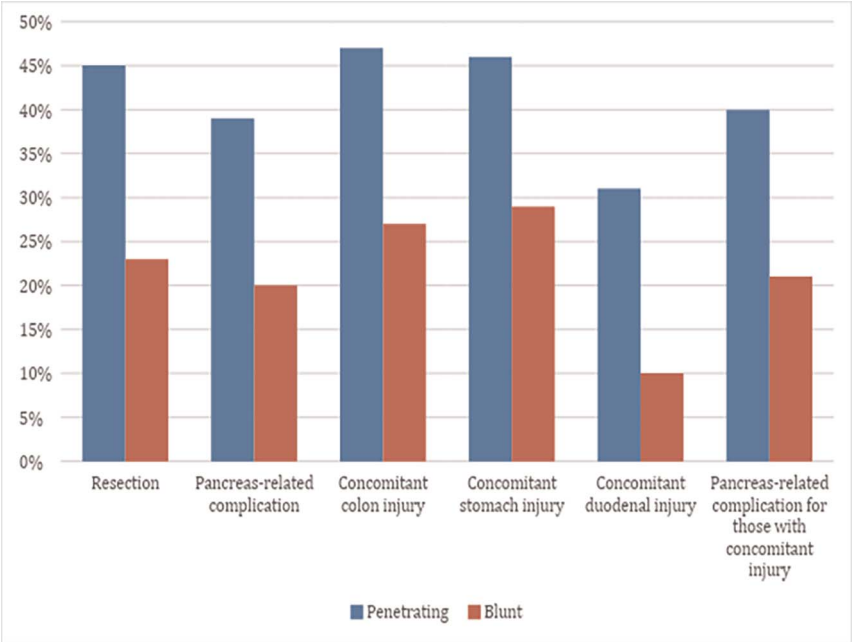

Figure 1. This figure represents the comparison of blunt versus penetrating mechanism in the multicenter cohort of pancreatic injury patients studied by the WTA Multicenter Trials Group on Pancreatic Injuries.[8]

Because of the retroperitoneal location of the pancreas, the signs and symptoms of pancreatic trauma can be subtle at the onset. The clinical examination of the patient can be variable and may not reveal the classic signs of acute abdomen despite presence of potentially catastrophic injury. Signs and symptoms of nausea, vomiting, and epigastric pain may accompany the presentation. The classic eponym of retroperitoneal bleeding, the Gray-Turner sign of a lateral abdominal wall hematoma, is rarely seen. All these factors make more complex the options for management. High index of suspicion based on trauma mechanism combined with thoughtful imaging is needed to avoid delays in diagnosis.[10]

Laboratory Evaluation

Laboratory evaluation with serum amylase or lipase has a good negative predictive value if used in the appropriate timeline. If these enzyme levels are within normal limits more than 3 hours after the traumatic injury has occurred, 95% of the time, there is no pancreatic injury. The sensitivity of a 3-hour postinjury combined serum amylase and lipase has been reported as 85% with 100% specificity.[11,12]

Diagnostic Imaging

Imaging is a crucial adjunct to the evaluation of pancreatic injury. On the other hand, it is important to understand the limits of imaging in detecting a pancreatic injury. An older (2009) but well-conducted multicenter study included 206 patients with laparotomy-documented pancreatic injury including 71 with pancreatic duct injury. In this study, 16 multidector computed tomography and 64 multidector computed tomography were found to have a sensitivity of 60% and 47% for detecting pancreatic injury and 54% and 52% for detecting pancreatic duct injury (95% and 90% specificity, respectively).[8]

Computed tomography findings suggestive of pancreatic injury include "fluid in the lesser sac, fluid between pancreas and splenic vein, hematoma of transverse mesocolon, thickening of left anterior renal fascia, duodenal hematoma or laceration, injury to spleen, left kidney, and left adrenal gland, chance (transverse) fracture of the lumbar spine, especially in a child."[1] Computed tomography findings diagnostic of pancreatic injury include "parenchymal hematoma or laceration, obvious transection of parenchyma/duct with fluid in the lesser sac, disruption of the head of pancreas, diffuse swelling characteristic of posttraumatic pancreatitis." What is often missing from these descriptions is the importance of timing for radiologic findings to occur. Imaging within 2 hours of injury often misses important signs of pancreatic injury; hence, repeat imaging is advised if suspicions are high or clinical scenario changes.

While there is general agreement that the status of the main pancreatic duct is fundamental to management strategies, duct injury can be difficult to diagnose. Nonetheless, the status of the main pancreatic duct is a principle of any grading system, as well as management strategy. In the setting of an acute abdominal injury, intravenous contrast-enhanced CT is the most common initial modality but has a low sensitivity and high specificity.[13] As mentioned earlier, delayed imaging can influence the findings seen on CT, so when in doubt, repeat the CT or explore the abdomen.

Direct visualization with endoscopic retrograde cholangiopancreatography (ERCP) and indirect imaging with magnetic resonance cholangiopancreatography (MRCP) have recently gained traction in the initial evaluation for pancreatic duct injury. The ability to obtain MRCP and ERCP can be limited by the stability of the patient, the presence of concomitant injuries, and institutional resources. MRCP and ERCP have been reported to have 90% to 100% sensitivity and specificity. However, in a

secondary analysis from the Western Trauma Association multicenter trials group on pancreatic injuries, MRCP was found to have only a 37% sensitivity, 94% specificity, 77% positive predictive value, and 73% negative predictive value for pancreatic duct injury. In the 36 patients who had both MRCP and ERCP done, 64% of cases had MRCP findings, which were discordant with the ERCP findings.[14] The timing of imaging was not reported, which likely is of significant interest. In addition, the use of secretin-stimulated MRCP may increase the sensitivity/specificity, but it has only been reported in limited case reports.[15–17]

Figure 2 highlights the generally reported sensitivity and specificity of the common diagnostic imaging modalities, but as noted, there is great variability dependent on timing, equipment, and expertise of interpretation.

Intraoperative Evaluation

While operative direct inspection of the pancreas is the current "criterion standard," it requires more than a casual glance at the body in the lesser sac. The complete intraoperative evaluation of the pancreas requires the following three key maneuvers: opening the entire lesser sac, which allows for evaluation of the anterior surface of the body of the pancreas, (2) full Kocher maneuver including taking down of hepatic flexure of the colon and mobilizing the duodenum, which allows for evaluation of the head of the pancreas, and (3) mobilizing the spleen to midline and lifting the spleen and pancreas as one out of the retroperitoneum, which allows for evaluation of the tail.[10]

Intraoperative evaluation for pancreatic duct injury requires that the pancreatic capsule be opened, but this should be limited to areas of suspicious injury. We would recommend this maneuver if any contusion or hematoma is evident. If there is hematoma present, the hematoma must be washed away to determine whether a pancreatic duct injury is present.[10] Two other methods to assist with the intraoperative evaluation for pancreatic duct injury are the use of cholecystokinin as a stimulating agent for pancreatic secretion and intraoperative cholangiopancreatography. Intraoperative cholangiography may be particularly helpful in the setting of trauma to the head of the pancreas. The recommended technique involves accessing the gallbladder with a 22-gauge angiocatheter and instilling 50 mL to 75 mL of three-quarter strength radio-opaque contrast under fluoroscopic visualization.[19,20]

More recently, the use of surgeon performed intraoperative ultrasound (IOUS) has been explored as an adjunct to diagnosis pancreatic duct injury. Moren et al.[21] and Biffl et al.[6,14,22] have been actively exploring current trends in the management of pancreatic injury using the Western Trauma Association Multi-institutional Trials group. In a report of 74 patients in whom IOUS was used, 48 of them were considered at severe risk, namely, Grade III, IV, or V categories. The authors compared the performance characteristics of CT, MRCP, ERCP, and IOUS in these patients, understanding that not every patient had all studies. As noted in the table, IOUS had the highest specificity and nearly perfect sensitivity, with the one false-negative IOUS occurring after a shotgun blast to the head of the pancreas (Grade V). The authors recommend use of a multifrequency probe (i.e., either a T or I shaped, side or end viewing; curvilinear array) (preferably 10–12 MHz), saline immersion, and use of duodenum, stomach, gastrohepatic and gastrocolic ligaments, and the transverse mesocolon as an acoustic window prior to dissection to avoid air entry into planes that then can create image artifact.

Table 1 highlights the intraoperative maneuvers that can be utilized to identify pancreatic duct injuries.

MANAGEMENT STRATEGIES

Using AAST Grading System to Determine Management Strategy

Many issues can influence management decisions, and the American Association for the Surgery of Trauma (AAST)

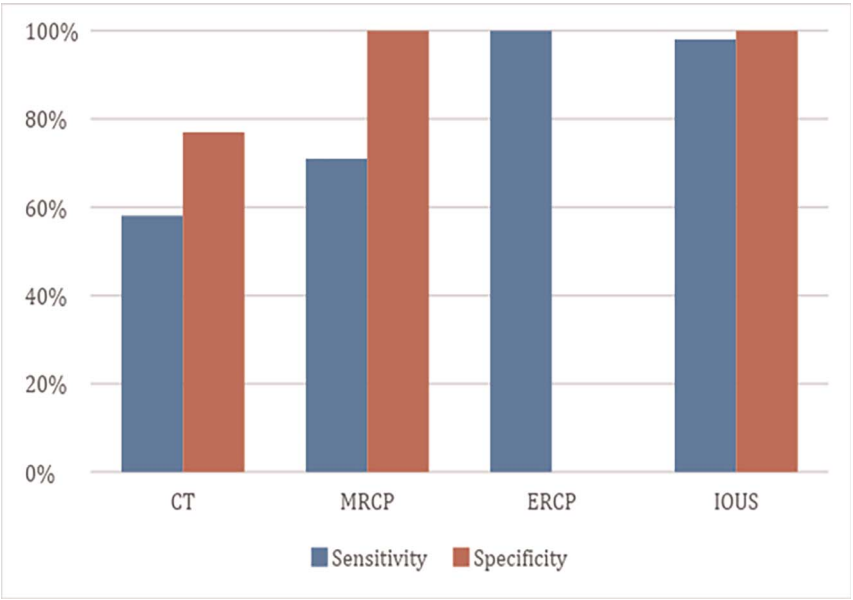

Figure 2. This is a representation of the test performance for detecting main pancreatic duct injuries in the study of 248 pancreatic injuries by Ball et al. (March 2024).[18]

TABLE 1. Intraoperative Evaluation for Pancreatic Injury

Maneuvers for the Intraoperative Evaluation of Pancreatic Injury
Key aspects of the procedure
1. Open lesser sac via gastrocolic momentum
2. Takedown the hepatic flexure and perform the Kocher maneuver
3. Mobilize the spleen to adequately visualize the body and tail
4. Open pancreatic capsule to assess gland surface at areas of hematoma/contusion
Other considerations
1. Trace all penetrating injuries
2. CCK given IV to assist injury identification
3. Intraoperative cholangiogram via gallbladder contrast infusion to identify cystic duct, duodenum, proximal pancreatic duct injuries, and anatomy
4. Intraoperative ultrasonography of the pancreas
5. Be vigilant, as an intact pancreatic capsule does not rule out pancreatic duct injury

Key aspects of intraoperative evaluation of the pancreas as well as important considerations are listed above.
CCK, cholecystokinin.

scoring system was designed both to unify reporting of pancreatic injuries and to help guide treatment strategies. Since 1990, the AAST grading system has been used to categorized pancreatic injury into five grades[23] (Table 2). When considered the many options for managing pancreatic injury listed in Table 3, the AAST guidelines provide useful direction. Pancreatic injury with contusion or laceration without duct injury is Grades I and II based on severity of the contusion/laceration. A pancreatic injury with duct injury that is to the left of superior mesenteric vessels is a Grade III injury. Grade IV is a transection with duct injury to the right of superior mesenteric vessels. Grade V would be a massive disruption of the pancreatic head. Note the implication of this grading system is that III, IV, and V all involve disruption of the main pancreatic duct. More recently, this grading system has been challenged around the distinction of Grade IV injuries. This will be discussed hereinafter in more detail.

Figure 3 represents contemporary management strategies based on these grades of injury, as recommended by the Western Trauma Association critical decisions algorithm in blunt pancreatic injury.[21] It serves as a guide for the evaluation and management of patient with possible blunt pancreatic injury and illustrates the complexity of decision-making steps.

AAST Grades I and II

Patients who are hemodynamically stable and found to have minor pancreatic injury can be safely managed nonoperatively. When discovered intraoperatively, minor laceration or contusions (Grade I) can be managed without drainage. When patients with other intra-abdominal injuries undergo operative intervention and are discovered to have major contusions or lacerations to the pancreas (Grade II) without evidence of ductal injury, closed-suction drainage is advised until it is certain there is no pancreatic fistula or enzyme leak. Drainage has been identified as an independent predictor of decreased mortality, and Eastern Association for the Surgery of Trauma guidelines conditionally recommend drainage of Grades I and II pancreatic injury discovered intraoperatively.[24,25] We have not found useful any efforts to cover a minor injury with a sealant or hemostatic agent, although it is often tempting to use omentum as a patch.

AAST Grade III

Distal pancreatectomy is generally recommended for major pancreatic injury that is anatomically to the left of superior mesenteric vessels and transects or injures the main pancreatic duct. A variety of closure techniques (and debates) have been described including suture versus stapled closure of the stump, with or without suture ligation of the main pancreatic duct, and buttressing with omental patch, or a variety of nonautologous sealants, "glues," or patches. Regardless, placement of drains is crucial to help with diagnosis and management of pancreatic fistula.

Pancreatic stump management has been extensively studied in elective pancreatectomy for malignant and benign diseases. There are two recent meta-analyses of handsewn versus stapled technique for stump closure after elective distal pancreatectomy. One identified a benefit to stapled closure when the pancreas thickness is less than 12 mm for prevention of postoperative pancreatic fistulas.[26] The other identified a benefit to the stapled technique when including observational studies, but no difference between stapled or handsewn in the randomized controlled trials.[27] The use of adjuncts to seal the pancreatic resection site is particularly controversial and inconsistent in results. The most recent systemic review and meta-analysis of randomized clinical trials suggested that covering the stump with nonautologous reinforcement (with a curious exception of the

TABLE 2. Pancreatic Organ Injury Scale

Pancreas Injury Scale				
Grade*	**Type of Injury**	**Description of Injury**	**ICD-9**	**AIS-90**
I	Hematoma	Minor contusion without duct injury	863.81–863.84	2
	Laceration	Superficial laceration without duct injury		2
II	Hematoma	Major contusion without duct injury or tissue loss	863.81–863.84	2
	Laceration	Major laceration without duct injury or tissue loss		3
III	Laceration	Distal transection or parenchymal injury with duct injury	863.92/863.94	3
IV	Laceration	Proximal transection or parenchymal injury involving ampulla	863.91	4
V	Laceration	Massive disruption of pancreatic head	863.91	5

*Advance one grade for multiple injuries up to Grade III. Proximal pancreas is to the patients' right of the SMV. With permission, from Biffl et al.[6] (https://www.aast.org/resources-detail/injury-scoringscale#pancreas).

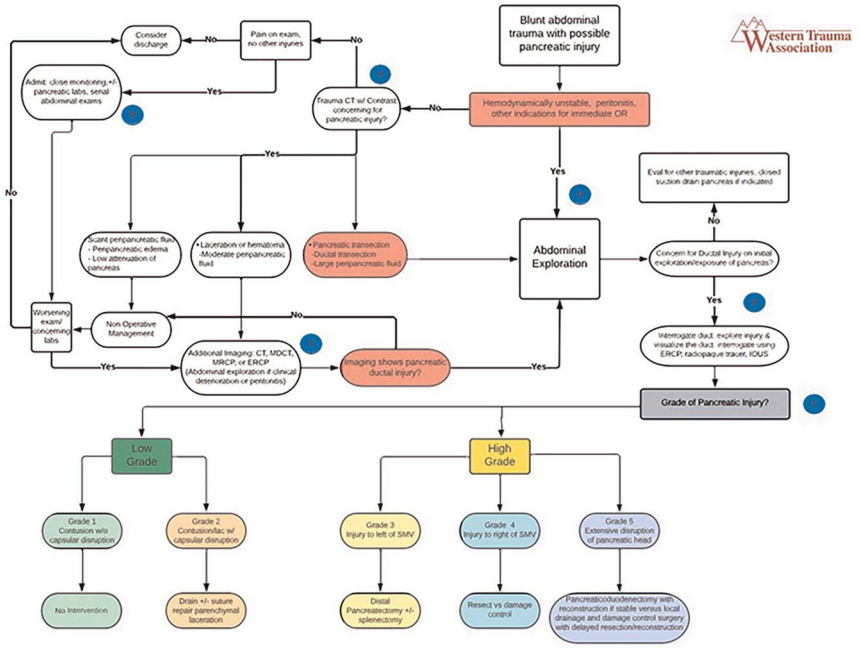

Figure 3. Western Trauma Association Blunt Pancreatic Trauma Management Algorithm (with permission).[19]

fibrin sealant patch Tachosil®, Takeda Pharmaceutical, Japan) was effective in preventing postoperative pancreatic fistula.[28]

We usually staple the pancreas with staple height dependent on pancreatic thickness; we also "u-stitch" close the main pancreatic duct if it can be identified after stapling. We do not use any hemostatic agents or "glue" or fibrin sealants but will drape omentum over the resected end if easily feasible. We prefer two 10-mm diameter Jackson-Pratt drains.

AAST Grades IV and V

Several operative options exist for these rare injuries. A subtotal or 70% to 90% pancreatectomy could be performed in rare cases where some portion of the proximal pancreas remains uninjured. This option has the additional challenge of closing the bulky proximal stump in the head of the pancreas along with the almost certain development of glucose intolerance, so alternatives have been tried and continue to be debated.[29]

The Letton-Wilson procedure involves suturing closed the head side of the pancreatic transection and internal drainage of the left remnant with a Roux-en-Y jejunal limb (Fig. 4D). After ligation of the exposed main pancreatic duct on the open transected pancreatic head or neck, the open end of the proximal aspect of the pancreas is oversewn or stapled. Then, approximately 2 cm of the distal pancreatic fragment is mobilized from the splenic vessels. An end-to-end distal pancreaticojejunstomy (invagination) is created in two layers using a 40-cm jejunal Roux limb. The Roux limb is passed through the right side of the transverse mesocolon that is fixed to the mesocolon. Jejunojejunostomy is performed and drains are placed.[29,30] Alternatively, an end-pancreatic duct to side mucosa of Roux limb

TABLE 3. Strategies, Indications, and Some Technical Details for the Management of Common Pancreatic Injuries

Strategy	Indications	Technical Tips
Nonoperative	AAST Grades I and II identified on imaging (conditional recommendation by EAST guidelines)	If there remains a question of pancreatic duct injury, use MRCP and ERCP in the stable patient
Endoscopic intervention	Consider for management of main pancreatic duct injury (AAST Grade III) in a stable patient or when duct injury is discovered in the postoperative setting	Requires advanced endoscopists
Operative drainage	AAST Grades I and II identified intraoperatively (conditional recommendation by EAST guidelines)	Use forceps bipolar electrocautery for hemostasis. Leave closed suction drains.
Distal pancreatectomy	AAST Grade III	Consider splenic preservation. Ligate or clip the small vessel branches between the spleen and pancreas.
Pancreatoduodenectomy	AAST Grade V	Consider staging this depending on the physiologic state of the patient into contamination and bleeding control, then resection, and then reconstruction.

EAST, Eastern Association for the Surgery of Trauma.

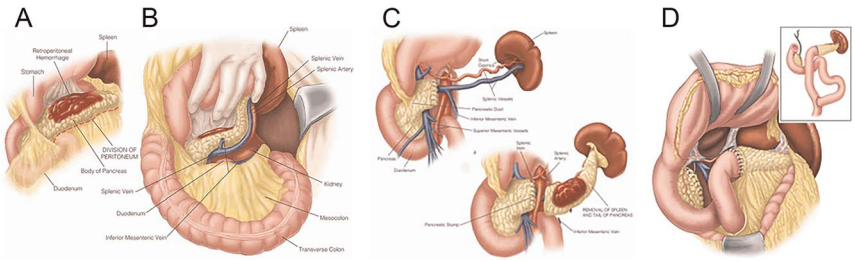

Figure 4. (*A*) Hematoma of the pancreas. (*B*) Exposure of the distal aspect of the pancreas. (*C*) Distal pancreatectomy with and without splenectomy. (*D*) Closure of proximal stump and Roux-limb drainage of the distal pancreas (with permission, this figure was adapted from Pancreatic Trauma[5]).

is an option. Either is preferred to simply closing the pancreatic duct and leaving the residual tail in situ, which has been tried with unacceptable results.

Using the Western Trauma Association multi-institutional study database, Ball et al.[31] have examined the outcome of simple drainage for patients with Grade IV pancreatic injuries. While an attractive alternative to the extensive resection and anastomoses typically described for this rare injury, the results of drainage alone are poor. Of 475 blunt pancreatic injuries, only 36 (8%) were confirmed as Grade IV. Two thirds underwent resections, and 12 patients had drainage alone. Pancreas-specific complications in the drainage group included 92% pancreatic leaks, 8% pseudocyst, and 8% walled-off pancreatic necrosis. Among patients with controlled pancreatic fistulas beyond 90 days, 67% required subsequent pancreatic operations (fistulojejunostomy or extended distal pancreatectomy). Among patients whose fistulas closed, 75% suffered from recurrent pancreatitis, and 67% had subsequent pancreatic operations. They conclude that whenever possible, resection is the preferred option for patients with Grade IV injures.

Pancreaticoduodenectomy is the procedure of choice in destructive combined duodenal and pancreatic head injuries (AAST Grade V pancreatic injury). Depending on the physiologic state of the patient, two- or three-staged pancreatoduodenectomy procedure can be performed. A two-staged procedure involves resection of the pancreas and duodenal head at the first operation, without reconstruction, which is performed a day or two later after correcting any physiologic abnormalities. Damage control principles of control of hemorrhage and contamination are applied in the setting of hypothermia, acidosis, coagulopathy. In a three-stage procedure, the primary operation involves closing the duodenal injury, ligating peripancreatic bleeders, and leaving closed suction drains in the first stage. The second stage would be the resection with stapling shut the common bile duct and the open end of the pancreas to prevent leakage from these ducts, leading to dilation of the ducts and making the gland firmer. When the physiology of the patient and the edema of the bowel is optimized, the reconstructive stage can be planned. A mortality rate of a low 13% has been reported when a traumatic pancreaticoduodenectomy is required following trauma.[32]

Figure 4 illustrates the most common anatomical considerations in the treatment of Grade III pancreatic injuries (insets *A* to *C*) and the rare anatomical management of Grade IV injuries with salvage of the distal pancreas (Fig. 4*D*).

MANAGEMENT STRATEGIES

Using Absence/Presence of Duct Injury to Determine Management Strategy

Sometimes, maybe often, the surgeon tries but cannot definitively identify an injury to the main pancreatic duct. Herein lies the greatest area of controversy in management. This has resulted in an alternative management strategy to the one described previously that follows the AAST Pancreatic Injury Scale. In this perhaps simplified approach, there are two options, based on whether the surgeon can identify a main pancreatic duct injury:

a. Drainage of the pancreas at the area of concern with closed suction drains;
b. Distal resection of the pancreas from the area of confirmed duct injury with a variety of technical details of this procedure.

Absence of Duct Injury

In the absence of duct injury on imaging and no intra-abdominal injury that requires operative exploration, nonoperative management would be appropriate. In the absence of duct injury but presence of "minor" pancreatic injury discovered on operative exploration for other intra-abdominal injuries, hemodynamic instability, or peritonitis, placement of drains is a well-accepted strategy. As described, intraoperative cholangiopancreatography and IOUS are excellent techniques to help identify main pancreatic duct injury in this setting. If there remains some question of duct injury, the consideration for postoperative MRCP or ERCP would be reasonable. If then duct injury is discovered postoperatively, endoscopy placement of pancreatic duct stent should be considered if the injury is proximal. The ability to offer endoscopic interventions is limited to the availability of advanced endoscopists and would need to be considered based on institutional resources and as a potential reason to transfer the patient to a higher level of care.

Presence of Duct Injury

In the presence of confirmed main duct injury, whether discovered on imaging or intraoperatively, distal pancreatectomy is performed when the injury is to the left of SMV. When the injury is to the right of the SMV, wide drainage should be considered as an alternative to a much more extensive pancreatectomy.

However, in the presence of accompanying injury to the duodenum or terminal common bile duct, damage-control strategies with a staged Whipple procedure is advised.

The most challenging of situations is when nonoperative treatment has been attempted, then a pancreatic duct transection is later discovered by MRCP or ERCP, and the injury or malalignment of the duct cannot be stented. Now the patient (and the caring surgeon) will have to deal with the long-term complication of an uncontrolled pancreatic fistula, pseudocyst, and dramatic retroperitoneal inflammatory storm.

MANAGEMENT STRATEGIES

Reconsidering AAST Grade IV Injuries

Having a common language to describe the variety and degree of pancreatic injury has been tremendous in providing consistency in clinical reporting, as well as research and quality improvement efforts, and has led to the development of the noted algorithms. However, more recently, concern has been raised that injuries to the head of the pancreas have been variably and inconsistently coded as either Grade II or Grade IV.[18,33] This variability likely arises from the inability to confirm the status of the pancreatic duct injury in this location. Ball et al.[18] have therefore proposed an update to the AAST grading system that assesses location of anatomic injury and whether the pancreatic duct is injured and, in their terms, "aligned or misaligned" (Fig. 5). In this proposed grading system alteration, parenchymal contusion or hematoma with an intact capsule or main duct is a Grade I injury. Grade II injury still requires that the main pancreatic duct be intact but would describe a pancreatic laceration with capsular disruption. Furthermore, there would be two subsections of Grade II injury to describe injury to the (A) left of and (B) right of the portal and SMV. Grade V remains the "disruption of the duodeno-pancreatic complex with main pancreatic and/or bile duct transection, or ampullary destruction." Grades III and IV continue as the AAST system to describe a pancreas with main duct injury that does not meet the description of Grade V injury. Grades III and IV are distinguished by the anatomic location of the injured duct to the left and right of the portal and SMV, respectively. Both Grades III and IV also have two subsections based on whether the main duct is (A) aligned or (B) misaligned or distracted. Presumably, the issue of alignment is germane to the ability to endoscopically stent the injured duct. The current iteration of the AAST Organ Injury Scale committee, the Patient Assessment Committee, has supported this modification, but to date, no clinical studies have applied this updated grading. This grading system has been met with some criticism and remains a subject of debate at this time.

PEDIATRIC PANCREATIC TRAUMA

Although nonoperative treatment is dominant for other blunt solid organ injury, less is known about the optimal management of blunt pancreatic trauma in children because of its infrequent occurrence (2–9%).[34] In addition, major ductal disruption in children is even less common (0.12 to 2.9% of blunt abdominal trauma in children).[35] The relative infrequency of this injury and proven efficacy of nonoperative management for other pediatric solid organ injuries have prompted authors to advocate similar algorithms for pediatric blunt pancreatic injuries.

Similar to the management of adults, most authors agree that isolated Grades I and II blunt pancreatic injuries may be safely managed without resection.[36,37] However, the safety of nonoperative approaches for more severe blunt pancreatic injury in children is less clear.

A review of the National Trauma Data Bank by Mora et al.[38] identified no differences in complication or mortality rates between operative and nonoperative treatment in 424 cases of pediatric patients with a pancreatic injury and Abbreviated Injury Scale score of 3 or greater. This is consistent with findings from a systematic review of 23 retrospective

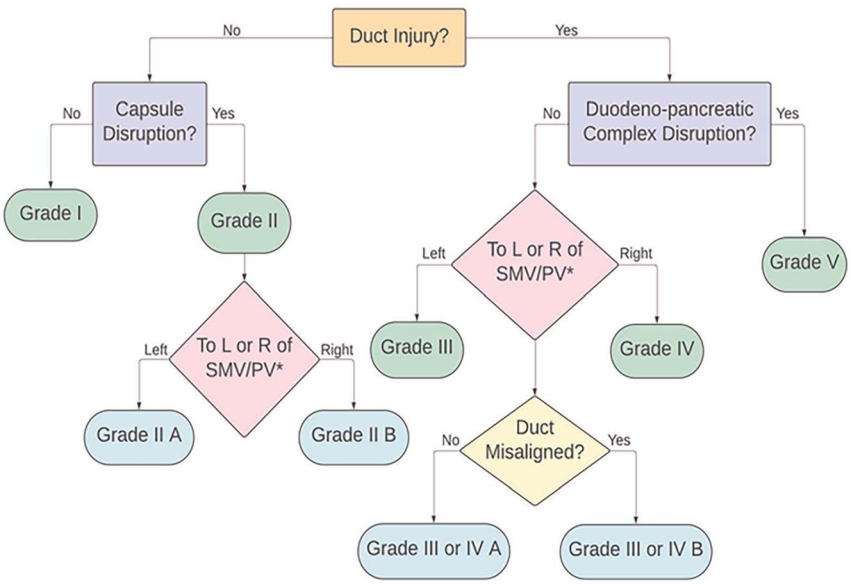

Figure 5. Flowchart created based on the suggested algorithm for updating the AAST grading system by Ball et al.[18]

studies, which reported that about half of children with Grades III to V blunt pancreatic injury were initially managed nonoperatively, with a success rate of 89%.[36] The data were generally of low quality, and the rationale for management decisions was not discussed in the included papers; thus, no specific features suggestive of successful nonoperative management were identified.

Other studies suggest that the nonoperative approach is associated with more pancreas-specific complications, longer time to diet tolerance, need for additional procedures, and prolonged hospital course and may not be justified when compared with the good recovery observed following distal pancreatectomy for AAST Grade III injuries.[34,35,39,40] These series suggest that increased pancreas-specific complications such as pseudocyst formation and recurrent pancreatitis will follow nonoperative management. An additional important finding from these studies is that exploration was performed for indications other than concern for pancreatic injury, such as free intraperitoneal air, shock, or refractory hypotension, in 40% of operatively managed patients.

Endoscopic retrograde cholangiopancreatography may aid in both diagnosis of ductal injury and subsequent management of complications. Houben et al.[41] reported a series of nine children in 2007 who underwent ERCP with stent placement for main duct injury. All patients avoided pancreatic resection, although 66% developed pancreatic fluid collections requiring drainage. Garvey et al.[42] published a similar experience of seven patients who underwent ERCP for pancreatic injury, two of whom required distal pancreatectomy, while four others were treated with stenting. Pancreatic stenting failed in one patient, who required distal pancreatectomy for persistent leak. Two stented patients developed pseudocysts, which required subsequent intervention.[42] Another multicenter review identified 100 children with pancreatic injuries who were treated nonoperatively and compared the cohort who underwent ERCP within 1 week after injury (n = 9) with those who did not (n = 91). There was a similar time to diet tolerance, time on parenteral nutrition, and total hospital stay. The authors concluded that ERCP was useful in grading pancreatic injuries but did not clearly hasten recovery after injury.[43]

Other groups have described ERCP as effective in the management of pancreatic complications arising after nonoperative treatment of pancreatic trauma, allowing them to effectively treat 75% of pancreatic fistulae, strictures, and pseudocysts without surgery.[44] Although ERCP provides an additional tool for management of pancreatic injuries, it does require the availability of a skilled pediatric endoscopist. In addition, the literature to date consists of small series, and the optimal role of endoscopic intervention remains unclear.

Overall, we feel that nonoperative management is best applied to patients with Grades I and II injuries. Endoscopic retrograde cholangiopancreatography may have a role in the care of patients being treated nonoperatively; however, children with ductal injury (Grades III to IV) appear to have fewer pancreas-related complications, shorter lengths of hospital stay, and fewer interventions with operative resection, although high-quality data supporting this approach are lacking. When in doubt, operative exploration and management of a pancreatic injury appear safest.

PANCREAS-RELATED COMPLICATIONS

Pancreas-related complications include peripancreatic abscess, pancreatic fistula, and delayed pancreatic pseudocyst. In the study of 1,240 patients with pancreatic injury referenced in the epidemiology section of this article, independent risk factors of pancreas-related complications as described were identified as high-grade pancreatic injury, (2) penetrating mechanism, and (3) management in a low-volume center.[6]

Pancreatic pseudocysts develop in approximately one of five patients with pancreatic injury. This complication is often managed nonoperatively and, with time, often resolves. However, endoscopic or surgical cyst-gastrostomy may be a management strategy in well-developed pseudocyst walls to hasten resolution of address symptoms of compression.[13]

Pancreatic fistula should be expected following pancreatic injury; it is that common. As such, careful comparison of the literature on management strategies to prevent and address high amylase output is essential. In the updated 2016 International Study Group of Pancreatic Fistula, a pancreatic fistula is defined as any measurable drain output with an amylase level greater than three times the upper limit of normal serum amylase.[45] Without clinical impact, this is considered a Grade A or biochemical leak and not a "true pancreatic fistula." Definition of a Grade B pancreatic fistula requires a change in management or persistent drainage for greater than 3 weeks, or percutaneous or endoscopic drainage or peripancreatic fluid collections. In addition, angiographic procedures for bleeding would be considered a Grade B pancreatic fistula. Grade C pancreatic fistulae refer to those that require (re)operation, organ failure, or death. While these definitions were developed primarily from elective pancreatectomy literature, uniformity of describing pancreatic fluid output is much needed, and these definitions should be used.

Authors from South Africa have proposed the Pancreatic Injury Mortality Score, which incorporates and builds on the AAST grading system and adds parameters for age older than 55 years, presence of shock on admission, presence of major vascular injury, and number of concomitant injuries (up to a score of 3 for three or more associated injuries).[46] This scoring system categorizes patients with pancreatic injury into low risk, intermediate risk, and high risk or mortality corresponding to scores of 0 to 4, 5 to 9, and 10 to 20 and 1%, 15%, and 50% mortality risk, respectively.

CONCLUSION

High index of suspicion based on trauma mechanism involving a high force to the central abdomen is required to avoid delay to diagnosis of pancreatic injury. Clinical examination, laboratory evaluation, and imaging with ultrasound and CT can help establish the diagnosis. Intraoperative evaluation, which requires full exposure of the pancreas, is the criterion standard of diagnostic evaluation. The AAST grading system allows some common language around describing a variety of pancreatic injuries. This grading system can be used to determine management strategies. Absence or presence of pancreatic duct injury can also help determine management strategies.

AUTHORSHIP

Each author contributed significantly to, and is willing to take public responsibility for, every aspect of the study: its design, data acquisition, and analysis and interpretation of data. Both authors were actively involved in the drafting and critical revision of the manuscript, and each provided final approval of the version to be published.

DISCLOSURE

Conflict of Interest: Author Disclosure forms have been supplied and are provided as Supplemental Digital Content (http://links.lww.com/TA/E307).

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