Duodenal and pancreatic injury continues to challenge the trauma surgeon. The relatively rare occurrence of these injuries, the difficulty in making a timely diagnosis, and high morbidity and mortality rates justify the anxiety these unforgiving injuries invoke. These issues also likely explain the hesitancy of many to address pancreatic injuries with operative intervention and the most recent literature exploring the options and consequences of nonoperative management.1-3

Mortality rates for pancreatic trauma range from 9 to 34%, with a mean rate of 19%. Duodenal injuries are similarly lethal, with mortality rates ranging from 6 to 25%. Complications following duodenal or pancreatic injuries are alarmingly frequent, occurring in 30 to 60% of patients.4-6 Recognized early, the operative treatment of most duodenal and pancreatic injuries is straightforward, with low morbidity and mortality. Recognized late, these injuries result in a protracted, difficult clinical course, often ending in a devastating outcome.7-11

History
An 1827 report of a traumatic transection of the pancreas as a result of a stagecoach wheel running over a patient is generally recognized as the first literature on pancreatic trauma.12 By 1903, Mickulicz was able to identify 45 cases of pancreatic trauma in the literature, of which 21 involved penetrating and 24 blunt injuries.13,14 He noted that all 20 patients not operated on died, and 18 of the 25 (72%) who were operated on survived—a remarkable success for the time. Mickulicz recommended a thorough exploration through a midline incision, suture control for hemostasis, and the placement of drains in all cases, recommendations that still hold today.13 In 1930, Stern reviewed 62 reported cases of pancreatic trauma, in which 30 of the patients survived and 32 died.14 His treatment recommendations were essentially the same as Mickulicz’s, although Stern perhaps foresaw the role of diagnostic peritoneal lavage in his recommendation to use “abdominal puncture” to aid in the diagnosis of pancreatic trauma.

The occurrence of complications was also noted early. In 1982, Kulenkampff reported what was likely a pancreatic pseudocyst following blunt trauma.15 In 1905, Korte reported a case of isolated pancreatic injury with total transection and resultant pancreatic fistula.16 The fistula closed spontaneously (as most do), and the patient survived. In 1946, Whipple reported that the catgut sutures used in and about the pancreas were likely to dissolve, leading to hemorrhage, fistula formation, duodenal leaks, and peritonitis; the use of silk was recommended.17

Wartime experience with pancreatic trauma emphasizes the high morbidity and mortality but also the infrequent occurrence of this injury. There were only 5 case reports of pancreatic injury from the American Civil War, with an 80% mortality;5 5 reported cases from British troops in World War I, with an 80% mortality; 62 cases (of 3,154 abdominal injuries) reported by the 2nd Auxiliary Surgical Group in 1944 and 1945 during World War II, with a 56% mortality; and 9 cases from the Korean War, with a 22% mortality.20 More direct surgical management of pancreatic wounds also occurred in each of these wartime experiences.

Diagnosis
The two most important determinants of outcome following pancreatic injury are the status of the main pancreatic duct and the time from injury to definitive management of a ductal injury. This was probably first recognized and emphasized by Baker and colleagues in 1962.21 Two subsequent reviews of the experience with pancreatic trauma at the University of Louisville confirmed and emphasized the importance of determining the status of the pancreatic duct. Heitsch and colleagues found that resection of distal ductal injuries as opposed to drainage alone significantly lowered postoperative morbidity and mortality,22 and Smego and colleagues confirmed this observation one decade later by noting that pancreatic resection distal to the site of ductal injury resulted in a decrease in the mortality rate at that institution from 19 to 3%.23 Our experience at Harborview Medical Center in Seattle supports this in that accurate determination of the status of the pancreatic duct with intraoperative pancreateography results in a decrease in complications from 55% to 15%.24 Although improvements in image quality have been noted,25 cross-sectional body imaging techniques currently used in the multitrauma patient (computed tomography [CT] of the abdomen) do not routinely have adequate sensitivity to assess the ductal status, and magnetic resonance imaging (MRI) is usually too unwieldy in the acute trauma patient.26 Hence, the challenge remains in making an early determination of the status of the pancreatic duct.

The diagnostic techniques of most use in a patient with a possible pancreatic injury depend on the mechanism of injury, other indications for early laparotomy, and the time interval following the initial abdominal insult. Patients with clear indications for laparotomy need little or no preoperative evaluations directed at identifying a possible pancreatic injury as the diagnosis of pancreatic injury must be made intraoperatively. However, establishing the presence of pancreatic injury in those not requiring immediate laparotomy for hemorrhage or bowel perforation is a challenge made more difficult by the knowledge that a missed pancreatic duct injury has dire consequences.27-30

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ACS Surgery: Principles and Practice

9 INJURIES TO THE PANCREAS AND DUODENUM — 1
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although there are isolated reports of patients with complete ductal transection being asymptomatic for weeks to months to years following the initial injury, it is more common for patients with initially missed pancreatic injuries to manifest an abdominal crisis within a few days of their injury. The failure of physical signs and symptoms to develop promptly is related to the retroperitoneal location of the pancreas, pancreatic enzymes remaining inactive following an isolated injury, and decreased secretion of pancreatic fluid after injury. Early identification of a subtle pancreatic injury therefore requires a high index of suspicion, a carefully planned approach, and close observation.

A high index of suspicion is warranted in all patients with high-energy direct blows to the epigastrium. The classic examples are a crushed steering wheel with an adult driver and a handle bar injury in a child. The energy of impact results in a crushing of the retroperitoneal structures against the spine and typically transecting the pancreas at this point. Soft tissue contusion in the upper abdomen and disruption of the lower ribs or costal cartilage are physical findings that should suggest possible pancreatic injury. Epigastric pain out of proportion to the abdominal examination is often another clue to a retroperitoneal injury.

**HYPERAMYLASEMIA**

Although the highest concentration of amylase in the human body is in the pancreas, hyperamylasemia is not a reliable indicator of pancreatic trauma. In one series, only 8% of blunt abdominal injuries with hyperamylasemia had pancreatic injury. Conversely, as many as 40% of patients with a pancreatic injury may initially have a normal serum amylase. In addition, there is evidence that isolated brain injury can cause elevated amylase or lipase via an unclear central mechanism. Nonetheless, the presence of hyperamylasemia should heighten suspicion for pancreatic injury. The time between pancreatic injury and serum amylase determination may be critical. In a report of 73 patients with documented blunt injury to the pancreas, serum amylase was determined within 3 hours of injury are not diagnostic. All 12 patients with a normal amylase were evaluated within 3 hours of injury. Patients with an elevated amylase were assayed 7 ± 1.5 hours after injury compared with 1.3 ± 0.2 hours after injury in those patients with normal serum amylase. These investigators concluded that serum amylase levels determined within 3 hours of injury are not diagnostic.

Our review of the available data led us to conclude that the sensitivity of serum amylase in detecting blunt pancreatic trauma varies from 48 to 85% and the specificity varies from 0 to 81%. The negative predictive value of serum amylase following blunt trauma is about 95%. Sensitivity and positive predictive value may improve if serum amylase is assayed more than 3 hours after injury. What this means is that 95% of patients with blunt trauma with a negative amylase will indeed not have a pancreatic injury. An elevated serum or peritoneal lavage effluent amylase does not necessarily confirm the presence of a pancreatic injury, but it does mandate further evaluation.

**IMAGING STUDIES**

Blunt abdominal trauma patients with hyperamylasemia who present with a reliable, benign abdominal examination are carefully observed and serial amylase is remeasured after several hours. Persistent elevation or the development of abdominal symptoms is grounds for further evaluation, which may include abdominal CT scan, endoscopic retrograde cholangiopancreatography (ERCP), or surgical exploration. If the abdominal examination is initially equivocal or unreliable, hemodynamically stable patients with hyperamylasemia should undergo a dual-contrast (intravenous and oral) abdominal CT scan as part of the initial evaluation. If the patient subsequently develops abdominal symptoms or the amylase fails to normalize, a directed evaluation of the pancreas is warranted, either by repeat abdominal CT, ERCP, or surgical exploration.

Abdominal CT scans have a reported sensitivity and specificity of 70 to 80% in diagnosing pancreatic injury, although the accuracy of this examination is largely dependent on interpreter experience, the quality of the scanner, and the time from injury. The CT findings of pancreatic injury include direct visualization of a parenchymal fracture, an intrapancreatic hematoma, fluid in the lesser sac, fluid separating the splenic vein and pancreatic body, thickened left anterior renal fascia, and retroperitoneal hematoma or fluid. These findings are often subtle, and rarely are they all present in one patient. Some of the CT signs of pancreatic injury may not yet be apparent if the patient is examined immediately after injury, perhaps attributing to the reports of false-negative CT scans in up to 40% of patients with significant pancreatic injuries. This, however, is not grounds for delaying a CT evaluation but is an argument for repeating a CT scan if symptoms persist.

Although ERCP has no role in the acute evaluation of the hemodynamically unstable patient, there has been a flurry of reports over the past decade regarding the utility of ERCP in diagnosing and managing pancreatic trauma. ERCP is currently the best imaging technique of the pancreatic duct and its divisions but usually requires anesthesia and is not readily or widely available. Most experience has been with ERCP in the late or missed diagnosis of pancreatic duct injury, occasionally with transdual stenting used to manage the injury, particularly in children. This is an evolving issue that will continue to foster investigations, but the principle of timely diagnosis and recognition and management of ductal injury remains. Early ERCP showing intact pancreatic ducts, including the secondary and tertiary radicals, without any extravasation permits nonoperative therapy if no associated injuries are present. The difficulty in this management scheme is determining which patients warrant ERCP and getting the ERCP accomplished promptly. MRI has emerged as a potential technique in the evaluation of the pancreatic duct in the earliest part of the 21st century. Although primarily used to date in elective circumstances, magnetic resonance pancreatography (MRCP) has been reported as a noninvasive alternative to determine the status of the main pancreatic duct in a small series of patients with pancreatic injury. To date, most reports suggest that MRCP is either unreliable or too unwieldy in the very acute phase after injury, but MRCP appears to be gaining increased interest in delayed diagnosis and management. Further study of its sensitivity and specificity in this setting is warranted, but the initial enthusiasm appears to have been tempered.
INTRAOPERATIVE EVALUATION

Classification of pancreatic injuries is based on the status of the pancreatic duct and the site of injury relative to the neck of the pancreas. Careful pancreatic inspection and injury classification are often complicated by the extent and severity of associated injuries and occasionally by the reluctance of the surgeon to mobilize retroperitoneal structures. Clues suggesting potential pancreatic injury include the injury mechanisms previously described, the presence of upper abdominal wall contusion or abrasion, and concomitant lower thoracic spine fractures. The presence of a upper abdominal central retroperitoneal hematoma, edema about the pancreatic gland and lesser sac, and retroperitoneal bile staining mandate thorough pancreatic inspection.

Inspection of the pancreas requires complete exposure of the gland. The initial steps in exposure are to open the lesser sac through the gastrocolic ligament just outside the gastropiploic vessels. Carry this exposure far to the patient’s left, fully opening the lesser sac and freeing up the transverse colon. The transverse colon is retracted downward and the stomach upward and anteriorly [see Figure 1]. Frequently, a few adhesions between the posterior stomach and the anterior surface of the pancreas need to be incised. A complete Kocher maneuver is required next to provide adequate visualization of the pancreatic head and uncinate process. In addition, mobilization of the hepatic flexure of the colon (a frequently overlooked maneuver) greatly facilitates visualization and bimanual examination of the head and neck. Inspection of the tail of the pancreas requires exposure of the splenic hilum. If injury involves the tail of the pancreas, mobilization is achieved first by division of the peritoneal attachments lateral to the spleen and colon. The colon, spleen, and body and tail of the pancreas are then mobilized forward and medially by creating a plane between the kidney and the pancreas with blunt finger dissection. This maneuver permits bimanual palpation of the pancreas and inspection of its posterior surface.

It is worth noting that injuries to the major duct occur in perhaps 15 to 20% of pancreatic trauma. In our institution, we managed 193 pancreatic injuries over a 15-year time frame. Only 27 (14%) had grade III injuries and 10 (5%) grade IV or V injuries. In the 1970s and 1980s, penetrating wounds were documented as more likely to cause pancreatic duct injury, but more recent reviews have not substantiated that observation. Regardless of the mechanism, the majority of pancreatic duct injuries can be diagnosed by careful inspection of the tract of injury following adequate exposure. All penetrating wounds should be traced from their...
entry point through the surrounding tissue to the point of exit or lodging of the missile. If the pancreas has been damaged by a knife or a bullet, it is necessary to determine the integrity of the major pancreatic duct. Most penetrating wounds to the margins of the gland can be inspected directly and duct integrity confirmed. However, penetrating wounds in the head or neck or central portion of the pancreas often require further evaluation. Occasionally, intravenous injection of 1 to 2 µg of cholecystokinin pancreatozymin (1 to 2 mL of sincalide) may stimulate pancreatic secretions enough to localize an otherwise unrecognized major duct injury. The remaining few injuries may require the more elaborate investigative techniques, including intraoperative pancreatography (see below).

Minor blunt contusions or lacerations of the pancreatic substance usually do not require further evaluation of the pancreatic duct and are effectively managed with closed suction drainage. An intact pancreatic capsule, however, does not necessarily rule out complete division of the pancreatic duct, and, rarely, blunt impact to the pancreas can result in transection of the major duct without complete transection of the gland. Establishing the status of the major ductal system under these circumstances remains an important step in determining therapy and in anticipating late morbidity and mortality. Routine performance of intraoperative pancreatography when proximal duct injury was suspected decreased the postoperative morbidity rate from 55% to 15% at our institution.

Intraoperative imaging of the pancreatic duct can be performed by one of three techniques: ERCP, direct open ampullary cannulation, or needle cholangiopancreatography. Intraoperative ERCP is cumbersome and often difficult to coordinate during an emergency operation, but it has been used and reported. Duodenotomy and direct ampullary cannulation, or even transection of the tail of the pancreas and distal duct cannulation, have been reported as useful techniques in the past, but current perioperative imaging, improved exposure and direct visualization of the pancreas, and effective use of wide closed-suction drainage and postoperative ERCP have largely abolished the use of these very invasive diagnostic techniques of imaging the pancreatic duct. Needle cholecystocholangiopancreatography remains a useful intraoperative adjunct in the evaluation of the pancreatic duct. This technique involves cannulating the gallbladder with an 18-gauge angiocatheter and injecting 30 to 75 mL of three-quarter-strength water-soluble contrast under fluoroscopic imaging. Clear images of the biliary tree are readily obtained, and in our experience, this technique is successful in imaging the pancreatic duct 64% (7 of 11) of the time. Contracture of the sphincter of Oddi with intravenous morphine may enhance the likelihood of pancreatic duct visualization. A cholecystectomy is not necessary following this procedure.

Classification of Pancreatic Injuries

Although a number of classification systems have been devised to catalogue pancreatic injuries, the American Association for the Surgery of Trauma (AAST) Committee on Organ Injury Scaling addresses the key issues of treatment of parenchymal disruption and major pancreatic duct status by focusing on the anatomic location of the injury for the more severe (grade III to V) injuries [see Table 1]. Table 1 also defines the Abbreviated Injury Scale (AIS) value that corresponds to the AAST grading system. The AIS has undergone a revision in 1998 and again in 2005. These differences are important since most commercially available trauma registries use AIS coding. The AIS coding system is sponsored and owned by the Association for the Advancement of Automotive Medicine. Duct injuries have different management alternatives than distal duct and parenchymal injuries [see Figure 2]. Parenchymal contusions or lacerations with minimal or no parenchymal tissue loss and no ductal injury (grade I or II) need only be externally drained. Combined duodenal and pancreatic head injuries that include the major duct or ampulla require a combined pancreaticoduodenectomy, commonly known as the Whipple procedure, but uncommonly required for trauma. The difficult decisions in managing pancreatic trauma involve patients with parenchymal disruption and major duct injury. By focusing on the anatomic location of the duct and parenchymal injury (proximal versus distal), this classification provides a useful management guide.

Treatment of Pancreatic Injuries

CONTUSIONS AND LACERATIONS WITHOUT DUCT INJURY

Minor pancreatic contusions, hematomas, and capsular lacerations (grade I) account for about 50% of all pancreatic injuries; lacerations of the pancreatic parenchyma without major ductal disruption or tissue loss (grade II) account for an additional 25% of pancreatic injuries. These injuries are the injury pattern commonly managed nonoperatively. If identified at operation, they require only hemostasis and adequate external drainage. No attempt should be made to repair capsular lacerations because closure may result in a pancreatic pseudocyst, whereas a controlled pancreatic fistula is usually self-limiting. Soft closed-suction drains (Jackson-Pratt) are preferred over Penrose drains or sump drains as intra-abdominal abscess formation is less likely, effluent is more reliably collected, and the excoriation of the skin at the exit site is significantly less with closed-suction drains. Drains are removed when the amylase concentrations in the drain are less than that of serum, generally within 24 to 48 hours. An international consensus group definition of pancreatic fistula is the persistence of any measurable volume of drain output on or after postoperative day 3 with an amylase content greater than three times serum amylase activity. As described below, there are three grades of pancreatic fistula complications [see Complications, below]. Drains are generally left in situ until there is no evidence of pancreatic leak.

Nutrition should be provided via the oral or gastric route as soon as possible. However, a prolonged gastric ileus or pancreatic complications may preclude standard gastric feeding in patients with severe injuries. Also, since most tube feeding formulas are high in fat and increase pancreatic effluent volume and amylase concentration, the low fat and higher pH (4.5) of elemental diets are preferred as they tend to be less stimulating to the pancreas.

DISTAL TRANSECTION AND DISTAL PARENCHYMAL INJURY WITH DUCT DISRUPTION

The anatomic distinction between proximal and distal pancreas is generally defined by the superior mesenteric
vessels passing behind the pancreas at the junction of the pancreatic head and body. Although there is no anatomic distinction in the gland itself between the head, body, or tail, this anatomic division is useful in estimating residual pancreatic endocrine and exocrine function. Innes and Carey have shown that a distal pancreatic resection at the portal vein removes an average of 56% (range 36 to 69%) of the gland by weight. Since most blunt trauma pancreatic injuries occur at the spine, which is just to the patient’s left of the portal vein as it crosses behind the pancreas, a “distal pancreatectomy” in this circumstance averages as a 56% gland resection. A resection at the common bile duct removes an average of 89% (range 64 to 95%) of the gland. Although reports of normal endocrine and exocrine function after 90% pancreatic resection. Operative intervention in this case is superior to nonoperative management in that the operation is definitive, the residual gland is adequate to preserve exocrine and endocrine function, and the recovery is relatively short. Nonoperative management is typically fraught with the complications of pseudocysts, abscess, prolonged and recurrent hospital admissions, and repetitive drainage procedures, including the technically challenging and invasive attempts at endoscopically traversing a transected distal duct.

If at celiotomy there is any concern regarding the status of the remaining proximal main pancreatic duct, intraoperative pancreatography should be performed through the open end of the proximal duct. If the remaining proximal duct is normal, the transected duct should be identified and closed with a direct “U”-stitch suture ligature with a nonabsorbable monofilament suture. The parenchyma can be closed with the large (4.8 mm) TA-55 staple, but we find that this excessively crushes the residual pancreas, so we prefer mattress sutures placed through the full thickness of the pancreatic gland from anterior to posterior capsule to minimize leak from the transected parenchyma. Although most surgeons prefer nonabsorbable suture for pancreatic stump closure, one report suggests that a lower complication rate is obtained with absorbable polyglycolic acid suture to oversew the pancreatic stump. A small omental patch can be used to buttress the surface, and a drain should be left near the transection line.

Concern for the possibility of postsplenectomy sepsis and subphrenic abscess formation following splenectomy has prompted several authors to describe distal pancreatectomy without splenectomy [see Figure 3]. The technical challenge in pancreatectomy with splenic salvage is in isolating and ligating the pancreatic branch vessels off the splenic vein and artery yet preventing injury to the splenic hilum and thrombosis of the splenic vein. Generous mobilization of the entire pancreatic gland and spleen is a prerequisite. An average of 22 tributaries of the splenic vein and seven branches of the splenic artery must be ligated. One report suggests that this maneuver will add an average of 50 minutes (range 37 to 80 minutes) to the operative time. Patton and colleagues reported splenic salvage in 21 of 33 patients (64%) who

### Table 1 AAST Organ Injury Scales for Pancreas and Duodenum

<table>
<thead>
<tr>
<th>Injured Structure</th>
<th>AAST Grade*</th>
<th>Characteristics of Injury</th>
<th>AIS-90 Score</th>
<th>AIS-2005 Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pancreas I</td>
<td>1</td>
<td>Small hematoma without duct injury; superficial laceration without duct injury</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>II</td>
<td>Large hematoma without duct injury or tissue loss; major laceration without duct injury or tissue loss</td>
<td>2; 3</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>Distal transection or parenchymal laceration with duct injury</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>Proximal† transection or parenchymal laceration involving ampulla</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>Massive disruption of pancreatic head</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Duodenum I</td>
<td>1</td>
<td>Single-segment hematoma; partial-thickness laceration without perforation</td>
<td>2; 3</td>
<td>2</td>
</tr>
<tr>
<td>II</td>
<td>Multiple-segment hematoma; small (&lt; 50% of circumference) laceration</td>
<td>2; 4</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>50–75% disruption (laceration) of segment D2 or 50–100% disruption of segment D1, D3, or D4</td>
<td>4; 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>Very large (75–100%) laceration of segment D2; rupture of ampulla or distal CBD</td>
<td>5</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>Massive duodenopancreatic injury; devascularization of duodenum</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

AAST = American Association for the Surgery of Trauma; AIS-90 = Abbreviated Injury Score, 1990 version; AIS-2005 = Abbreviated Injury Score, 2005 version; CBD = common bile duct.

*Advance one grade for multiple injuries, up to grade III.
†Proximal pancreas is to the patient’s right of the superior mesenteric vein.
underwent distal pancreatic resection (8 blunt, 13 penetrating). The increased operative time and potential blood loss incurred while performing pancreatectomy without splenectomy must be balanced against the slight risk of overwhelming postsplenectomy sepsis. The balance would seem to favor splenic salvage only when the patient is completely hemodynamically stable and normothermic and the pancreatic injury is isolated or present with only minor associated injuries.

**PROXIMAL TRANSECTION OR INJURY WITH PROBABLE DUCT DISRUPTION**

Injuries to the pancreatic head represent the most challenging management dilemmas. The key principles of immediate management are, in order, control bleeding, halt contamination, and define the anatomy of the injury. Effective management can only follow these steps. It is essential that the surgeon define the pancreatic duct anatomy in proximal pancreatic injuries. This can usually be accomplished by local inspection and exploration of the defect to determine the duct status. Techniques of intraoperative pancreateography have been described above and are strongly recommended if local exploration alone is inadequate to determine the status of the main pancreatic duct. The only exception to this approach is the hemodynamic unstable patient with hypothermia, acidosis, and coagulopathy, in which case, simple damage control surgery is advised. Most experienced surgeons express reservations regarding performance of a duodenotomy to perform pancreatography, but a needle cholecystocholangiopancreatography can often image the pancreatic duct along with the distal common bile duct (64% in our experience). If this proves unsuccessful, then wide external drainage with several closed-suction drains should be performed with planned early postoperative ERCP (preferred), or MRCP should be the plan. If major proximal duct injury is confirmed by postoperative ERCP, pancreatic duct stenting rather than near-total pancreatectomy may be an option depending on local expertise. However, at least one report has had discouraging results with stenting, notable for long-term stricture development and acute sepsis.

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**Figure 2. Treatment of pancreatic injury. Algorithm outlining the treatment of pancreatic injury. CT = computed tomography; ERCP = endoscopic retrograde cholangiopancreatography.**

<table>
<thead>
<tr>
<th>Grade I</th>
<th>Grade II</th>
<th>Grade III</th>
<th>Grade IV</th>
<th>Grade V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide nonoperative management. Repeat CT as needed.</td>
<td>Provide operative or nonoperative management. Repeat CT between 4 and 24 hours.</td>
<td>Perform distal pancreatectomy, with or without splenic salvage.</td>
<td>Unstable patient: treat with hemostasis and drainage, with postoperative ERCP to define duct anatomy and allow duct stenting if indicated. Stable patient: divide pancreas completely, oversew proximal stump, and perform Roux-en-Y anastomosis of distal pancreatic remnant to jejunal limb. Consider adding pyloric exclusion.</td>
<td>Perform pancreaticoduodenectomy (Whipple procedure).</td>
</tr>
</tbody>
</table>

**Operation**

Unroofing: Carefully inspect to confirm absence of duct injury; close suction drainage. Perform ERCP to determine status of duct. If duct not injured, follow with a CT scan or ultrasonography.

**Duct injury**

If duct injury is confirmed, perform either transductal stenting or operative exploration as a Grade III-V.

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**History of high-energy direct blow to epigastrium is suggestive. Obtain serum amylase levels. Perform CT with oral IV contrast (repeated if necessary).**

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**Nonoperative management**

Repeat CT between 4 and 24 hours. Perform ERCP to determine status of duct. If duct not injured, follow with a CT scan or ultrasonography. If duct injury is confirmed, perform either transductal stenting or operative exploration as a Grade III-V.
If the proximal duct is injured, but the ampulla and duodenum are spared (rare), two options are available. One option is extended distal pancreatectomy, resulting in subtotal removal of the gland. The proximal residual gland will drain into the duodenum in a normal fashion if the duct is intact. Wide external drainage of the residual pancreatic surface must be provided. We have not added pyloric exclusion or duodenal defunctionalization or diverticulization to this procedure, although others advocate its use in this circumstance. If there is concern that the residual proximal pancreatic tissue is inadequate to provide endocrine or exocrine function, the second option is to preserve the pancreatic tail distal to the injury using a Roux-en-Y pancreaticojejunostomy [see Figure 4]. This requires division of the pancreas at the site of injury, débridement of injured parenchyma, secure closure of the proximal duct and parenchyma, and anastomosis of the open end of the divided distal pancreas to the Roux-en-Y jejunal limb. A review of 399 patients with pancreatic injury from four separate publications revealed that only 2 (0.5%) patients underwent Roux-en-Y drainage of the distal segment of a transected pancreatic gland. Although rarely employed and complicated by the need for a combination of pancreatic resection, pancreatic-jejunal anastomosis, and construction of the Roux-en-Y limb, this operation needs to be in the armamentarium of trauma surgeons.

The report by Patton and colleagues from Memphis, supported by the experience of University of Mississippi reported by Duchesne and colleagues, is compelling for the effectiveness of drainage alone rather than extended pancreatectomy, particularly for proximal pancreatic gland injury in which the duct status is unclear. In the Patton and

Figure 3. Distal pancreatectomy with and without splenic salvage. Illustrated is distal pancreatectomy with salvage of the spleen (a) and without splenic salvage (b).
colleagues’ study, 37 patients with proximal pancreatic injury were managed by closed-suction drainage alone, resulting in a modest 13.5% fistula and abscess rate. Pancreatography was not performed in these patients, so the status of the pancreatic duct was not defined, and it remains unclear whether this technique is truly effective in the presence of a major pancreatic duct injury. In the Duchesne and colleagues report, 35 patients had AAST grade I or II pancreatic injuries by CT scan and were intentionally managed nonoperatively. Five (14.3%) failed nonoperative management because of missed bowel injury \( (n = 2) \) and pancreatic abscess \( (n = 3) \), all classified as AAST grade II injuries. These failures of

Figure 4. Roux-en-Y pancreaticojejunostomy. If a patient has a grade IV injury to the pancreatic head and there is concern regarding whether the proximal residual gland would have adequate endocrine and exocrine function if the distal gland is resected in an extended distal pancreatectomy, an option is to preserve the uninjured portion of the distal gland. This is done by dividing the pancreas at the site of the injury and performing a Roux-en-Y pancreaticojejunostomy to allow the distal pancreas to drain into the jejunal limb.
operative management survived but had a significantly longer length of stay (19 days versus 9 days). Operative exploration and drainage of even low-grade pancreatic injuries remain a prudent approach.

Both of these reports emphasize the importance of determining the status of the pancreatic duct. If the duct and its branches are not injured, nonoperative management is likely to be successful, and the role for detailed description of pancreatic duct anatomy advocated by Takishima and colleagues is relevant. If no effort is made at determining the status of the pancreatic duct, at least wide drainage is mandatory. This approach is likely to be successful most of the time since injury to the main pancreatic duct is unusual; if it fails, however, the consequences are significant and morbid.3,6

If the main pancreatic duct is injured or transected, distal resection is preferred, with the option of Roux-en-Y drainage of a long or significant distal pancreas that the surgeon is loath to sacrifice. Damage control drainage remains a viable lifesaving first operation. Finally, postoperative ERCP and transduodenal injury stenting appear to be another viable option, particularly in children, and particularly with very experienced endoscopists.1,53

In the case of an incomplete pancreatic parenchymal transection, some surgeons have described an end jejunum-to-side pancreas anastomosis. This technique is not recommended because of the difficulty in ensuring the integrity of the anastomosis and potential for a high-output pancreatic fistula from the posterior pancreatic wound. Stone and colleagues from Emory University illustrated the high complication rate associated with this dated technique. Of 7 patients in whom the technique was used (among 283 patients), 5 (71%) developed a fistula and 3 (43%) died.66

Insertion of a needle catheter jejunostomy or small feeding tube jejunostomy at the time of initial celiotomy should be considered for all patients with grade III to V pancreatic injuries. This allows early postoperative enteral nutrition, rather than committing the patient who cannot tolerate oral or gastric feedings to total parenteral nutrition.68 There is some morbidity related to surgically placed feeding tubes. Our experience is that feeding jejunostomies have a major complication rate of 4% in severely injured patients.97 Needle catheter jejunostomies were associated with fewer complications than the larger, Witzel tube jejunostomy—hence, our preference for this smaller-caliber feeding tube and elemental or short-chain polypeptide feeding formulars, which we prefer.10,97

**Combined Pancreatic-Duodenal Injuries**

Fortunately, severe combined pancreatic head and duodenal injuries are rare. Forty-eight of 1,404 patients (3%) with pancreatic injuries reported between 1981 and 1990 underwent pancreatoduodenectomy.88 These injuries are most commonly caused by penetrating wounds and occur in association with multiple other intra-abdominal injuries. In fact, these associated injuries are the primary cause of mortality and emphasize again the priorities of hemorrhage control and contamination control in dealing with pancreatic or duodenal injury. The major immediate mortality in patients with combined pancreatic and duodenal injuries is attributable to major vascular injury in the vicinity of the head of the pancreas. If immediate control of hemorrhage and resuscitation can be obtained, the Whipple resection remains the preferred option in that select group of patients with unreconstructable injury to the ampulla or proximal pancreatic duct or with combined massive destruction of the duodenal and pancreatic head. Essentially, in these patients, pancreatoduodenectomy is the completion of surgical débridement of devitalized tissue. For patients with hemodynamic instability, hypothermia, coagulopathy, and acidosis, a staged operative approach (damage control surgery) is advocated, first obtaining control of hemorrhage, then managing bowel and bacterial contamination, and, lastly, identifying the anatomy of the injury, followed by resuscitation in the intensive care unit. The patient is returned to the operating room for definitive reconstruction and anastomoses when stabilized, generally 24 to 48 hours later.

Because of the large number of possible combinations of injuries to the pancreas and duodenum, no one form of therapy is appropriate for all patients. In Feliciano and colleagues’ review of 129 cases of combined pancreatic-duodenal injuries, 24% of the patients were treated with simple repair and drainage, 50% underwent repair and pyloric exclusion, and only 10% required a Whipple procedure.82 The best treatment option is predicated on the integrity of the distal common bile duct and ampulla, as well as the severity of the duodenal injury [see Figure 5]. For that reason, every patient with a combined pancreatic-duodenal injury requires a cholangiogram, a pancreatogram, and evaluation of the ampulla. When the common bile duct and ampulla are intact (as is the situation in the majority of the cases), the duodenum can be closed primarily and the pancreatic injury treated as previously described. If the status of the pancreatic duct cannot be made intraoperatively, wide external drainage of the pancreatic head with closed suction drains should be performed rather than a total pancreactectomy and early postoperative ERP or MRCP performed.

It may be advisable to divert gastric contents away from the duodenal repair in the presence of severe injury to the duodenum. Duodenal “diverticulization” employs primary closure of the duodenal wound, antrectomy, vagotomy, end-to-side gastrojejunostomy, T-tube common bile duct drainage, and lateral tube duodenostomy. The concept is to completely divert both gastric and biliary contents away from the duodenal injury, provide enteral nutrition via the gastrojejunostomy, and convert a potential uncontrolled lateral duodenal fistula to a controlled fistula [see Figure 6]. A less formidable and less destructive alternative is the “pyloric exclusion,” which does not employ antrectomy, biliary diversion, or vagotomy [see Figure 7].72,89–91 This procedure is performed through a gastrotomy and consists of grasping the pylorus with a Babcock clamp and suturing closed the pylorus with an absorbable size 0 polyglycolic acid or Maxon suture and constructing a loop gastrojejunostomy. This diverts gastric flow away from the duodenum for several weeks while the duodenal and pancreatic injuries heal. The pylorus eventually opens (2 weeks to 2 months), and the gastrojejunostomy functionally closes. Pang and colleagues at Chang-Gung Memorial Hospital in Taiwan described a technical method of controlled release of the pyloric exclusion knot, thereby timing the opening of the pyloric...
occlusion. Marginal ulceration at the site of gastrojejunostomy has been reported from 5 to 33% of patients in whom a vagotomy was not performed. Pyloric exclusion is generally reserved for severe combined duodenal and pancreatic head and duodenal injuries in which a Whipple procedure is not required. Few advocate pyloric exclusion for isolated pancreatic injuries.

In very massive injuries of the proximal duodenum and head of the pancreas, destruction of the ampulla and proximal pancreatic duct or distal common bile duct may preclude reconstruction. In addition, because the head of the pancreas and the duodenum have a common arterial supply, it is essentially impossible to entirely resect one without making the other ischemic. In this situation, a pancreatoduodenectomy is required. Between 1961 and 1994, 184 Whipple procedures were reported for trauma, with 26 operative deaths (14%) and 39 delayed deaths, for a 64% overall survival rate. However, more recent experience suggests that with appropriate selection criteria, pancreatoduodenectomy for injury can be performed with morbidity and mortality similar to those described for resections done for cancer.

Nonoperative Management in Children

Major pancreatic duct injury in children is rare, with an incidence of 0.12% of children with blunt abdominal trauma. Most pediatric pancreatic injuries are grade I or II injuries, without major pancreatic duct injury. As a result, several authors have advocated managing all blunt pediatric pancreatic injuries nonoperatively, with bowel rest, serial abdominal CT to observe for pseudocyst formation, and subsequent percutaneous drainage as required. However, the high morbidity and prolonged hospital course of these patients may not be justified given the good recovery from distal pancreatectomy with splenic salvage. Pseudocysts develop in 40 to 100% of children with major ductal injury, and recurrent episodes of pancreatitis can occur remote to the time of injury. ERCP with proximal stenting of ductal injuries is an additional adjunct to care in these patients but requires the availability of a skilled pediatric endoscopist. A report from Toronto details the management of 35 children with pancreatic trauma over a 10-year time period. Twenty-three had early diagnosis (<24 hours), whereas in 12, the diagnosis was initially missed. Twenty-eight were managed

Figure 5. Treatment of duodenal injury. Algorithm outlining the treatment of duodenal injury. CBD = common bile duct; NG = nasogastric; TPN = total parenteral nutrition; WBC = white blood cell count.
nonoperatively. A subsequent report examined in more detail 10 of these patients having a pancreatic duct transection. Forty-four percent developed pseudocyst, and all were managed with percutaneous drainage; 75% had atrophy of the distal pancreatic remnant, but there was no evidence of endocrine or exocrine dysfunction. A report from Japan demonstrated 100% pseudocyst development in five children with pancreatic duct injury managed nonoperatively. The data seem to suggest that pediatric pancreatic injuries can be successfully managed nonoperatively, but with a high incidence of pseudocyst formation requiring further hospitalization and interventions and with atrophy of the distal remnant. Other pediatric surgical authors point out the benefits of distal pancreatectomy in terms of shortening hospital stay and interventions.

Complications

The incidence of complications following pancreatic injury remains uncomfortably high. Between 20 and 40% of patients who undergo surgical intervention of a pancreatic injury have a complicated postoperative course and even higher if a combined pancreaticoduodenal wound has occurred [see Table 2].

Although the majority of complications related to pancreatic injury are self-limiting or treatable, sepsis and multisystem organ failure are responsible for nearly 30% of the deaths in pancreatic trauma. In some series, up to one half of the postoperative complications could have been avoided with careful inspection of the pancreas and accurate determination of the status of the main pancreatic duct.

FISTULA

Postoperative pancreatic fistula has been defined as any measurable drain output with an amylase greater than three times serum. This is the most common complication following pancreatic injury, with an incidence of 7 to 20%, rising to 26 to 35% after combined pancreaticoduodenal injury. Direct suture closure of the main pancreatic duct may help minimize this complication, but fibrin sealants do not seem to provide any advantage. The vast majority of these are minor (less than 200 cc/day) and spontaneously resolve within 2 weeks of injury, providing that adequate external drainage has been provided. In a multicenter review of distal pancreatectomy for trauma, the postoperative fistula rate was 14% (10 of 71), with spontaneous fistula closure in 89% (8 of 9) of survivors in 6 to 54 days.
extirpation of a residual pancreatic sequestrum to facilitate fistula closure. This compares with a 3.3% fistula rate in elective distal pancreatectomy for chronic pancreatitis. High-output fistulae (greater than 700 cc/day) are rare and generally require longer periods of external drainage or surgical intervention for resolution. If a high-output fistula fails to progressively decrease in volume or persists more that 10 days, ERCP is indicated and can be most helpful in establishing the cause of the persistent fistula and planning further therapy. Nutritional support must be provided throughout this period. The surgeon’s foresight in placing a feeding jejunostomy at the time of initial trauma laparotomy is now rewarded. Low-fat, higher pH elemental feeding formulas cause less pancreatic stimulation than standard enteral formulas and should be tried prior to committing the patient to total parenteral nutrition. A somatostatin analogue (octreotide acetate [Sandostatin]) has shown promise in treating prolonged, high-output pancreatic fistulae, but only after eradicating any infection and in the absence of pancreatic duct obstruction or stricture.

Pyloric exclusion as an adjuvant to standard fistula management probably diminishes fistula output, but its shortening of the time to fistula closure remains to be proven. Somatostatin analogues do seem to prevent postoperative complications and fistula formation in patients undergoing elective pancreatic resection, although nonrandomized reports on the efficacy of somatostatin analogues in pancreatic trauma patients are contradictory. In addition, the trials demonstrating a decrease in postoperative complications with octreotide use in elective pancreatic resection initiated octreotide in the preoperative period, a time frame not applicable to the trauma setting. Treatment typically begins with 50 µg subcutaneously every 12 hours but can increase to 1,000 µg/day. Octreotide has been included in total parenteral nutrition solutions, although this remains controversial and is not recommended by the 1997 package insert because of the formation of glycosyl octreotide conjugates that may decrease efficacy. Major side effects are unpredictable changes in serum glucose, pain at the injection site, and a variety of nonspecific gastrointestinal complaints.

**Abscesses**

The incidence of abscess formation after pancreatic trauma ranges from 10 to 25%, depending on the number and type of associated injuries. Early operative or percutaneous decompression or evacuation is critical, although the mortality rate in this group of patients remains about 25%. The intra-abdominal abscess is most often subfascial or peripancreatic; a true pancreatic abscess is unusual, resulting from inadequate débridement of dead tissue or inadequate initial drainage. True pancreatic abscesses are often not amenable or responsive to percutaneous drainage, and prompt surgical débridement and drainage are required. Percutaneous decompression may be helpful in distinguishing between abscess and pseudocyst.

### Table 2 Factors Determining Severity of Duodenal Injury

<table>
<thead>
<tr>
<th>Factor</th>
<th>Mild</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Means of injury</td>
<td>Stab</td>
<td>Blunt force or missile</td>
</tr>
<tr>
<td>Size of injury</td>
<td>≤ 75% of circumference</td>
<td>&gt; 75% of circumference</td>
</tr>
<tr>
<td>Location of injury in duodenum</td>
<td>D3, D4</td>
<td>D1, D2</td>
</tr>
<tr>
<td>Interval between injury and repair</td>
<td>≤ 24 hr</td>
<td>&gt; 24 hr</td>
</tr>
<tr>
<td>Adjacent injury to CBD</td>
<td>Absent</td>
<td>Present</td>
</tr>
</tbody>
</table>

CBD = common bile duct.
PANCREATITIS

Transient abdominal pain and a rise in the serum amylase concentration may be anticipated in 8 to 18% of postoperative patients.23,24,11 This type of pancreatitis is treated with nasogastric decompression, bowel rest, and nutritional support and can be expected to resolve spontaneously. A much more infrequent but deadly complication is hemorrhagic pancreatitis. The first sign of this complication may be bloody pancreatic drainage or a fall in the serum hemoglobin concentration, with the patient rapidly becoming desperately ill. It is fortunate that this complication occurs in less than 2% of operative pancreatic trauma patients since mortality may approach 80% with no effective treatment.61,75

SECONDARY HEMORRHAGE

Postoperative hemorrhage requiring blood transfusion may occur in 5 to 10% of pancreatic trauma patients, particularly when inadequate external drainage has been afforded after pancreatic debridement or when intra-abdominal infection has developed.13,113 These patients generally require reoperation for control, although angiographic embolization may be an effective alternative.

PSEUDOCYSTS

Missed blunt pancreatic injuries, or those intentionally managed nonoperatively, often result in the formation of a pseudocyst. One report tabulated 22 pseudocysts in 42 blunt pancreatic trauma patients managed nonoperatively.27 The status of the pancreatic duct is the key determinant to treatment of a pancreatic pseudocyst. If the pancreatic duct is intact, percutaneous drainage of the pseudocyst is likely to be effective. If the pseudocyst is secondary to a major pancreatic ductal disruption, percutaneous drainage will not provide definitive therapy but will convert a pseudocyst to a chronic fistula. ERCP should therefore precede any percutaneous drainage. If pancreatic duct stenosis or injury is demonstrated, treatment options include (1) reexploration and partial gland resection, (2) distal gland internal Roux-en-Y drainage, and (3) endoscopic transpapillary stenting of the pancreatic duct.89 The experience of Kouchi and colleagues of Japan suggests that a pseudocyst greater than 10 cm in size will require surgical decompression.8

EXOCRINE AND ENDOCRINE INSUFFICIENCY

Both exocrine and endocrine insufficiency are unusual after pancreatic trauma. Animal and human studies suggest that a residuum of 10 to 20% of normal pancreatic tissue is adequate for pancreatic function,24,113 implying that any resection distal to the mesenteric vessels should leave adequate functioning pancreatic tissue. The multicenter study of 74 cases of distal pancreatic resection described earlier documented only 1 case of endocrine deficiency (diet-controlled hyperglycemia following 80% pancreatectomy) and no instance of exocrine insufficiency.84 Balasegaram reported no pancreatic insufficiency after resections of up to 90% of the pancreas.103 In contrast, patients with chronic pancreatitis who undergo distal pancreatectomy have an incidence of diabetes ranging from 15% (0 to 33% gland resected) to 64% (50 to 75% gland resected).76

References


