Diagnosis and Classification of Pancreatic and Duodenal Injuries in Emergency Radiology

Ulrich Linsenmaier, MD, PhD • Stefan Wirth, MD • Maximilian Reiser, MD, PhD • Markus Körner, MD

Pancreatic and duodenal injuries after blunt abdominal trauma are rare; however, delays in diagnosis and treatment can significantly increase morbidity and mortality. Multidetector computed tomography (CT) has a major role in early diagnosis of pancreatic and duodenal injuries. Detecting the often subtle signs of injury with whole-body CT can be difficult because this technique usually does not include a dedicated protocol for scanning the pancreas. Specific injury patterns in the pancreas and duodenum often have variable expression at early posttraumatic multidetector CT: They may be hardly visible, or there may be considerable exudate, hematomas, organ ruptures, or active bleeding. An accurate multidetector CT technique allows optimized detection of subtle abnormalities. In duodenal injuries, differentiation between a contusion of the duodenal wall or mural hematoma and a duodenal perforation is vital. In pancreatic injuries, determination of involvement of the pancreatic duct is essential. The latter conditions require immediate surgical intervention. Use of organ injury scales and a surgical classification adapted for multidetector CT enables classification of organ injuries for trauma scoring, treatment planning, and outcome control. In addition, multidetector CT reliably demonstrates potential complications of duodenal and pancreatic injuries, such as posttraumatic pancreatitis, pseudocysts, fistulas, exudates, and abscesses.

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Introduction

Blunt pancreatic and duodenal trauma is uncommon, amounting to less than 2% of all abdominal injuries. These injuries often occur during traffic accidents as a result of the direct impact on the upper abdomen of the steering wheel or the handlebars.

The duodenum and pancreas can be injured simultaneously; isolated injuries are rare (<30%). Coexisting injuries are common (50%–98%), with an average of three to four for each patient. Identification of a blunt injury of the duodenum and pancreas may be difficult because imaging findings are often subtle. Delays in diagnosis, incorrect classification of the injury, or delays in treatment can increase the morbidity and mortality considerably (1–4).

The morbidity and mortality associated with a trauma to the duodenum and pancreas are remarkably high. Mortality for pancreatic injuries ranges from 9% to 34%; for duodenal injuries it ranges from 6% to 29%. However, only 5% of the pancreatic injuries and 30% of the duodenal injuries are directly related to the fatal outcome. The variability in morbidity and mortality is caused by several factors: the presence of coexisting injuries, the mechanism of injury, the time to diagnosis, the presence or absence of major duodenal injury, and duodenal perforation, which are considered to be predictors of outcome (5).

The probability of complications after duodenal or pancreatic trauma ranges between 30% and 60% and in many cases is the result of missed findings or diagnostic delays or both. Delayed diagnoses and therapeutic interventions often result in a difficult clinical course with a dubious outcome. However, within the first 48 hours after pancreatic injury, most patients succumb to hemorrhage from splenic, hepatic, or vascular injuries (3,5,6).

Organ injuries most commonly associated with pancreatic trauma are hepatic (46.8% of cases), gastric (42.3%), major vascular (41.3%), splenic (28.0%), renal (23.4%), and duodenal (19.3%). The high energy transfer and the proximity of the duodenum and pancreas to other vital structures result in few isolated injuries (3,5,6).

Coexisting injuries and fatal hemorrhage are responsible for early deaths, while infections and multiorgan failure cause most late ones. Approximately one-third of the patients who survive the first 48 hours develop complications related to their pancreatic or duodenal injury. Common complications of duodenal and pancreatic injuries include pancreatitis, pseudocysts, fistulas, intraabdominal abscesses, pneumonia, and anastomotic breakdown, and these are related to the development of multiorgan failure and septicemia (7–9).

About 37% of late deaths are primarily attributable to the injury itself and usually occur within 1–3 weeks of the injury or later (7–9). The time between the injury and the diagnosis and definitive treatment is an important factor in the development of complications and their resulting mortality. When a definitive diagnosis is delayed for more than 24 hours, up to 40% of patients are at risk of death, as opposed to 11% of those patients operated on within 24 hours. Another study has confirmed these observations and notes that all of the deaths directly related to duodenal or pancreatic injuries occurred in cases in which diagnosis was delayed (10–12).

Today, computed tomography (CT) provides the safest and most comprehensive means of diagnosis of duodenal and pancreatic injury in hemodynamically stable patients (13–18). In this article, we review anatomic considerations, mechanisms of injury, clinical features, and laboratory findings. We also describe scanning protocols and the current role of multidetector CT, present a grading system for injuries and complications, and discuss the roles of endoscopic retrograde cholangiopancreatography (ERCP) and magnetic resonance (MR) cholangiopancreatography (MRCP) after trauma.

Anatomic Considerations

Duodenum

The duodenum, the first part of the small intestine, extends from the pylorus to the duodenojejunal flexure, known as the ligament of Treitz. It is divided into four sections: the duodenal bulb, descending part, transverse part, and ascending part. The first part of the duodenum passes backward and upward toward the neck of the gallbladder, and most of it is intraperitoneal. The descending part forms an acute angle, descends 7–8 cm, and is located entirely retroperitoneally. The transverse third part of the duodenum runs 10–12 cm to the left horizontally and is retroperitoneally located in front of the inferior vena cava, lumbar spine, and aorta. The ascending fourth part of the duodenum runs 2–3 cm retroperitoneally and upward to the left. The superior mesenteric vessels run downward over the anterior surface of the third portion of the duodenum (15,19).

Pancreas

The pancreas is situated in an upper dorsal retroperitoneal position in a relatively protected zone of the abdominal cavity. The pancreas is about 15–20 cm long and 1.0–1.5 cm thick; it weighs roughly 90–100 g.
Posterior to the pancreas are the aorta, inferior vena cava, left kidney, renal veins, and right renal artery. The pancreatic head lies adjacent to the concave contour of the duodenum. The splenic vein and splenic artery run superior and posterior to the body and tail of the pancreas and can be exposed surgically relatively easily. The proximity of many vascular structures and the far dorsal location of the inferior vena cava and portal vein make injuries to the pancreatic head far more difficult to handle and can affect the morbidity and mortality. The superior mesenteric vein and artery lie just behind the neck of the pancreas and are enclosed posteriorly by the uncinate process. The main pancreatic duct of Wirsung usually traverses the entire length of the gland.

**Mechanisms of Injury**
In general, their retroperitoneal location usually protects the pancreas and duodenum from many instances of minor abdominal trauma.

Pancreatic and duodenal injuries usually result only from severe anteroposterior compression trauma against the spinal column, mostly in connection with seat belt injuries, deceleration trauma, and handlebar compression trauma. Less common mechanisms of injury are sports injuries, falls, and blows to the upper abdomen.

Most blunt pancreatic injuries (>65%) occur in the pancreatic body. Those to the pancreatic tail and head are less common. Blunt pancreatic trauma is more common among children because of more intense transmission of energy and less protection by a usually thinner layer of peripancreatic fat.

Force exerted on the right upper quadrant can affect the pancreatic head or uncinate process and cause injuries in the descending and transverse portions of the duodenum. Coexisting injuries can affect the liver, bile duct, gallbladder, right kidney, and ascending colon. Force exerted on the left upper quadrant results mainly in injuries left of the superior mesenteric artery, to the pancreatic body or tail as well as to the transverse and ascending portions of the duodenum. Coexisting injuries can affect the spleen, stomach, and left kidney.

**Clinical Features**
Clinical symptoms comprise a triad of leukocytosis, raised serum amylase activity, which can be absent in the first few days, and upper abdominal pain.

However, clinical signs are often vague and nonspecific, sometimes even nonexistent. Therefore, major pancreatic injuries can occur with initially minimal epigastric symptoms. Blunt pancreatic and duodenal trauma can occur in patients with multiple trauma, and many will have undergone intubation or received sedatives and therefore cannot provide reliable data for evaluation. To obtain a reliable history in an emergency situation is difficult and in many cases barely feasible.

Injuries to the pancreas and duodenum are also likely to be masked by most typical coexisting injuries.

**Laboratory Findings**
The most common test is the analysis of serum amylase activity. This can be raised, although in up to 40% of cases it remains normal for 2–48 hours after an injury. Repeated testing is recommended, but results do not indicate the severity of the injury. Instead, continuously increased activity or increasing activity are more reliable and have been used for follow-up studies and to monitor the extent of an established pancreatic injury. In addition, the latter features can indicate the need for intervention or operation. Increased activity in general is not specific, as it may occur with salivary gland, facial, small bowel, or hepatic trauma or if the patient is intoxicated.

Serum lipase activity is also not specific for pancreatic injury. It has been used in children with pancreatic trauma but is not considered cost-effective. Trypsinogen-activating peptide has not been fully evaluated so far, and no reliable data are available.

**Multidetector CT Protocols**
The use of multidetector CT reduces motion artifacts and enables high-resolution scans, in particular high-quality multiplanar reformatted images. The detector collimation of primary axial images is 0.6–2.5 mm and the pitch is 1.0–1.8, depending on the available scanner technology. In standard CT studies, the axial images are reconstructed with a thickness of 2.5–5.0 mm, but axial images are best reconstructed at 2.5–3 mm, with a 10%–20% overlap. The thinnest possible slice thickness should be used for creation of multiplanar reformatted and maximum intensity projection images. Coronal and sagittal reformatted images are used routinely at 1.8–2.5-mm thickness. Curved planes along the duodenal or pancreatic axes are optional to clarify findings.

The absence of a pancreatic parenchymal phase (35–40-second delay) in whole-body CT is an obvious limitation of standard portal venous emergency abdominal CT. Combined scans with a whole-body protocol and CT angiography technique are used in most patients with multiple trauma. Although there are no reliable data so far, including the pancreatic parenchymal phase.
Delayed scanning (at 2–3 minutes) is performed optionally and is helpful in cases of suspected active abdominal (including pancreatic) hemorrhage.

The use of oral contrast media remains controversial, optionally given in one or two doses of 400–600 mL (17,27–29). The standard CT technique includes the use of positive oral contrast media, if possible. If isolated injury of the duodenum is suspected, dedicated techniques can be applied, such as use of large quantities of negative oral contrast media or sodium bicarbonate or butylscopolamine given orally to distend the duodenal wall (30). These techniques improve the diagnostic quality but are generally not likely to be used for emergency diagnoses.

**CT Findings in Duodenal Injury**

CT is an essential means of diagnosing traumatic lesions of the duodenum. Experience has shown...
extraluminal gas, or a lack of continuity of the duodenal wall. Duodenal contusion is suspected with edema or hematoma of the duodenal wall, intramural gas accumulations, and focal duodenal wall thickening (>4 mm) as findings of small bowel injury. Fluid or a hematoma in the retroperitoneum, stranding of retroperitoneal fatty tissue, or pancreatic transection can be present in both conditions (Figs 1–4) (15,17,18,27,28,30,33–35).

A study of 27 children showed that retroperitoneal extraluminal free air or oral contrast material on CT images provided a reliable way to differentiate duodenal perforation from contusions of the duodenal wall (36). In another study, CT

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In 20%–40% of the cases studied, initial CT findings of patients with pancreatic injuries may be within normal limits in the first 12 hours after the injury; however, much of the published data is still based on the single-detector CT technique. CT diagnosis of pancreatic injuries shows variable sensitivity and specificity because many findings are subtle, absent, or at times slow to develop. The sensitivity and specific-

CT Findings in Pancreatic Injury
Correct, early diagnosis of pancreatic injuries is essential for injured patients. Detection of the injury patterns by using CT depends on a reliable and robust technique, particularly timing of an emergency CT study after injury and correct timing of the contrast material bolus, as well as the experience of the radiologist involved (15).

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jury with multidetector CT has been measured in a single study at 91% (17,28,40). CT findings may be subtle, and sometimes the pancreas may appear normal. The integrity of the pancreatic duct is the most important factor in the decision whether or not to operate. CT is limited in detection of pancreatic injuries when only little peripancreatic fat tissue is present and in detection of subtle pancreatic duct injuries (4,20,38,39,41,42). Specific signs of pancreatic injuries on CT scans are fractures or lacerations of the pancreas, edema or hematoma of the pancreatic parenchyma, active hemorrhage from the pancreas, and blood collections between the parenchyma and the splenic vein (43,44) (Figs 5–10).

Figure 7. Grade III pancreatic injury. (a) Axial CT image shows diffuse edema of the pancreatic parenchyma with some defined areas of contusion (black arrow). There is a transection across the pancreatic body (white arrow). A grade II splenic laceration is also present (arrowhead). (b) Axial T2-weighted MR image shows the contusions to the pancreatic body (arrow) and the distal transection (arrowhead). (c) Coronal T2-weighted MR image shows an injury to the pancreatic duct (arrow).

Figure 8. Grade III pancreatic injury in a patient who experienced blunt abdominal trauma. (a) Axial CT image shows a complete transection of the distal part of the pancreas (white arrow). Active bleeding is also present (black arrow). An injury to the pancreatic duct was associated with this lesion. The liver and spleen were also injured, resulting in massive intraperitoneal hemorrhage (white arrowheads). Contrast material extravasation as a sign of active bleeding of the spleen is also evident (black arrowhead). (b) Coronal image shows the pancreatic transection (arrows).
injuries such as liver or splenic injuries (46,47). Grading pancreatic and duodenal injuries enables an exact description of injuries, can influence management, and allows a comparison of outcomes and effective quality control of treatment.

Major variables for pancreatic injury are anatomic site (proximal compared with distal); the type of injury, such as hematoma, laceration, or transection; and the state of the main pancreatic duct. The most accepted system today was published by the American Association for the Surgery of Trauma (AAST) and differentiates between grade I to V hematomas, contusions, lacerations with and without ductal involvement, and complete disruption of the organ as well as the site of the injuries (Table 1) (48).

Major variables for duodenal injury are involvement of one or more portions of the organ, the type of injury (such as hematoma, laceration, or partial or complete disruption), and...
involvement of the ampulla and bile duct. No recent data on CT-based grading are available as yet. However, according to the surgery literature, the AAST grading system (grades I–V) is in use. Even if this system is not fully adapted to be used as a CT grading scale—the extent of transections, in particular, probably cannot be reliably evaluated with CT—it allows the grading of duodenal CT findings (Table 2) (15,49).

### Complications of Pancreatic Trauma

The morbidity ranges between 11% and 62%, covering all types of complications. Most common are pancreatic fistulas (23%), posttraumatic pancreatitis (10%), and the formation of pseudocysts (5%). Posttraumatic internal pancreatic fistulas form an abnormal connection between the pancreas and adjacent organs or spaces and structures owing to continuing leakage of pancreatic secretions from disrupted pancreatic ducts. The mean morbidity rate in patients with pancreatic trauma is 36%, and the mortality for injuries graded I and II is stipulated at around 7%. However, it increases dramatically with grade III and IV injuries to about 29% (15,38,50).

### Roles of ERCP and MRCP

Arguments in favor of using ERCP and MRCP to detect duodenal or pancreatic trauma are not clear, even if they are performed after repeated CT and the ongoing suspicion of pancreatic or biliary duct injury (51–53).

ERCP has also been used as a minimally invasive procedure for placement of pancreatic duct stents. It has also been used postoperatively after laparotomy with persistent leakage of pancreatic fluid and with posttraumatic strictures of the pancreatic duct (40,54).

### Table 2

**Scoring Duodenal Injury**

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<th>Grade</th>
<th>Injury</th>
<th>Description</th>
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<tr>
<td>I</td>
<td>Hematoma, laceration</td>
<td>Involvement of a single portion of the duodenum</td>
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<tr>
<td>II</td>
<td>Hematoma, laceration</td>
<td>Involvement of more than one portion, disruption of &lt;50% of the circumference</td>
</tr>
<tr>
<td>III</td>
<td>Laceration</td>
<td>Disruption of 50%–75% of the circumference of D2; disruption of 50%–100% of the circumference of D1, D3, and D4</td>
</tr>
<tr>
<td>IV</td>
<td>Laceration</td>
<td>Disruption of &gt;75% of the circumference of D2 or involvement of the ampulla or distal common bile duct</td>
</tr>
<tr>
<td>V</td>
<td>Laceration, vascular injury</td>
<td>Massive disruption of the duodenopancreatic complex or devascularization of the duodenum</td>
</tr>
</tbody>
</table>

Source.—References 3 and 48.

Note.—Major variables are involvement of one or more parts of the organ, type of injury (hematoma, laceration, or disruption), and involvement of the ampulla and bile duct. The duodenum is divided into the duodenal bulb (D1), descending part (D2), transverse part (D3), and ascending part (D4).
MRCP and ERCP should be considered only for patients in stable condition, but as an option nonenhanced CT can be performed after ERCP (45,55–61).

**Conclusions**

CT of pancreatic and duodenal injuries is challenging and requires close attention to the choice of technique and the subtle signs of injury. Repeated CT should be considered for patients in stable condition when there is a strong suspicion of pancreatic injury despite normal findings at admission CT.

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**References**


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