

The management of complex pancreatic injuries

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Summary

Major injuries of the pancreas are uncommon, but may result in considerable morbidity and mortality because of the magnitude of associated vascular and duodenal injuries or underestimation of the extent of the pancreatic injury. Prognosis is influenced by the cause and complexity of the pancreatic injury, the amount of blood lost, duration of shock, speed of resuscitation and quality and nature of surgical intervention. Early mortality usually results from uncontrolled or massive bleeding due to associated vascular and adjacent organ injuries. Late mortality is a consequence of infection or multiple organ failure. Neglect of major pancreatic duct injury may lead to life-threatening complications including pseudocysts, fistulas, pancreatitis, sepsis and secondary haemorrhage. Careful operative assessment to determine the extent of gland damage and the likelihood of duct injury is usually sufficient to allow planning of further management. This strategy provides a simple approach to the management of pancreatic injuries regardless of the cause. Four situations are defined by the extent and site of injury: (i) minor lacerations, stabs or gunshot wounds of the superior or inferior border of the body or tail of the pancreas (i.e.

remote from the main pancreatic duct), without visible duct involvement, are best managed by external drainage; (ii) major lacerations or gunshot or stab wounds in the body or tail with visible duct involvement or transection of more than half the width of the pancreas are treated by distal pancreatectomy; (iii) stab wounds, gunshot wounds and contusions of the head of the pancreas without devitalisation of pancreatic tissue are managed by external drainage, provided that any associated duodenal injury is amenable to simple repair; and (iv) non-reconstructable injuries with disruption of the ampullary-biliary-pancreatic union or major devitalising injuries of the pancreatic head and duodenum in stable patients are best treated by pancreatoduodenectomy. Internal drainage or complex defunctioning procedures are not useful in the emergency management of pancreatic injuries, and can be avoided without increasing morbidity. Unstable patients may require initial damage control before later definitive surgery. Successful treatment of complex injuries of the head of the pancreas depends largely on initial correct assessment and appropriate treatment. The management of these severe proximal pancreatic injuries remains one of the most difficult challenges in abdominal trauma surgery, and optimal results are most likely to be obtained by an experienced multidisciplinary team.

Incidence

Traumatic injury to the pancreas is uncommon, occurring in 2 - 3% of severe abdominal injuries.¹⁻⁸ Recent data, however, reveal an increasing incidence of pancreatic trauma due to both high-speed automobile accidents and an escalation in civil violence involving increasingly dangerous weapons.⁹⁻¹⁰ In North American cities, penetrating abdominal injuries from gunshot wounds are the most common cause of pancreatic trauma, while in Western Europe, England and Australia traffic accidents predominate.^{1,6,8-10} This geographical variation in aetiology results in considerable disparity in the reported severity and type of pancreatic injuries.^{6,10}

Mechanism of injury

The unique anatomical features of the pancreas influence the site and type of injury. The proximity of major vascular

structures and surrounding viscera adds to the complexity of pancreatic injuries. Leakage of pancreatic exocrine secretions with duct disruption exacerbates the mechanical effects of direct pancreatic injury, with peri-pancreatic oedema and tissue and fat necrosis.^{11,12}

The nature and consequence of penetrating injuries depend on the type and kinetic energy of the wounding agent. Penetrating injuries with adjacent contusions occur in single-fragment missile wounds, while severe pancreatic fragmentation can occur with shotgun wounds. High-velocity missiles may produce devastating and often lethal abdominal injuries.

Blunt trauma to the pancreas and duodenum is usually the result of a direct blow to the upper abdomen caused by assault, pedestrian road traffic accidents or deceleration of the torso against an unyielding surface or steering wheel, as in an unrestrained driver or passengers without seat

belts.^{1,7,10,11} The mechanism of injury in blunt trauma relates to the magnitude and direction of the impact force and the retroperitoneal position of the pancreas closely applied to the lumbar spine.¹² Blunt midline upper abdominal trauma results in posterior compression of the anterior abdominal wall against the spine, with injury to the intervening pancreas overlying or to the left of the portal vein and superior mesenteric vessels.¹⁰ Impact forces concentrated to the right of the midline produce crush injuries of the pancreatic head and duodenum against the spine,¹³ while those to the left damage the tail. Serious associated injuries including liver lacerations and avulsion injuries of the common bile duct and gastroduodenal, right and middle colic vessels compound the effect of the pancreatic trauma. Factors influencing overall mortality rates include the degree and duration of preoperative shock, the number and magnitude of associated injuries and the location and complexity of the pancreatic injury.^{6,11,14}

Associated injuries

Isolated injuries to the pancreas are uncommon.¹⁵⁻¹⁸ The incidence of associated injuries ranges from 50% to 90%, with a mean of 3.5 organs injured.^{17,19,20} These associated injuries cause most of the morbidity and mortality in patients with pancreatic trauma. The organs most commonly injured are the liver (42%), stomach (40%), major vessels (35%), thoracic viscera (31%), colon and small bowel (29%), central nervous system and spinal cord, skeleton and extremities (25%) and duodenum (18%).^{1,10,11,21} Colonic injuries are more common after penetrating than blunt trauma, and increase the risk of postoperative sepsis.^{6,10} Penetrating injuries result in damage to retroperitoneal vessels in a third of patients.^{6,11,19}

The principles of management of pancreatic trauma include the need for early diagnosis and accurate definition of the site and extent of injury in order to facilitate optimal surgical intervention.^{1,10,11,19,21,22} Failure to accomplish this may result in serious sequelae if the injury is underestimated or inappropriately treated.^{1,2,11} The management of combined injuries to the pancreas and duodenum is complex, especially where devitalised tissue and associated damage to contiguous vital structures including the bile duct, portal vein, vena cava, aorta or colon are present.^{1,6,10,11,23} Major

complications including pancreatic fistula, pseudocyst, abscess or haemorrhage occur in one-third of surviving patients.^{1,10,12,19,24,25} The gravity of major pancreatic injuries and the potentially serious complications necessitate a comprehensive and multidisciplinary approach to their management.¹

Classification of injuries

Comparisons between various forms of treatment are often difficult to analyse, as isolated pancreatic injuries are infrequent, experience in most centres is limited, and there is no universally acceptable injury classification system. Several classifications have been proposed for pancreatic injuries,^{9,11} with the system initially devised by Lucas²² the most widely used (Table I).

Diagnosis

Delay in diagnosis and intervention is the most important cause of increased morbidity and mortality. The retroperitoneal position of the pancreas contributes to delay in diagnosis, as clinical signs may be subtle and late in onset. Blunt trauma to the pancreas may be clinically occult, and parenchymal and duct injury may go unrecognised both during initial evaluation and during surgery.⁹ Awareness of these factors and recognition of the mechanism of injury should therefore lead to a high index of suspicion for pancreatic injury.

Serum amylase levels correlate poorly with the presence or absence of pancreatic trauma.¹³ Amylase levels may be normal in severe pancreatic damage or may be elevated when no demonstrable injury to the gland has occurred. The incidence of hyperamylasaemia in patients with proven blunt pancreatic trauma ranges from 3% to 75%. Conversely, the pancreas has been found to be injured in anything from 10% to 90% of patients with hyperamylasaemia after blunt abdominal trauma. Even measuring serum isoamylase levels has also yielded disappointing results.¹⁰ Bouwman *et al.*²⁶ evaluated the role of serum amylase and its isoenzymes after blunt trauma in diagnosing pancreatic trauma. They reported that 33% (20/61) of patients had hyperamylasaemia, but only 2 (3%) actually had pancreatic injury.²⁶ The measurement of isoenzyme levels was not helpful in improving the sensitivity or specificity in this study.

However, a retrospective study by Takishima²⁷ evaluating serum amylase levels in 73 patients with blunt pancreatic injury led to a different conclusion. Hyperamylasaemia was noted on admission in 84% (61/73) of the patients. The 12 patients with a normal serum amylase level were all admitted 3 hours or less after the trauma. There was a significant correlation ($p < 0.001$) between time elapsed from trauma to admission and serum amylase level.²⁷ Measuring serum amylase levels more than 3 hours after blunt trauma may therefore avoid false-negative results in pancreatic injuries, and a serially rising serum amylase level in a patient with abdominal tenderness and pain may be a better indicator of pancreatic injury. Other causes for a raised serum amylase level after blunt trauma to be considered include acute alcohol intake, bowel infarction or injury to duodenum, stomach or small bowel.¹

TABLE I. MODIFIED LUCAS CLASSIFICATION OF PANCREATIC INJURY^{4,22}

Class 1. Simple superficial contusion or peripheral laceration with minimal parenchymal damage. Any portion of the pancreas can be affected, but the main pancreatic duct is intact

Class 2. Deep laceration, perforation or transection of the neck, body or tail of the pancreas with or without pancreatic duct injury

Class 3. Severe crush, perforation or transection of the head of the pancreas with or without ductal injury

Class 4. Combined pancreaticoduodenal injuries, subdivided into:

- (a) minor pancreatic injury
- (b) severe pancreatic injury and duct disruption

Imaging

Plain abdominal radiographs

A plain radiograph of the abdomen could raise the suspicion of pancreatic trauma, especially when features of duodenal injury are present. Gas bubbles in the retroperitoneum, adjacent to the right psoas muscle, around the kidneys or anterior to the upper lumbar vertebrae seen on frontal or cross-table radiographs may indicate a duodenal injury.^{6,19} Free intraperitoneal gas may also be present. Fractures of the transverse processes of the lumbar vertebrae are collateral evidence of significant retroperitoneal trauma. Other indirect signs of pancreatic injury are displacement of the stomach or transverse colon, or a general 'ground-glass' appearance.^{19,22} Oral iodinated contrast may demonstrate a duodenal leak, with or without distortion of the duodenal C-loop.

Ultrasound

As part of the initial assessment of trauma patients, ultrasound has proved to be an effective and reliable imaging technique for assessing the presence of free abdominal fluid, which is most likely to be due to blood.²⁸⁻³⁰ Focused abdominal ultrasound in trauma (FAST) is increasingly being used at a number of centres as the initial imaging modality to assess trauma patients. However, directed ultrasound evaluation of pancreatic trauma is frequently difficult owing to associated abdominal injuries, overlying bowel gas, obesity or subcutaneous emphysema.^{30,31}

Computed tomography

Computed tomography (CT) is well suited to the evaluation of pancreatic trauma and is both more sensitive and more specific than ultrasonography.³² The main indications for CT are in haemodynamically stable patients with abdominal pain or tenderness following trauma who have a suspected pancreatic injury, and in the assessment of late complications of pancreatic trauma. An intravenous iodinated contrast bolus provides the optimal contrast enhancement of the pancreas necessary to identify subtle fractures. The CT findings of post-traumatic pancreatitis are time-dependent and may not be evident on scans performed immediately after injury. The features of injury or post-traumatic pancreatitis are focal or diffuse pancreatic enlargement, oedema and infiltration of the peripancreatic soft tissues and thickening of the anterior pararenal fascia, with or without acute fluid collections in or around the pancreas.³² Other nonspecific CT findings of pancreatic trauma include blood or fluid tracking along the mesenteric vessels, fluid in the lesser sac, fluid between the pancreas and splenic vein or thickening of the anterior pararenal fascia.

The features of pancreatic trauma may however be subtle, particularly in the period immediately after injury and in adults with minimal retroperitoneal fat. Pancreatic contusions may appear as low-attenuation or heterogeneous focal or diffuse enlargement of the pancreas. Pancreatic lacerations may be seen as linear, irregular, low-attenuation areas within the normal parenchyma. Unless the two edges of a fracture or transected pancreas are separated by low-attenuation fluid or haematoma, the diagnosis of pancreatic transec-

tion may be difficult on CT (Fig. 1). The location of the pancreatic laceration or fracture, whether to the left or right of the superior mesenteric artery, and the depth of the laceration may help predict pancreatic duct disruption.¹

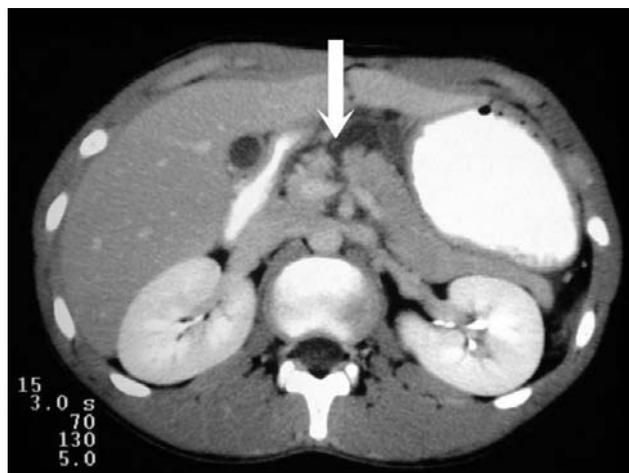


Fig. 1. CT scan showing fracture (arrow) at the pancreatic neck.

Common CT pitfalls in diagnosing pancreatic injury include unopacified bowel or fluid in the lesser sac mimicking focal pancreatic enlargement or contusion, streak artefacts or focal fatty replacement of pancreatic parenchyma simulating a pancreatic laceration.¹ Other CT findings that mimic pancreatic injury include blood or fluid tracking around the pancreas from injuries to the adjacent duodenum, spleen or left kidney, pelvic haematoma tracking superiorly in the retroperitoneum and retroperitoneal oedema from vigorous intravascular volume resuscitation.¹

The ability of CT to accurately diagnose pancreatic injury depends on the quality of the CT scanner, the technique used, the experience of the observer and the timing of the examination in relation to the injury. CT had an 85% sensitivity within the first 24 hours after the acute pancreatic injury, and a 90% sensitivity overall.³³ Within 12 hours after a pancreatic injury, CT scans may be normal in a significant proportion of cases owing to an obscured fracture plane, overlying or intervening blood or close apposition of the edges of the pancreatic injury. Repeat scanning 12 - 24 hours after the injury may reveal an obvious injury that was initially subtle.

The overall imaging sensitivity in detecting all grades of pancreatic injury has been estimated at 80%, but major ductal injury detection has been reported to be as low as 43%, even with modern imaging techniques. Further analysis of missed injuries also suggests that CT is inaccurate in grading the degree of pancreatic injury and often a lower grade of injury is diagnosed by CT than is found at laparotomy.^{28,29,30,32}

Endoscopic retrograde cholangiopancreatography (ERCP)

Until recently, ERCP had been the most accurate method of detecting pancreatic duct integrity by demonstrating extravastation of contrast from the ducts (Fig. 2).³⁴⁻³⁸ Preoperative ERCP is seldom feasible in acute pancreatic trauma, as most patients require urgent laparotomy for



Fig. 2. ERP showing duct injury (arrow) at the pancreatic neck.

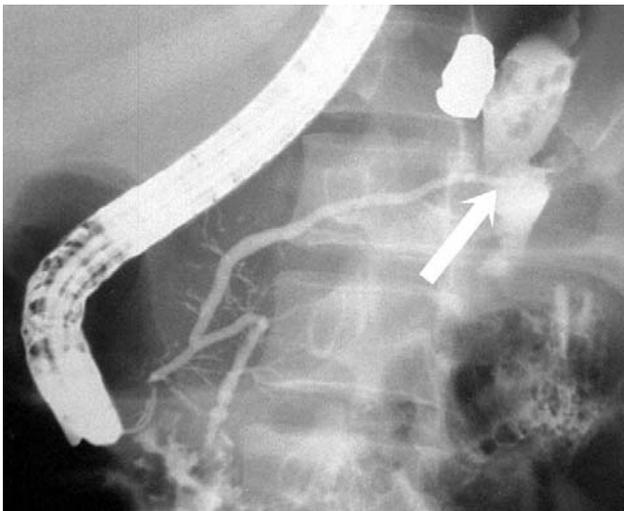


Fig. 3. ERP demonstrating distal pancreatic fistula (arrow) after an abdominal gunshot injury.

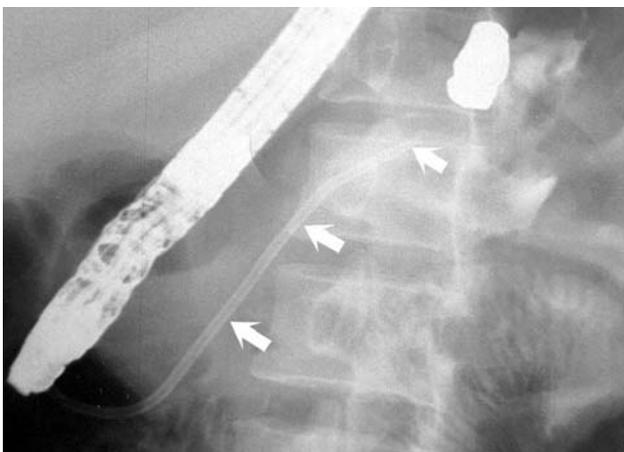


Fig. 4. Endoscopically placed pancreatic stent (arrows) to treat fistula shown in Fig. 3.

bleeding or associated injuries.^{9,39} ERCP in stable patients after blunt trauma to the pancreatic head or neck may also be technically difficult owing to distortion of recognisable mucosal landmarks, including the papilla, caused by intramural haematoma or surrounding peripancreatic oedema.³⁹ The concept of intraoperative ERCP to define pancreatic duct anatomy is appealing as it avoids opening the duodenum and performing a potentially difficult operative cannulation of the papilla during laparotomy when a pancreatic duct injury is suspected.⁴⁰ However, even in centres with the necessary expertise, the logistic difficulties involved in performing an emergency intraoperative ERCP can outweigh the potential benefits. In addition, the patient's supine position, the need for high quality X-ray facilities and the necessity for complete visualisation of the pancreatic duct increase the technical difficulties.

ERCP is an invasive procedure associated with complications, including pancreatitis in 3% of patients. The results are operator-dependent, and failure to cannulate the ampulla or completely fill the pancreatic duct may occur in up to 10% of patients.⁴¹ Patients with minor duct injury without leakage from the pancreatic parenchyma can be treated non-surgically.⁴²⁻⁴⁵ Confirmation of major ductal injury with extravasation requires operative intervention in most patients, unless duct continuity is present and facilities exist to place an endoscopic pancreatic stent.^{42,46} ERCP has the added subsequent advantage of allowing endoscopic intervention with transpapillary stenting for persistent pancreatic fistulas (Figs 3 and 4)⁴⁷ or transgastric or transduodenal drainage of traumatic pancreatic pseudocysts.^{34,35,48,49}

Magnetic resonance cholangiopancreatography (MRCP)

MRCP is a valuable additional imaging modality providing a non-invasive, accurate and rapid means of assessing the pancreatic duct. MRCP sequences depict the fluid-filled pancreatic and bile ducts as high-signal structures without the use of any contrast material, avoiding the risks of ERCP-related complications.⁵⁰ MRCP findings indicating injury to the pancreatic duct include focal disruption or interruption of the duct, focal or diffuse dilation of the upstream duct (with a diameter of 3 mm or more), and communication between the duct and intrapancreatic or peripancreatic fluid collections. Unlike retrograde pancreatography, MRCP is able to provide additional useful information concerning the upstream pancreatic duct architecture and injury, even without continuity with the downstream duct.

The development of rapid MR imaging techniques and MR-compatible physiological monitoring and ventilation devices allows imaging to be performed on patients with acute injuries, although it may still be logistically difficult. Even though several images are required to show the pancreatic duct at various angles, scans can be completed in less than 10 minutes, an important advantage for the acutely and severely traumatised patient. Some MRCP sequences do not require breath-holding, with little degradation of image quality, even if the patient is unable to co-operate fully. Special sequences may also suppress artefact formation from metallic objects such as surgical clips and bullet fragments.⁵⁰ Complementing MRCP with conventional magnetic resonance imaging (MRI) extends evaluation to the pancreatic parenchyma.⁵⁰

Management

The initial management of the patient with pancreatic trauma is similar to that of any patient with severe abdominal injury.^{1,10,11} The priorities of primary management include maintaining a clear airway, urgent resuscitation and ventilatory and circulatory support.^{1,2,3,4,10,51} Venous access, blood group and cross-match, volume replacement, and measurement of haemoglobin concentration, white cell count, packed cell volume, urea, creatinine, electrolytes and blood gases are rapidly obtained.^{10,11} The mechanism and type of injury are established while physical examination and resuscitation are in progress. In patients with blunt abdominal trauma, information should be sought regarding the mechanism of injury and the vector of force (e.g. steering wheel, bicycle or motorcycle handlebar, sports injury or assault). The injury may seem trivial or innocuous and the initial assessment may be misleading with scant clinical signs because of the retroperitoneal location of the pancreas. A nasogastric tube and urinary catheter are essential.¹⁰ Urgent laparotomy is required in all patients with evidence of major intraperitoneal bleeding, associated visceral trauma, or peritonitis.¹

A long midline incision provides optimal exposure.^{1,2,12} In the presence of shock and haemoperitoneum, the first priority is to identify the source of bleeding. Immediate survival is dependent upon successful control and repair of major vascular injuries.^{1,2} The inaccessible retropancreatic position of the superior mesenteric, splenic and portal veins make proximal and distal clamping or circumferential control of individual vessels impractical during massive bleeding. Rapid initial control is therefore best obtained by surgical packing or digital pressure. Early duodenal mobilisation and bimanual compression of the bleeding site is helpful if there is suspicion of major portal or superior mesenteric vein injury. Vigorous resuscitation with blood and blood components should continue until bleeding has been staunched and normovolaemia achieved. Attention is then directed to other priority visceral injuries before dealing with the pancreatic trauma.

Intraoperative evaluation of the pancreas

In most patients, the diagnosis of pancreatic injury is made at laparotomy.^{1,2,15,16} Importantly, however, blunt trauma to the pancreas may result in damage to the main pancreatic duct without transection of the gland.⁵² Minor contusions or lacerations of the pancreatic substance do not usually require further definitive treatment, but this decision can only be made after careful local exploration to exclude a major duct injury. Determining the presence and extent of a pancreatic injury intraoperatively requires recognition of the features indicating a potential pancreatic injury, adequate exposure of the pancreas, definition of the integrity of the pancreatic parenchyma and determination of the status of the major pancreatic duct.^{1,2} This may be complicated by the extent and severity of associated injuries. Gross inspection and palpation of the pancreas alone can be misleading as retroperitoneal or subcapsular haematoma and peripancreatic oedema may mask major parenchymal and duct injuries.¹¹ Clues suggesting the presence of a pancreatic injury include a lesser sac fluid collection, retroperitoneal bile-staining, or crepitus or haematoma overlying the pancreas at the base of the transverse mesocolon or visible through the gastrohepatic lig-

ament.⁷ Fat necrosis of the omentum or retroperitoneum may be present if there has been undue delay before laparotomy.⁷ With such findings, complete visualisation of the gland and accurate determination of the integrity of the pancreatic duct is crucial, remembering that failure to recognise a major pancreatic duct injury is the principal cause of post-operative morbidity.

The lesser sac is entered through the gastrocolic omentum outside the gastroepiploic arcade^{13,14} and, by retracting the transverse colon inferiorly and the stomach superiorly, exposure of the anterior surface and the superior and inferior borders of the body and tail of the pancreas is obtained.¹² Surrounding haematoma may complicate adequate assessment of the tail and further detailed evaluation may require division of the lateral peritoneal attachments. If necessary, the spleen, tail and body of the pancreas are reflected forwards and medially by developing a plane between the kidney and the pancreas.^{2,12} This manoeuvre allows full exposure and bimanual palpation of the tail and body of the pancreas. Intraoperative features indicating a major pancreatic duct injury include a transected pancreas, a visible duct injury, a laceration involving more than half of the width of the pancreas or a large central perforation.^{11,53,54}

For fuller inspection of the pancreatic head and uncinate process, both an extensive Kocher manoeuvre to mobilise the second part of the duodenum medially toward the superior mesenteric vessels and complete mobilisation at the ligament of Treitz are required.^{1,55,56} Dissection and inferior reflection of the hepatic flexure of the colon and the right transverse mesocolon further improve exposure of the second portion of the duodenum and uncinate process.^{4,55,57} All penetrating wounds should be traced through their entire intra-abdominal course to exclude pancreatic or other visceral injury.^{13,57} Intraoperative evaluation of the head of the pancreas includes assessment of the integrity of the main pancreatic duct, whether the pancreatic head or duodenum are devitalised, the presence and extent of duodenal injury, whether the ampulla is disrupted, if the bile duct is intact or whether a vascular injury has occurred.

Intraoperative pancreatography

Several radiological methods of intraoperative pancreatography to delineate the pancreatic duct have been recommended.¹³ The easiest and most convenient is to perform a conventional operative cholangiogram through the cystic duct after removing the gallbladder, or alternatively by inserting a 25-gauge butterfly needle into the common bile duct and injecting 10 ml full-strength water-soluble iodinated contrast with fluoroscopic control. The images obtained may be useful to assess the intrapancreatic bile duct, the integrity of the ampulla and continuity of the pancreatic duct if there is contrast reflux into the pancreatic duct. In the presence of an associated open duodenal injury, the papilla may be conveniently accessible and should then be located.¹ A firm squeeze of the gallbladder helps to identify the ampullary opening by producing bile at the ampulla. A fine lacrimal probe passed through the papilla into the pancreatic duct in the neck may provide sufficient information by demonstrating the position of an intact duct away from the site of the injury. A soft 5Fr paediatric feeding tube can be used for operative pancreatography by cannulating the ampulla of Vater. Previously advised distal pancreatic resec-

tion to obtain a retrograde pancreatogram is no longer acceptable. A skilled endoscopist may be of assistance in performing an intraoperative ERCP if logistics permit.³⁹

Treatment

Class 1: Contusions and lacerations without duct injury

Seventy per cent of pancreatic injuries are minor and include contusions, haematomas and superficial capsular lacerations without an underlying major ductal injury. Control of bleeding and simple external drainage without repair of capsular lacerations are sufficient treatment. Either a Penrose drain or a soft closed suction or sump drain may be used. A closed silastic suction drain is preferred, as pancreatic secretions are more effectively controlled, skin excoriation at the drain exit site is reduced, and bacterial colonisation is less of a risk than when a sump or gravity drain is used.^{19,58}

Class 2: Distal injury with duct disruption

Injury to the neck, body or tail of the pancreas with major lacerations or transections and associated pancreatic duct injury is best treated by distal pancreatectomy.^{13,58} Optimal management of the divided pancreatic duct and the resection margin after distal pancreatectomy remain controversial. Some surgeons have advocated the use of a Roux-en-Y pancreatojejunostomy to incorporate and drain the resection margin to prevent the development of a pancreatic fistula.^{10,11} In patients with multiple injuries, the added risk of an anastomotic leak is not warranted and this procedure therefore is *not* recommended.^{13,23,53} A visible pancreatic duct at the resection margin should rather be ligated with a transfixing suture.¹³ Oversewing or stapling the transected end of the pancreas and using simple methods to buttress or seal the cut margin are sufficient, and have not led to increased fistula formation.¹³

Class 3: Proximal injury with probable duct disruption

It is especially important to exclude a pancreatic duct injury in trauma to the head of the pancreas. Injuries to the head of the pancreas that do not involve the main pancreatic duct are best managed by simple external drainage. Even if there is a suspected isolated pancreatic duct injury (as may occur with a localised penetrating injury), provided there is no devitalisation and the ampulla is intact, external drainage of the injured area is often the safest option.^{25,58,59} A controlled fistula thus created either settles spontaneously or may later require elective internal drainage after definition of the exact site of duct leakage. Techniques describing onlay Roux-en-Y loop anastomoses to incorporate an injured area in the head of the pancreas are not advisable because of the difficulty in assuring the integrity of the anastomosis in the acute situation.^{10,11,13}

Class 4: Combined major pancreaticoduodenal injuries

Severe combined pancreatic head and duodenal injuries are uncommon, and usually result from gunshot wounds or blunt trauma with other associated intra-abdominal injuries. In determining the best option for patients with combined injuries, it is crucial to define the integrity of the common

bile duct, pancreatic duct and ampulla and the viability of the duodenum. If the existing injury is in the second part of the duodenum, careful retraction of the edges of the wound or extension of the laceration in the direction of the papilla may provide adequate exposure of the papilla. As previously indicated, gentle passage of a probe through the ampulla is generally sufficient to exclude injury to the bile duct and ampulla and provides a convenient guide to the position of the pancreatic duct in relation to the injury.^{1,2} Alternatively, a cholangiogram performed through the gallbladder, cystic or bile duct may provide the same information.¹³ If there is unobstructed flow of contrast into the duodenum without extravasation, it can be assumed that the common bile duct and ampulla are intact. The presence of bile staining in the retroperitoneum or around the lower bile duct in the hepato-duodenal ligament is confirmation of bile duct injury or ampullary avulsion.¹³ If the duodenal injury involves the third or fourth part of the duodenum remote from the ampulla and there is concern about ductal integrity, a duodenotomy opposite the papilla can be used to evaluate the ductal system.¹¹

If the common bile duct and ampulla are shown to be intact, the duodenal laceration is repaired and the pancreatic injury treated according to the site of the injury. As with class 3 injuries, division or damage to the main pancreatic duct and parenchyma near the junction of head and neck are optimally managed by resection of the neck, body and tail. Penetrating injury in the pancreatic head without devitalisation is best treated by careful drainage of the area. Localised ischaemia at the site of the duodenal injury should be debrided before primary duodenal closure, and if there is concern about the integrity of the duodenum, decompression using a carefully placed nasogastric tube in the duodenal loop is useful.^{1,2}

With a severe injury to the duodenum in association with a lesser pancreatic head injury, some authors advise diversion of gastric and biliary contents away from the duodenal repair. Several complex and innovative techniques have been described to deal with this situation, including diversion by a duodenal 'diverticulisation' procedure with primary closure of the duodenal wound, a vagotomy, an antrectomy with an end-to-side gastrojejunostomy, a T-tube common bile duct drainage, and a tube duodenostomy.⁶⁰ The aim is to convert a potentially uncontrolled lateral duodenal fistula into a controlled end-fistula by diversion of gastric and biliary contents away from the duodenal injury, while making provision for early enteral nutrition via a gastrojejunostomy. An alternative option avoiding a vagotomy and antrectomy is the 'pyloric exclusion' procedure.⁶¹ The pylorus is closed with an absorbable suture performed through a gastrotomy, and a side-to-side gastrojejunostomy provides temporary diversion of gastric flow away from the duodenum while the duodenal and pancreatic injuries heal. The pylorus opens when the sutures dissolve 3 or 4 weeks later, or the sutures can be removed endoscopically after an intact duodenum has been confirmed. In a small number of selected patients, pyloric exclusion has proved useful in managing severe duodenal injuries combined with pancreatic head injuries in which a Whipple procedure is not justified.⁵⁹ We believe, however, that the same objectives can be achieved by less complex procedures and in this situation we use primary duodenal closure, external catheter drainage near the site of

the repair, a diverting gastrojejunostomy without closure of the pylorus and a fine-bore silastic nasojejunal feeding tube.^{1,3}

Pancreaticoduodenectomy

Reconstruction may not be possible in some combined injuries of the proximal duodenum and head of the pancreas with extensive tissue devitalisation, with complete disruption of the ampulla involving the proximal pancreatic duct and distal common bile duct, or avulsion of the duodenum from the pancreas.^{2,56,62,63} In these situations, the only rational option is resection (Fig. 5). Pancreaticoduodenectomy has the advantage of removing all injured tissue and allows reconstruction of the digestive tract and preservation of pancreatic function. The decision to resort to pancreaticoduodenectomy is based upon the extent of the pancreatic injury, the size and vascular status of any duodenal injury, the integrity of the distal common duct and ampulla of Vater, the status of the major peripancreatic vascular structures and the experience of the surgeon. Specific indications that have been proposed for pancreaticoduodenectomy for trauma are: (i) extensive devitalisation of the head of the pancreas and duodenum so that reconstruction is not possible; (ii) ductal disruption of the pancreatic head in association with injuries to the duodenum and distal common bile duct; (iii) injury to the ampulla of Vater, with disruption of the main pancreatic duct from the duodenum; (iv) uncontrollable bleeding from vessels in the head of the pancreas; and (v) inaccessible exsanguinating retropancreatic portal or superior mesenteric vein injury.^{62,64,65}

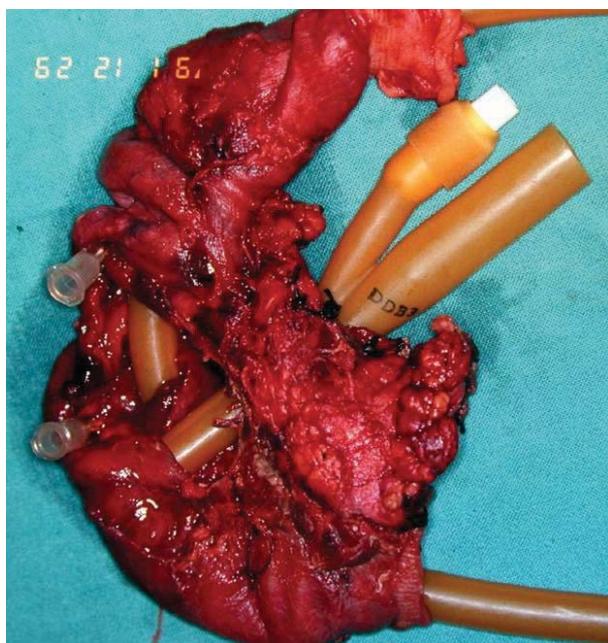


Fig. 5. Pancreaticoduodenectomy specimen showing disruption of the ampulla.

The technical procedure of an emergency pancreaticoduodenectomy for trauma is similar to the elective operation, but with appropriate modifications if the patient is hypotensive with active bleeding from the pancreas. In situations where there is exsanguinating bleeding due to an injury to the retropancreatic portal mesenteric venous system, the steps of the procedure change and are directed to accelerated expo-

sure and control of the site of bleeding.⁶⁶ The duodenum and head of the pancreas are rapidly mobilised medially by the Kocher manoeuvre and the portal mesenteric venous system is compressed manually between the thumb on the anterior aspect of the pancreas and the second and third fingers, inserted behind the head of the pancreas. While the first assistant controls the bleeding by compression in this manner, the lesser sac is opened, the stomach retracted superiorly, the hepatic flexure of the colon mobilised inferiorly, the superior mesenteric vein identified inferior to the neck of the pancreas and the portal vein identified superiorly.² The neck of the pancreas is divided to gain direct access to the region of the injury. Once exposure of the portal-mesenteric-splenic venous confluence has been achieved, the vascular injuries are identified and repaired.⁶⁶

Associated vena caval lacerations are best repaired by direct suture techniques. It may be possible to repair the vena cava both anteriorly and posteriorly without mobilising and clamping the cava above or below the injury. Digital or stick-sponge pressure superior and inferior to the rent usually controls bleeding while the defects are closed. A small posterior caval defect often can be sutured through a larger anterior rent without rotating the vessel. This is helpful when the wound in the vena cava is at the level of the renal veins. If a posterior rent cannot be visualised in this area, the right kidney is mobilised, elevated and rotated medially, exposing the junction of right renal vein and vena cava.⁶⁷

Pancreaticoduodenectomy may be necessary in 1 - 2% of isolated pancreatic injuries and in up to 10% of combined pancreaticoduodenal injuries.⁶⁶⁻⁷¹ The need for resection is usually obvious at first sight when there is massive destruction with gross devitalisation of the duodenum or pancreatobiliary, duodenal and ampullary disruption is present. Blunt trauma may result in a near-complete *de facto* pancreaticoduodenectomy. Fifty-five publications have documented pancreaticoduodenectomy for pancreatic trauma in 205 patients, with an overall mortality of 35%.^{2,72} Six series recorded 10 or more patients^{14,21,56,66,69,73} (Table II). Ten patients underwent pancreaticoduodenectomy for either gunshot (8) or blunt trauma (2) to the pancreas at the Los Angeles County-University of Southern California Medical Center.⁶⁶ Seven patients had a standard resection and 3 underwent total pancreatectomy. Four of the 10 patients survived. Of 117 patients with pancreatic injuries treated over a 6-year period in Seattle, 10 underwent pancreaticoduodenectomy for non-reconstructable injury to the ampulla or severe combined pancreaticoduodenal injuries.⁶⁹ Seven injuries were due to gunshot wounds and 3 to blunt trauma. Ninety per cent of the patients had associated intra-abdominal injuries, with an average of 3.4 organ systems involved. All 10 patients survived. Thirteen of 129 patients with pancreaticoduodenal injuries treated during an 18-year period in Houston underwent pancreaticoduodenectomy for complex trauma.²¹ Ten had a standard resection and 3 total pancreatectomy. Six of the 13 patients died.

During a 12½-year period at Los Angeles County-University of Southern California Medical Center, 18 patients with complex pancreaticoduodenal injuries underwent pancreaticoduodenectomy.⁵⁶ The mean revised trauma score was 6.84 ± 2.13 , and the mean injury severity score was 27 ± 8 . Seventeen patients had penetrating injuries (94%) and 1 a blunt injury (6%). One of the 18 patients had an emergency department thoracotomy and died; 5 of the

TABLE II. PANCREATICODUODENECTOMY FOR TRAUMA

		No. of patients	Deaths	Mortality
Yellin⁶⁶	1975	10	6	60%
Oreskovich⁶⁹	1984	10	0	0%
Jones¹⁴	1985	12	7	58%
Feliciano²¹	1987	13	6	46%
Asensio⁵⁶	2003	18	6	33%
Krige⁷³	2005	17	3	17%
Overall		80	28	35%

remaining 17 patients required operating room thoracotomies, and only 1 survived (80% mortality). Indications for pancreaticoduodenectomy were uncontrollable retropancreatic bleeding and non-reconstructable injury to the head of the pancreas and intrapancreatic portion of the distal common bile duct. Mean blood loss was 6 888 ml and overall survival was 67% (12 of 18 patients).

Seventeen of 270 patients with pancreatic injuries underwent a Whipple's resection for trauma in our hospital during a 20-year period.⁷³ Eleven had gunshot wounds involving the head of the pancreas, 5 had blunt trauma to the abdomen and 1 had been stabbed in the epigastrium. Nine of the 17 patients were shocked on admission to the trauma unit. The mean number of associated injuries was 3.4; 6 patients had associated inferior vena caval injuries and 3 had portal or superior mesenteric vein injuries. Twelve underwent a pylorus-preserving pancreaticoduodenectomy and 5 a standard Whipple's resection. Four of the 17 patients required an initial damage control operation and underwent subsequent resection once they were stable. Three patients died postoperatively of multi-organ failure. All of the survivors had complications. Five patients developed anastomotic leaks due to pancreatic (2), biliary (2) or duodenojejunal fistulas (1). Two patients had delayed gastric emptying and 3 required percutaneous catheter drainage of intra-abdominal fluid collections. Three patients had late complications, including alcohol-induced pancreatitis, malabsorption (which resolved on pancreatic enzyme replacement therapy) and hepatic duct stone 10 years after the Whipple's resection. Factors complicating resection and predicting poor outcome were shock on admission, the number of associated injuries, coagulopathy, hypothermia, marked jejunal oedema and traumatic pancreatitis.⁷³

Technical problems in the reconstruction of pancreatic and biliary anastomoses may arise due to the small size of the undilated ducts and jejunal oedema. The parenchyma of the pancreatic remnant is also frequently swollen if there has been a delay between the injury and the operation, and the pancreatic duct may be small or obscured if posterior in the gland. Invagination of the end of the pancreas into a Roux-en-Y jejunal loop has been the most widely used pancreatic-enteric anastomosis. We have used a pancreatogastrostomy in this situation, with minimal morbidity.⁷³ Biliary-enteric continuity is commonly restored by means of a side-to-side hepaticojejunostomy, using the high bile duct reconstruction technique with preplaced sutures. In desperate situations with a minute common bile duct, the gallbladder can be used for the anastomosis after ligating the bile duct below the cystic duct insertion. Since major vascular injuries are frequent,

massive blood loss, coagulopathy and hypothermia are often present at the time the pancreatic repair is undertaken.

In unstable patients with serious associated injuries, simple controlled drainage and delayed reconstruction may be the most judicious procedure.⁷⁴⁻⁷⁶ Damage control surgery is advised in patients with haemodynamic instability despite full resuscitation, clinical or proven coagulopathy, hypothermia, associated complex and other major multiple visceral injuries, severe metabolic acidosis and an intraoperative blood transfusion that has exceeded 10 units of packed red blood cells.⁷⁷⁻⁸⁰

Postoperative care

The principles of postoperative care in patients undergoing resection for complex pancreatic injuries are similar to those in patients with other major abdominal injuries.¹ Attention is paid to ventilatory status, fluid balance, renal function, intestinal ileus and nasogastric tube losses. Meticulous charting of drain content and volume are important. Prolonged ileus and pancreatic complications may preclude normal oral intake in severely injured patients. The standard composition of regular tube feeds increases pancreatic secretions. The low-fat and higher pH (4.5) formulation of an elemental diet is less stimulating to the pancreas, and should be attempted before instituting parenteral nutrition. A catheter jejunostomy using a submucosal needle technique or a fine-bore silastic nasogastric tube with a weighted tip placed at the initial operation in complex pancreatic injuries allows the option of early postoperative enteral feeding, rather than total parenteral nutrition. The enteral route is more efficient for nitrogen utilisation and may better restore immune competence, as well as being cheaper with less morbidity.

Complications

The most common specific complication following pancreatic injury is a pancreatic fistula. This occurs in 10 - 20% of major injuries to the pancreas. Most fistulas are minor and resolve spontaneously within 1 or 2 weeks of injury, provided adequate external drainage has been established. High-output fistulas (> 700 ml/day) usually indicate major pancreatic duct disruption. A sinogram is then useful to define the site of the fistula, as well as aid in the planning of further treatment if a high-output fistula fails to progressively decrease in volume or persists longer than 10 days. Supplementary nutritional support is standard management, but the role of somatostatin and octreotide is unproven. Persistent fistulas require endoscopic pancreatography and transpapillary stent insertion, or if this fails, operative intervention with distal pancreatic resection for leaks in the pancreatic tail or a Roux-en-Y cystjejunostomy for proximal leaks.

Peripancreatic, subhepatic and subphrenic fluid collections are commonly seen on US or CT after pancreatic trauma.⁸¹⁻⁸³ An infected collection should be suspected in any patient who develops an elevated temperature, raised white cell count, prolonged ileus or unexplained upper abdominal tenderness postoperatively (Fig. 6). US or CT scan are necessary to confirm the diagnosis. Clinical evidence of intra-abdominal sepsis mandates guided aspiration to obtain fluid for bacteriology and amylase content. Empiric broad-spectrum parenteral antibiotic therapy should be instituted to cover the full bacterial spectrum until definitive culture

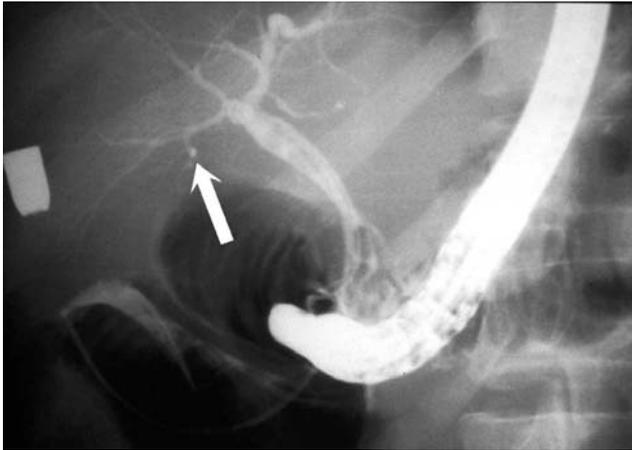


Fig. 6. ERC after Whipple's resection and Imanaga reconstruction showing small intrahepatic bile leak (arrow) due to bullet injury.

results become available. Percutaneous aspiration or catheter drainage is usually effective in patients with accessible unilocular collections and no evidence of pancreatic necrosis.

The presence of necrotic pancreatic tissue generally mandates surgery with debridement of non-viable tissue and generous external catheter drainage, although percutaneous insertion of large-bore drainage catheters may be beneficial in selected cases. Secondary haemorrhage from the pancreatic bed or surrounding vessels as a consequence of infected devitalised tissue and retroperitoneal autodigestion from uncontrolled pancreatic drainage is an uncommon but formidable complication after pancreatic trauma. Failing control by angiographic embolisation, operative exposure and packing with abdominal swabs may be life-saving.^{1,2}

Pseudocysts after abdominal trauma may occur as a result of undetected pancreatic duct disruption with continued leakage of pancreatic enzymes and may present weeks or months after the original pancreatic injury (Fig. 7).^{5,84-86} Surgical strategy in the management of traumatic pseudocysts will depend on the site and nature of the duct injury, the maturity of the cyst wall and the clinical urgency.⁸⁴ If the pseudocyst is symptomatic or enlarging in size, MRCP or

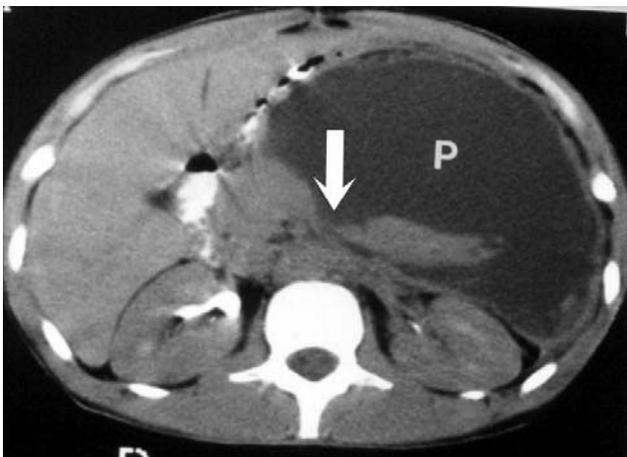


Fig. 7. CT scan of pancreatic pseudocyst (P) following blunt abdominal injury showing pancreatic fracture (arrow) over vertebral column.

ERC provide accurate anatomical delineation of the duct injury. If there is minimal communication with a side-duct or if the leak involves the distal duct, percutaneous ultrasound-guided aspiration should be attempted.²⁴ Pseudocysts with proximal major duct injury should be drained endoscopically²⁴ if there is adequate juxtaposition with stomach or duodenum and if there is a visible intraluminal bulge endoscopically and a thin interposing wall (< 10 mm) on imaging.^{48,49} If endoscopic drainage is not feasible, internal surgical drainage as a cystgastrostomy, cystduodenostomy or cystjejunostomy is required.⁵

Conclusion

Injuries to the pancreas are uncommon but may result in considerable morbidity and mortality owing to the magnitude of associated trauma and delay in diagnosis. Prognosis is determined by the cause of the injury, the extent of blood loss, the presence or absence of shock, rapidity of resuscitation, magnitude of associated injuries and nature and site of the pancreatic injury. Early mortality is due to uncontrolled or massive bleeding from associated vascular or visceral injuries.^{52,57} Late mortality is a consequence of infection and multiple organ failure. Neglect of major duct injury may lead to serious complications including fistulas, pseudocyst formation, sepsis, pancreatitis, and bleeding.^{8,83}

Most pancreatic injuries are minor and can be treated by external drainage.⁹ The commonest major injury is a prevertebral laceration of the proximal body or neck of the pancreas which requires a distal pancreatectomy.^{9,19} Major fractures to the right of the portal vein with an intact bile duct are similarly best treated by distal resection. Pancreaticoduodenectomy is reserved for maximal injuries to the head of pancreas and/or duodenum in which salvage or reconstruction is not feasible.² All procedures should include effective drainage of the pancreatic injury. The trend to increasingly conservative surgery for most pancreatic injuries without elaborate enteric anastomoses or obligatory intraoperative pancreatography represents a simplification of past methods and allows preservation of pancreatic tissue without increasing morbidity.^{57,58} With careful assessment of the injury by inspection, pancreatic complications can be reduced without the need for complex resections, enteric diversions and pancreaticoenteric anastomoses.^{83,87}

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