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*Retrospective Cohort Study*

**Surgical Management of High-Grade Pancreatic Injuries: Insights from a High-volume Pancreaticobiliary Specialty Unit**

Surgical Management of High-Grade Pancreatic Injuries

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## **Abstract**

### **BACKGROUND**

The management of high-grade pancreatic trauma is controversial.

### **AIM**

This study reviews our single-institution experience on the surgical management of blunt and penetrating pancreatic injuries.

### **METHODS**

A retrospective review of records was performed on all patients undergoing surgical intervention for high-grade pancreatic injuries (AAST Grade III or greater) at the Royal North Shore Hospital in Sydney between January 2001 and December 2022. Morbidity and mortality outcomes were reviewed, and major diagnostic and operative challenges were identified.

### **RESULTS**

Over a twenty-year period, 14 patients underwent pancreatic resection for high-grade injuries. Seven patients sustained AAST Grade III injuries and 7 were classified as Grades IV or V. Nine underwent distal pancreatectomy and 5 underwent pancreaticoduodenectomy. Overall, there was a predominance of blunt aetiologies (11/14). Concomitant intra-abdominal injuries were observed in 11 patients and traumatic haemorrhage in 6 patients. Three patients developed clinically relevant pancreatic fistulas and there was one in-hospital mortality secondary to multi-organ failure. Among stable presentations, pancreatic ductal injuries were missed in two-thirds of cases (7/12) on initial CT imaging and subsequently diagnosed on repeat imaging or ERCP. All patients who sustained complex pancreaticoduodenal trauma underwent pancreaticoduodenectomy without mortality. The management of pancreatic trauma is evolving. Our experience provides valuable and locally relevant insights into future management strategies.

## CONCLUSION

We advocate that high-grade pancreatic trauma should be managed in high-volume hepato-pancreato-biliary specialty surgical units. Pancreatic resections including pancreaticoduodenectomy may be indicated and safely performed with appropriate specialist surgical, gastroenterology, and interventional radiology support in tertiary centres.

**Key Words:** Pancreas; Trauma; Injury; Pancreatectomy; Pancreaticoduodenectomy; Damage control surgery

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**Core Tip:** The management of pancreatic trauma is evolving. This study presents a single-centre series of patients undergoing operative management for pancreatic trauma in Australia. We advocate that high-grade pancreatic trauma should be managed in high-volume hepato-pancreato-biliary specialty surgical units.

Penetrating and blunt trauma presentations are associated with varied patterns of injury. There is a growing role for endovascular and endoscopic techniques in the contemporary management of pancreatic trauma. Pancreatic resections including pancreaticoduodenectomy may be indicated and safely performed with appropriate specialist surgical, gastroenterology, and interventional radiology support in tertiary centres.

## INTRODUCTION

Pancreatic injuries are relatively uncommon, but present with significant diagnostic and therapeutic challenges. Occurring in less than 2% of all trauma presentations and 1-12%

of abdominal trauma<sup>[1-3]</sup>, they are associated with morbidity and mortality rates as high as 40%<sup>[4-7]</sup>. Diagnosis is difficult as clinical examination and standard imaging modalities are unreliable in the early phase of injury. As the pancreas is mostly retroperitoneal, initial signs and symptoms are non-specific and are frequently overlooked in the presence of concomitant injuries. Furthermore, blunt and penetrating aetiologies tend to be associated with different patterns of injury. Patients presenting with penetrating trauma or with hemodynamic instability typically proceed to exploratory laparotomy without prior imaging, where pancreatic injuries are evaluated intraoperatively. Meanwhile, stable patients presenting with blunt abdominal trauma tend to be imaged and managed conservatively<sup>[3]</sup>.

Recommendations from the *American Association for the Surgery of Trauma (AAST)*<sup>[8]</sup> consider the location and extent of parenchymal injury and main pancreatic duct integrity as key determinants for definitive management<sup>[6, 9]</sup>. For distal injuries with duct disruption (Grade III), distal pancreatectomy is the mainstay of treatment. The management of proximal injuries (Grades IV and V) is more complex by comparison. In select cases, proximal injuries with no devitalization of the pancreatic head or those involving the duodenum and ampulla may be managed with external drainage. More commonly, combined pancreaticoduodenal injuries tend to require surgical repair, with concurrent duodenal decompression with diversion or pyloric exclusion procedures. In exceptional circumstances, Whipple's resection or pancreaticoduodenectomy may be indicated where repair is not feasible.

Despite these pathways, the management of high-grade pancreatic injuries is debated, especially in patients with haemodynamic instability. In modern trauma management, those who are critically injured typically proceed to damage control surgery with staged reconstruction<sup>[10, 11]</sup>. This involves a laparotomy with the primary objective of haemorrhage and contamination control, with return to theatre for definitive repair once physiological stabilisation has been achieved. This has been the preferred approach as definitive surgery in the presence of deranged physiology in the acute setting has historically been associated with adverse outcomes. As such, the

trauma pancreaticoduodenectomy is typically performed as a two-stage procedure, with resection performed at the initial laparotomy followed by completion of anastomoses at reoperation within 48 h<sup>[12]</sup>. Despite limited evidence, this has been widely adopted due to the perceived risk of increased morbidity and mortality associated extensive reconstruction at index laparotomy. However, delayed definitive management is not without major complications, which would favour immediate reconstruction where it can be safely achieved.

Due to its rarity, the management of high-grade pancreatic trauma is not standardised, and retrospective cohort and observational studies are invaluable in informing current standards of care. The literature consists predominantly of studies conducted in regions such as North America and South Africa, where penetrating abdominal trauma occur with high prevalence. However, blunt abdominal trauma is more common than penetrating trauma in Australasian centres. While pancreatic injuries are estimated to occur in 20-30% of penetrating abdominal trauma, they are observed in less than 2% of blunt trauma cases worldwide<sup>[13]</sup>. Furthermore, trauma services are not centralised in Australian healthcare settings. These regional differences are likely to have important implications for patient management and outcomes.

This study reviews the experience of a high-volume hepato-pancreato-biliary specialty unit within a low-volume trauma centre in Australia. Our findings aim to provide valuable and locally relevant insights into the management of pancreatic trauma, providing a compelling argument for single stage pancreatic trauma management in units that perform a high volume of elective hepato-pancreato-biliary procedures.

## **MATERIALS AND METHODS**

Following district ethics approval, a retrospective review of records was conducted for all patients presenting to a single tertiary centre who required pancreatectomy for high-grade pancreatic injuries (AAST Grade III or greater) from 2001-2022.

Patients were identified from a prospectively maintained database. Patient demographics (age and sex), injury characteristics (mechanism and associated injuries) and clinical data, pertaining to the initial presentation (haemodynamic stability and GCS score on admission), diagnostic details (investigations and findings), surgical procedures, and morbidity and mortality outcomes were extracted. Pancreatic injuries were graded according to the American Association for Surgery of Trauma (AAST) Organ Injury Scale<sup>[8]</sup>. Descriptive statistical analyses were performed on using SPSS version 28.0 (IBM Corporation, Armonk, NY).

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## RESULTS

### *Patient cohort and injury characteristics*

From January 2001 to December 2022 a total of 14 patients (median age 23 years, 8/14 male) underwent pancreatectomy following blunt ( $n=11$ ) and penetrating ( $n=3$ ) trauma. Nine underwent distal pancreatectomy and 5 underwent Whipple's resection. Seven patients sustained AAST Grade III injuries and 7 were classified as Grades IV to V, involving proximal injuries. Demographic and clinical characteristics of this study cohort are summarised in Table 1. The median length of stay was 15.3 days (range 3.1–40.4). Pancreatectomy-specific complications occurred in 7 patients, including intraabdominal sepsis ( $n=4$ ) and clinically-relevant pancreatic fistula ( $n=3$ ). There was one in-hospital mortality.

### *Blunt trauma*

Among the patients presenting with pancreatic injury associated with blunt abdominal trauma, the mean age was 20 years (range, 17–38) and 7 patients were male. Seven patients were classified as AAST Grade III and 4 as Grade IV. The most common cause of blunt injury was motor vehicle accidents ( $n=6$ ). All but one were associated with major organ injuries requiring surgical intervention, including injury to the liver,

spleen, kidneys, and small bowel. Two patients sustained additional injury to major vascular structures, including transection of the thoracic aorta and renal arteries. Three patients were hemodynamically unstable at the time of presentation and proceeded to surgery on the day of injury, of which 2 underwent damage control laparotomies. Pancreatic injuries were identified on CT performed *en route* to theatre in one case and intraoperatively in the other. Among stable presentations, the median injury-to-surgery time was 3.5 days. Ten patients were investigated with imaging prior to surgery; pancreatic injury was missed in 5 cases and subsequently detected on repeat imaging. Grades III and IV were definitively diagnosed by initial CT ( $n=3$ ); delayed CT ( $n=3$ , ranging from 2-30 days from injury) MRCP ( $n=3$ ); ERCP ( $n=1$ ); and intraoperatively ( $n=1$ ). Among patients managed for blunt trauma, 9 proceeded to DP and 2 to PD. Two patients developed major postoperative complications and there was one in-hospital mortality.

### ***Penetrating trauma***

Among patients presenting with penetrating trauma, the mean age was 32 years (range, 26-51), with 2/3 patients being female. Two patients sustained knife trauma, and one a gunshot injury. All involved proximal injuries to the head of the pancreas. Two were classified as AAST Grade V injuries, involving major disruption of the pancreatic head combined with duodenal injury. All had associated injuries to solid organs and major vascular structures. Two were investigated with CT imaging prior to surgery. All penetrating injuries were managed with PD with immediate reconstruction at index laparotomy. Major complications were reported in 2 cases, and there were no mortalities.

## **DISCUSSION**

Fourteen trauma presentations proceeded to pancreatic resection over a 20-year period at our tertiary centre. Overall, there was a predominance of blunt aetiologies (11/14), with 7 patients sustaining AAST Grade III injuries and 7 sustaining Grades IV or V. Nine underwent distal pancreatectomy and 5 proceeded to pancreatoduodenectomy.

### *Morbidity and mortality*

Our morbidity and mortality rates are consistent with previous reports from the UK<sup>[14]</sup>, Asia<sup>[15]</sup>, and Australia<sup>[16]</sup>. This is likely due to the predominance of blunt injuries (11/14), with penetrating trauma comprising a minority of cases in this series (3/14). Motor vehicle accidents represented the prevailing mechanism of the blunt aetiologies (6/11), while penetrating pancreatic injuries were most frequently sustained by self-inflicted stabbings (2/3). Based on published data from American and South African centres, penetrating injuries are more common due to higher prevalence of shootings and stabbings<sup>[17-20]</sup>, occurring in 48%–81% of cases in the US<sup>[21]</sup> and 53-72% in South Africa<sup>[22, 23]</sup>.

For high-grade pancreatic injuries, morbidity and mortality rates have been reported to be as high as 40%<sup>[24, 25]</sup> and 60%<sup>[26-28]</sup> respectively. Penetrating injuries are associated with higher mortality compared to blunt injuries, with comparable morbidity. The high mortality associated with penetrating injuries is due to concomitant vascular and solid organ injury; up to 90% of penetrating pancreatic injuries have associated intra-abdominal injury, most commonly involving the liver, large intestine, and major vessels<sup>[29]</sup>. In this series, 11/14 were associated with additional intra-abdominal injuries and 6/14 with vascular injury. We report one mortality following blunt abdominal trauma from multiorgan failure and none resulting from penetrating trauma.

Morbidity associated with pancreatic injury is attributed primarily to pancreas-specific complications, which are critically determined by the involvement of the main pancreatic duct. Pancreatic fistulae occur most frequently, with incidence rates of up to

50%. Other major complications include the formation of pseudocysts, peripancreatic collections and abscess, and post-traumatic pancreatitis<sup>[13, 30]</sup>. In this series, major complications occurred in 7/14 of cases, which involved intraabdominal sepsis and pancreatic fistulae (Table 1).

### ***Diagnostic challenges - Blunt trauma***

In our series, 10/14 patients sustained blunt trauma and were haemodynamically stable at the time of their presentation. There are several challenges pertaining to the initial management in such cases. While helical CT imaging represents the best non-operative modality for the investigation of intraabdominal injuries, the ability to evaluate pancreatic injury is limited in the acute phase. Early radiological findings tend to be subtle and non-specific, such that up to 40% of initial CT scans for patients with pancreatic injuries have false negative results<sup>[31, 32]</sup>. In our series, ductal injury was missed in 7/10 patients presenting with blunt trauma who underwent investigation with CT imaging. These were subsequently diagnosed on repeat CT or endoscopic retrograde pancreatography (ERCP). Disruption to the main pancreatic duct is recognized as the most important prognostic factor in patients sustaining pancreatic trauma and is estimated to occur in over one third of cases<sup>[17, 33]</sup>. A high index of suspicion should therefore be maintained; repeat imaging with CT or early use of MRCP or ERCP should be considered where there is clinical suspicion for ductal involvement, in the presence of persistent abdominal pain, serum hyperamylasemia, or when initial CT is equivocal<sup>[34]</sup>.

### ***Haemorrhage control - Penetrating trauma***

All penetrating injuries in this series involved major vascular structures. Penetrating injuries to the pancreas are often complicated by concurrent injury to the abdominal aorta, inferior vena cava (IVC), and portal vein. The clinical presentation of such cases

can be highly variable. Patients sustaining venous haemorrhage into the minimally distensible retroperitoneal space may be stable due to haematoma-induced tamponade at presentation<sup>[35, 36]</sup>, with no overt clinical signs or symptoms until a substantial amount of blood has been lost. These presentations should be cautioned for potential sudden decompensation. In contrast, free intraperitoneal haemorrhage typically induces haemodynamic shock, necessitating urgent laparotomy for haemorrhage control.

Surgically, haemorrhage associated with pancreatic proximal injuries are harder to manage than those with the body and tail; the splenic artery and vein, coursing superiorly/posteriorly to the pancreatic body and tail, are readily accessed and controlled<sup>[37]</sup>. In contrast, combined pancreaticoduodenal injuries are often associated with damage to the portal vein, IVC, and mesenteric vessels, where haemorrhage control and stabilisation take precedence over resection or reconstructive attempts. In this series, the emerging role of endovascular technologies in haemorrhage control and resuscitation is evident. For 2 patients, angiographic embolization was employed to control intraabdominal haemorrhage resulting from injuries to the gastroduodenal and renal arteries respectively. In one earlier case, cross-clamping of the proximal aorta was performed at damage control laparotomy. Currently, resuscitative endovascular balloon occlusion (REBOA) provides a minimally invasive alternative in many centres for non-compressible truncal haemorrhage<sup>[38, 39]</sup>. The endovascular approach may offer the advantage of expedient control without the need for extensive dissection to the aortic hiatus, which can be technically challenging. Its increasing use has been supported by evidence of improved survival outcomes over traditional approaches<sup>[40-42]</sup>.

### *Staged vs immediate reconstruction – Complex proximal injuries*

Overall, the evidence-base for decision making in the management of complex high-grade injuries is limited<sup>[1]</sup>. Controversy still surrounds pancreaticoduodenectomy in the trauma setting, <sup>2</sup> with only a small number of single-centre retrospective studies

published over the last two decades<sup>[43]</sup>. The emergency pancreaticoduodenectomy is performed in less than 1% of high-grade traumatic injuries, with previous studies reporting prohibitive mortality rates<sup>[44-46]</sup>. While immediate resection is typical for injuries to the pancreatic body and tail, resections for proximal injuries of the pancreatic head and duodenum are usually performed as part of damage control surgery with staged reconstruction. Within our series, all trauma patients proceeding to pancreaticoduodenectomy involved reconstruction at index laparotomy with favourable outcomes. Two of 5 cases were complicated by postoperative collections treated with drainage (Clavien-Dindo III) and there were no postoperative mortalities.

Our results contribute to the sparse literature on PD in the trauma setting. In a recent systematic review, de Carvalho *et al.* compared outcomes for two-staged *vs* one-staged approach to PD for high-grade trauma<sup>[47]</sup>. Their review of the literature until 2020, comprising of data from 149 patients submitted to PD for AAST Grade IV and V pancreatoduodenal injuries, reported a mortality rate of 28.2%. Subgroup analysis comparing outcomes for staged and immediate reconstruction approaches based on haemodynamic status showed no significant difference in mortality for unstable patients, with rates of 38.7% and 34.2% respectively. For stable patients, one-stage PD was exclusively performed, and this was associated with a mortality rate of 14.6%.

While a staged approach has traditionally been favoured over immediate reconstruction for the critically injured and unstable patient, there is increasing evidence for the safety of one-staged PD in experienced centres<sup>[12, 47]</sup>. In the largest single-centre cohort study to date, Krige *et al.* compared the outcomes of patients who underwent PD for complex pancreatic injuries ( $n=14$ ) to those who underwent an initial damage control operation prior to definitive surgery ( $n=5$ )<sup>[12]</sup>. The results of this study suggest that PD may be safely achieved in the presence of specialist multidisciplinary hepato-pancreato-biliary care. Our experience has similarly demonstrated favourable outcomes in a cohort of 5 patients presenting with mixed aetiologies, of whom 2 were unstable at the time of presentation. It is well-established that delayed definitive management predisposes to increased morbidity; the development of pancreatic fistulae

predisposes to pseudoaneurysms formation and secondary haemorrhage, peritonitis, intraabdominal collections, and sepsis<sup>[48]</sup>. Thus, where the clinical status of the patient and surgical expertise permits, immediate reconstruction should be considered for proximal pancreatic injuries.

### *Model of care*

Conducted within one of the highest-volume hepato-pancreato-biliary surgical units in Australia, this study is uniquely placed to evaluate complex pancreatic resections in the trauma setting. In high-volume trauma centres, as in North America or South Africa, these presentations are typically managed by a dedicated team of trauma surgeons<sup>[49, 50]</sup>. In low-volume trauma centres, multiple subspecialty teams are often involved, with one coordinating acute surgical care<sup>[51]</sup>. In such a centre, these results show that pancreatic can be safely managed with the support of surgical subspecialty, gastroenterology, and interventional radiology services. Patients presenting with high-grade trauma may therefore benefit from transfer to tertiary hepato-pancreato-biliary centres, either acutely or following their initial management by acute general surgical and trauma teams.

### *Strengths and limitations*

Despite a modest sample size, this series captures the evolving practices in trauma management and the impact of concurrent advancements in surgical techniques over twenty years. Our cohort further represents a patient population that has been underrepresented in the literature. Several limitations are inherent to its single-centre retrospective design, lack of data on long-term outcomes and bias to institutional practice. Finally, patient outcomes and interventions were not stratified by injury severity or by other coexisting injuries. Given the variability of pancreatic trauma

presentations, prospective studies are needed to substantiate recommendations on management of high-grade pancreatic injuries.

## **CONCLUSION**

This study presents a single-centre series of patients undergoing operative management for pancreatic trauma in Australia. Our experience provides locally relevant insights into the future management of penetrating and blunt pancreatic injuries. There is a growing role for minimally invasive techniques, including endovascular control of traumatic haemorrhage and interventional endoscopy in the diagnosis and management of pancreatic ductal disruption. Finally, in contrast to previous publications, we demonstrate that for high-grade pancreaticoduodenal injuries, with adequate expertise supported by modern techniques, resection and reconstruction can be safely achieved with favourable outcomes by high-volume specialist pancreatic surgeons.

## **ARTICLE HIGHLIGHTS**

### ***Research background***

The management of high-grade pancreatic trauma is controversial.

### ***Research motivation***

The literature consists predominantly of studies conducted in regions such as North America and South Africa, where penetrating abdominal trauma occur with high prevalence. However, blunt abdominal trauma is more common than penetrating trauma in Australasian centres, and are underrepresented in the literature. While pancreatic injuries are estimated to occur in 20-30% of penetrating abdominal trauma, they are observed in less than 2% of blunt trauma cases worldwide<sup>[13]</sup>. Furthermore, trauma services are not centralised in Australian healthcare settings. These regional differences are likely to have important implications for patient management and outcomes.

### ***Research objectives***

This study reviews the experience of an Australian tertiary referral center, with the aim of providing locally relevant insights into the management of high-grade pancreatic injuries.

### ***Research methods***

A retrospective review of records was performed on all patients undergoing surgical intervention for high-grade pancreatic injuries (AAST Grade III or greater) at a single Australian centre between January 2001 and December 2022.

### ***Research results***

Over a twenty-year period, 14 patients underwent pancreatic resection for high-grade injuries. Seven patients sustained AAST Grade III injuries and 7 were classified as Grades IV or V. Nine underwent distal pancreatectomy and 5 underwent pancreaticoduodenectomy. Overall, there was a predominance of blunt aetiologies (11/14). Concomitant intra-abdominal injuries were observed in 11 patients and traumatic haemorrhage in 6 patients. Three patients developed clinically relevant pancreatic fistulas and there was one in-hospital mortality secondary to multi-organ failure. Among stable presentations, pancreatic ductal injuries were missed in two-thirds of cases (7/12) on initial CT imaging and subsequently diagnosed on repeat imaging or ERCP. All patients who sustained complex pancreaticoduodenal trauma underwent pancreaticoduodenectomy without mortality.

### ***Research conclusions***

Penetrating and blunt trauma presentations are associated with varied patterns of injury. The management of pancreatic trauma is evolving; there is a growing role for endovascular and endoscopic techniques in the contemporary management of pancreatic trauma. Pancreatic resections including pancreaticoduodenectomy may be

indicated and safely performed with appropriate specialist surgical, gastroenterology, and interventional radiology support in tertiary centres.

*Research perspectives*

We advocate that high-grade pancreatic trauma should be managed in high-volume hepato-pancreato-biliary specialty surgical units.

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