

Blunt High-Grade Pancreatic Injury in Children: A 20-Year Experience in Two Pediatric Surgical Centers

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ABSTRACT

Background: Pancreatic trauma is uncommon in pediatric patients and presents diagnostic and therapeutic challenges. While non-operative management (NOM) of minor pancreatic injuries is well accepted, the management of major pancreatic injuries remains controversial.

Objectives: To evaluate management strategies for major blunt pancreatic injury in children.

Methods: Data were retrospectively collected for all children treated for grade III or higher pancreatic injury due to blunt abdominal trauma from 1992 to 2015 at two medical centers. Data included demographics, mechanism of injury, laboratory and imaging studies, management strategy, clinical course, operative findings, and outcome.

Results: The cohort included seven boys and four girls aged 4–15 years old (median 9). Six patients had associated abdominal (mainly liver, n=3) injuries. The main mechanism of injury was bicycle (handlebar) trauma (n=6). Five patients had grade III injury and six had grade IV. The highest mean amylase level was recorded at 48 hours after injury (1418 U/L). Management strategies included conservative (n=5) and operative treatment (n=6): distal (n=3) and central (n=1) pancreatectomy, drainage only (n=2) based on the computed tomography findings and patient hemodynamic stability. Pseudocyst developed in all NOM patients (n=5) and two OM cases, and one patient developed a pancreatic fistula. There were no differences in average length of hospital stay.

Conclusions: NOM of high-grade blunt pancreatic injury in children may pose a higher risk of pseudocyst formation than OM, with a similar hospitalization time. However, pseudocyst is a relatively benign complication with a high rate of spontaneous resolution with no need for surgical intervention.

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and the spectrum of injuries is wide, ranging from contusions and minor lacerations to complete transection of the main pancreatic duct. Injuries involving ductal disruption are defined as high grade (III–V) on the Organ Injury Scale and are relatively rare [3]. It is generally accepted that hemodynamically stable children with minor pancreatic injuries may be managed conservatively, as practiced for other solid organ injuries in the pediatric population. However, the management strategies for major pancreatic duct injuries are still diverse and controversial [3,4].

The aim of this study was to review the experience in managing major pancreatic injury in children as a result of blunt abdominal trauma in two pediatric medical centers.

PATIENTS AND METHODS

A retrospective descriptive analysis was conducted of all children who presented at Schneider's Children Medical Center and Meir Medical Center between 1992 and 2015 with pancreatic injury grade III or higher due to blunt abdominal trauma. The following data were collected from the medical files: demographics, mechanism of injury, presenting symptoms, signs on physical examination, findings on laboratory and imaging studies, management strategy, length of hospital stay, complications, and outcome. The study was approved by the local ethics committee.

Analysis of variance with repeated measures and Fisher's exact test were used for statistical analysis. The study protocol was approved by the local institutional review board with waiver of informed consent.

RESULTS

The demographic and clinical characteristics of patients are described in Table 1 and Table 2. The cohort included 11 children (7 boys and 4 girls) who were 4 to 15 years old (median 9 years). The mechanism of injury was variable: bicycle accident (handlebar injury, n=6), fall from height (n=1), skiing accident (n=1), crush injury (n=2, wall collapse, bookshelf collapse), and a direct blow while playing (n=1). The injury was limited to the pancreas in five patients, four of them due to handlebar trauma,

Pancreatic injury secondary to blunt abdominal trauma is uncommon in the pediatric population (0.2–12%) [1]. The leading mechanism of injury is bicycle handlebar trauma [2]

Table 1. Demographics and clinical characteristics

Characteristic	n
Male/Female ratio	7/4
Age, mean (range)	9 years (4–15 years)
Mechanism of injury	
Bicycle accident (handlebar injury)	6
Fall from height	1
Direct blow while playing	1
Wall collapse (crush injury)	1
Bookshelf collapse (crush injury)	1
Skiing accident	1
Isolated pancreatic trauma	5
Associated with other abdominal injury (6)	
Liver	3
Spleen	2
Bowel	2
Kidney	2
Vascular	1
Presentation	
Diffuse abdominal tenderness	9
Vomiting	3
Handlebar sign	6
Hemodynamic instability	2
Injury grade	
III	5
IV	6
Pancreatic duct involvement	
Head	3
Body	4
Tail	4

Figure 1. Handlebar sign in patient 1


while six patients had associated abdominal injuries with diverse mechanisms of injury. The liver was the most common intra-abdominal organ involved in those patients ($n=3$), followed by the spleen, small bowel, and kidney in two patients each. One patient had a portal vein laceration.

Nine patients presented with diffuse abdominal tenderness and three with vomiting. Handlebar sign at the injury site was recorded in all six patients in whom bicycle handlebar trauma was the mechanism of injury [Figure 1].

After initial resuscitation and computed tomography (CT) scan, patient 3 became unstable and was transferred within 1 hour to the operating room. Nine patients presented within 24 hours following the trauma and another patient was primarily managed in another country and referred to our institution 2 months after injury (patient 2, Table 2). The indications for surgery in these patients were hemodynamic instability and associated abdominal injuries.

All patients underwent focused assessment with sonography in trauma (FAST) and CT [Figure 2]. Magnetic resonance cholangiopancreatography (MRCP) was performed in one patient. Pancreatic injury was classified by CT as grade III in five patients and grade IV in six patients. The most prevalent site of pancreatic duct involvement was the tail ($n=4$) followed by the body ($n=4$) and head ($n=3$).

No significant correlation was found between amylase admission levels and grade of injury. The mean amylase level was 392 U/L (30–6474 U/L) at presentation and 902.3 U/L (159–2812 U/L) 24 hours after trauma. The highest mean amylase level (1418 U/L, range 148–2458 U/L) was recorded at 48 hours. ANOVA with repeated measures revealed a significant change in amylase level during the first 10 days after injury. There was an increment from day 1 to day 2, when levels peaked, followed by a steady decline from day 2 to day 8, at which point levels plateaued ($P=0.02$). A second peak was detected in

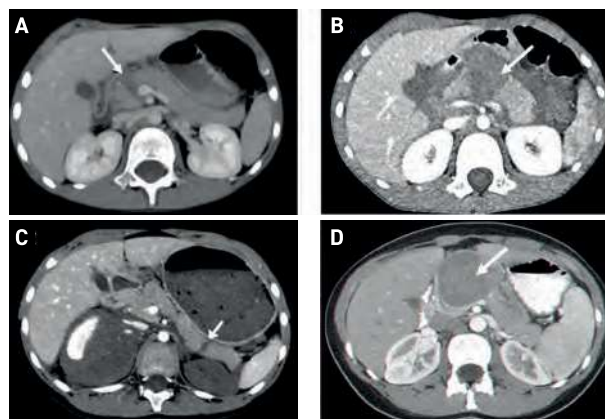
Figure 2. CT images showing [A] patient 1: pancreatic head transection, [B] patient 9: pancreatic body transection, [C] patient 8: pancreatic tail transection, and [D] patient 10: pancreatic mass


Table 2. Clinical characteristics, management, and complications

Patient number	Sex	Age, years	Injury mechanism	Isolated pancreatic trauma	Imaging findings	Grade of injury	Site of duct involvement	Management	Complications
1	Male	6	Bike handlebar	Yes	Pancreatic partial transection, no distention of Wirsung	IV	Head	Conservative*	Pancreatic pseudocyst, resolved
2	Male	12	Bike handlebar	No	Total pancreatic rupture****	IV	Body	(1) Exp lap, lavage and drainage**** (2) Exp lap excision of pancreatic necrotic tissue, drainage of pseudocyst (3) Distal pancreatectomy	Pancreatic pseudocyst, resolved
3	Female	4	Fall from height	No	Pancreas transection, hepatic injury grade 1	III	Tail	Exploratory laparotomy temporary packing and drainage. Relaparotomy 12h later for hemostasis and drainage of pancreatic hematoma**	
4	Female	15	Bike handlebar	No	Peripancreatic hematoma, pancreatic transection with little distention of Wirsung	III	Tail	Conservative*	Pancreatic pseudocyst, resolved
5	Male	9	Bike handlebar	Yes	Complete transection of pancreas, no distention of Wirsung's duct	IV	Body	Conservative*	Pancreatic pseudocyst, resolved
6	Male	15	Skiing accident	No	Transection of distal pancreas, spleen injury grade 1	III	Tail	Conservative*	Pancreatic pseudocyst, percutaneous drainage
7	Male	7	Bike handlebar	Yes	Proximal pancreatic transection	IV	Head	Exploratory laparotomy, peritoneal lavage and drainage	Pancreatic pseudocyst, resolved
8	Male	9	Wall collapse	No	Pneumoperitoneum, vascular damage right kidney, liver laceration, spleen injury grade 1, pancreatic laceration	III	Tail	Distal pancreatectomy	Pancreatic fistula managed conservatively
9	Male	8	Bike handlebar	Yes	Pancreatic transection, hematoma 3 cm	III	Body	Distal pancreatectomy	
10	Female	15	Direct blow to abdomen	Yes	Mass 5.5 cm around pancreas head, discontinuous main duct	IV	Head	Central pancreatectomy***	
11	Female	8	Bookshelf collapse	No	Small liver laceration, transection at pancreatic body	IV	Body	Conservative*	Pancreatic pseudocyst, percutaneous drainage

*Bed rest, nothing by mouth, intravenous fluid administration, nasogastric tube decompression, total parenteral nutrition, intravenous H₂ blockers, analgesia and octreotide

**Urgent relaparotomy due to hemorrhagic shock caused by porta hepatic vascular injury

***Incidental tumor, excision, pancreatic tail anastomosed to posterior wall of stomach

****Initial management in another country 2 months prior

PI = post injury

four patients and was associated with the presence of a pancreatic pseudocyst or fistula. In one patient, despite the development of a pancreatic cutaneous fistula 2 months after injury, serum amylase level showed a single isolated peak and was maintained thereafter within the lower range (80–170 U/l).

Six patients underwent operative management (OM) and five were managed conservatively (non-operative management [NOM]). The time from admission to surgery was variable; 1 hour (n=1), 24 hours (n=1), 48 hours (n=2), 3 days (n=1), and 12 days (n=1). Distal pancreatectomy was performed in three patients (patients 2, 8, 9), central pancreatectomy in one (patient 10), and exploratory laparotomy and drainage in two patients (patients 3, 7). Patient 3 underwent surgery another time for hemodynamic instability caused by a porta hepatis vascular injury. Central pancreatectomy was performed in patient 10 for an incidental mass of the pancreatic body. The distal part was anastomosed to the stomach.

NOM in the remaining five patients included bed rest, nothing by mouth, intravenous fluid administration, nasogastric tube decompression, total parenteral nutrition (TPN), administration of intravenous H₂ blockers, analgesia, and administration of octreotide.

The average length of stay (LOS) in the OM group was 27 days (range 11–39, median 31), and in the NOM group, 26 days (range 25–28, median 27).

Complications included pancreatic pseudocyst (NOM: n=5, OM: n=2) and pancreatic fistula at the drain site (OM: n=1). Patients with complications presented on average 23 days after injury (range 1–60 days, median 21) with symptoms of aggravating relapsing abdominal pain and, in some cases, fever. The diagnosis was made by ultrasound in all patients and additional CT scan in one patient who complained of severe abdominal pain 1 month after trauma (patient 11).

Pancreatic pseudocyst developed in all 5 patients in the NOM group. Three of them resolved spontaneously, and two underwent percutaneous drainage owing to the large size of the cysts (11.5 × 9 cm, patient 6; 9 × 6 cm, patient 11), with no signs of resolution. In the OM group, 3 of the 6 patients had complications. Pseudocyst (n=2) and fistula (n=1) that were managed conservatively. The average pseudocyst size in both the NOM and OM groups was 6.2 × 6 cm (range 2.3 × 2 to 11.5 × 9 cm). There was no mortality in our series.

DISCUSSION

Pancreatic injuries present diagnostic and therapeutic challenges and are associated with significant morbidity and mortality. Nevertheless, there are as yet no practical guidelines for management of such injuries in the pediatric age group. Although several studies have addressed the approach to blunt pancreatic trauma in children, few have concentrated on the optimal management of high-grade injuries involving major duct disruption, which remains controversial [5–7].

These injuries warrant special attention since prognosis is di-

rectly linked to the grade of injury [7,8]. In children with high-grade blunt pancreatic injury, the high overall morbidity (30–50%) and mortality (10–30%) are attributed mainly to associated injuries involving the liver, porta hepatis, and duodenum and to incorrect injury grading [9,10]. While in poly-trauma, pancreatic injuries may be masked by signs of other severe abdominal injuries, pancreatic injury may be initially unnoticed, as in patient 8, due to the deep retroperitoneal location of the pancreas [9].

The most common mechanism of injury was bicycle handlebar trauma, in correlation with previous reports [2,5,7]. In these cases, the fixed retroperitoneal pancreas is compressed by the crushing force applied to the upper abdomen between the handlebar and the posteriorly located vertebral bodies. Bike handlebar trauma is usually localized and less likely to involve injuries to other intra-abdominal organs than other mechanisms of pancreatic injury. Nevertheless, it is important that all patients be thoroughly investigated for additional injuries, regardless of the mechanism. The most frequent organs injured in our cohort were the liver, spleen, and intestines. Hemodynamic instability at admission was linked to associated abdominal injuries.

The majority of our patients (n=9/11) presented within 24 hours following trauma and were diagnosed early. Delayed diagnosis of blunt pancreatic injury has been associated with poor prognosis and higher morbidity and mortality and often occurs in patients with vague and nonspecific symptoms [1,5,11,12]. Grading of pancreatic injury is based on CT imaging [5,11], which remains the most widely available study, with a reported sensitivity of 65–80% and specificity of 80% [9,10,13,14]. Although MRCP has higher sensitivity in identifying the pancreatic duct, it was not superior to CT for determining duct integrity [15].

In our study, CT scan identified ductal laceration in 10/11 patients. Patient 8 imaging findings were interpreted as a grade I injury, and a transection of the pancreatic duct was revealed only during surgery that was performed to control ongoing bleeding.

Serum amylase level is an unreliable screening tool for pancreatic injury. Initial amylase values do not correlate with the severity of pancreatic injury [16], may be normal in up to 40% of patients [9,17], and can be attributed to other abdominal injuries, mainly bowel. In addition, an increase in amylase levels may be detected only 3 hours after injury [16,18]. Jobst et al. [19] noted a correlation between amylase levels and injury severity, others found no correlation between initial or peak enzyme levels and injury grade [20].

In the present study, no correlation was found between admission amylase levels and grade of injury. However, we observed a post-injury increment in amylase levels at 8 hours and 24 hours after injury and a peak at 48 hours. Furthermore, in the late phase after injury, the development of complications such as pseudocyst or pancreatic cutaneous fistula correlated with a second peak in amylase levels in half of the patients. Canty and Weinman [16] suggested that amylase levels of 1100 IU/dl or higher may be considered a sign of pseudocyst formation. These

patients present with relapse or worsening of abdominal pain, anorexia, vomiting, and sometimes a palpable upper-abdominal mass. Therefore, clinical deterioration that occurs 2–4 weeks following trauma and is accompanied by increased amylase levels warrants further investigation by imaging studies.

Concerning management strategy, Naik-Mathuria and colleagues [8] proposed a management pathway for high-grade pancreatic injuries in pediatric patients. In their cohort of 86 patients, 73% of injuries were grade III, 24% grade IV, and 3% grade V. All patients were treated with NOM. Several studies have described the advantages of OM for higher grade pancreatic injuries, namely fewer complications, shorter time to return to oral feeding, and shorter LOS [1,5,7,16,17]. Conversely, NOM has been associated with increased risk of pseudocyst and pancreatic fistula [21]. In the National Trauma Bank Review, among patients with duct involvement, no statistically significant differences were found in injury characteristics or outcomes between those treated surgically or conservatively, while LOS was significantly higher in the OM group (median 11 vs. 7 days) [7].

In terms of LOS, we found no difference between the NOM group (average 27 days, median 31 days) and the OM group (average 26 days, median 27 days). Those with a longer LOS had severe trauma with associated abdominal injuries. Pseudocyst, the main complication, developed in all patients in the NOM group and in one-third of the patients in the OM group. This complication presented clinically with worsening of abdominal pain and increased amylase levels.

Although non-statistically significant, we observed a higher rate of pseudocyst formation in the NOM group. The high prevalence of pseudocyst formation with conservative management in this and earlier studies reemphasizes the importance of a low threshold of suspicion for this complication to timely diagnostic testing and detection. Patients with recurrent abdominal pain coupled with raised amylase levels should be thoroughly assessed for pseudocyst [22]. In a multicenter, retrospective review of 100 children treated with NOM following blunt pancreatic injury, 42% developed organized fluid collections. Among them, 64% were observed and 36% underwent drainage. No significant differences were recorded between the two groups in terms of TPN use, hospital length of stay, time to tolerate regular diet, or need for definitive procedure [20].

The average time from injury to diagnosis of complications in our cohort was 23 days (including peripancreatic fluid collections). In the OM group, the complications resolved following conservative management. In the NOM group, three of five pseudocysts resolved spontaneously and two, which were relatively large, were treated by percutaneous drainage. Canty and Weinman [16] reported spontaneous resolution of pseudocyst in 55% of cases. Pseudocyst following traumatic injury is amenable to conservative management [23], as in our study.

Endoscopic retrograde cholangiopancreatography (ERCP) is valuable in selected cases of major pancreatic injury as both a

diagnostic and therapeutic tool due to its high sensitivity [1]. It offers the possibility of improving drainage by performing sphincterotomy or placing pancreatic stents across duct injuries and provides definitive treatment for some patients. In a retrospective study of nine patients treated for pancreatic main (n=7) and hepatic (n=2) duct injuries secondary to blunt abdominal trauma, ERCP was diagnostic in three patients and therapeutic in five [24].

Despite the efficacy of ERCP for direct visualization of ductal injury, it is still not widely used in the pediatric population mainly because it requires the availability of highly qualified personnel to perform the technically difficult procedure on emergent basis. Other concerns are post-procedure complications, mainly pancreatitis, cholangitis and duodenal perforation [9]. In a retrospective multicenter study of pediatric patients with blunt pancreatic trauma who were managed nonoperatively, early ERCP intervention had similar outcomes to patients who were only observed in terms of LOS and time on TPN [25].

CONCLUSION

The optimal management of high-grade blunt pancreatic injuries in children is debatable. Although the rate of pseudocyst formation is higher with nonoperative management, the majority resolves spontaneously and the rest require drainage with no need for laparotomy. Hospital LOS is the same for both strategies. A multicenter randomized prospective trial is needed to establish the optimal approach to higher grade pancreatic injuries.

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Capsule

Organoids regenerate human bile ducts

Bile ducts carry bile from the liver and gall bladder to the small intestine, where it aids digestion. Cholangiocytes are epithelial cells that line bile ducts and modify bile as its transported through the biliary tree. Chronic liver diseases involving cholangiocytes account for a large fraction of liver failure and the need for liver transplantation. Because liver donors are in short supply, **Sampaziotis** and colleagues used organoid technology to develop a

cell-based therapy using human tissue. Cholangiocyte organoids were transplanted into the intrahepatic ducts of deceased human donor livers undergoing ex vivo normothermic perfusion. The livers could be maintained for up to 100 hours, and the transplanted organoids engrafted, exhibited function, and could repair bile ducts.

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Capsule

Microbiome connections with host metabolism and habitual diet from 1,098 deeply phenotyped individuals

The gut microbiome is shaped by diet and influences host metabolism; however, these links are complex and can be unique to each individual. **Asnicar** and colleagues performed deep metagenomic sequencing of 1203 gut microbiomes from 1098 individuals enrolled in the Personalised Responses to Dietary Composition Trial (PREDICT 1) study, whose detailed long-term diet information, as well as hundreds of fasting and same-meal postprandial cardiometabolic blood marker measurements were available. They found many significant associations between microbes and specific nutrients, foods, food groups, and general dietary indices, which were driven especially by the presence and diversity of healthy and plant-based foods. Microbial biomarkers of obesity were reproducible across external publicly available cohorts and in agreement

with circulating blood metabolites that are indicators of cardiovascular disease risk. While some microbes, such as *Prevotellacopri* and *Blastocystis* spp., were indicators of favorable postprandial glucose metabolism, overall microbiome composition was predictive for a large panel of cardiometabolic blood markers including fasting and postprandial glycemic, lipemic, and inflammatory indices. The panel of intestinal species associated with healthy dietary habits overlapped with those associated with favorable cardiometabolic and postprandial markers, indicating that our large-scale resource can potentially stratify the gut microbiome into generalizable health levels in individuals without clinically manifest disease.

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