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RESEARCH

Non-operative versus operative management of high-grade pancreatic trauma in children: lessons from a Belgian long-term follow-up cohort

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Abstract

Pancreatic trauma in children is rare but may result in severe complications, particularly in injuries involving duct transection. Optimal management—surgical versus conservative—remains debated. We aimed to compare long-term complications between both management approaches. This multicenter retrospective and prospective study analyzed children (< 18 years) with grade III–V pancreatic trauma treated between 2009 and 2019 at Belgian Level 1 trauma centers. Patient characteristics, management, and outcomes were assessed with long-term follow-up. Among 31 patients, 35% underwent surgery and 65% were managed conservatively. Pseudocyst formation was significantly higher in the non-operative group (85%) vs. surgical (18%, $p = 0.0013$). Long-term complications included pancreatic atrophy (35%), recurrent pancreatitis (19%), and exocrine dysfunction; no endocrine insufficiency was reported.

Conclusion: Surgical and conservative management of grade III and IV trauma are safe for pediatric pancreatic trauma, though pseudocysts are common in the conservative approach and often require endoscopic drainage. Ongoing follow-up is essential to monitor for long-term complications such as pancreatitis and pancreatic atrophy.

What is Known:

- *Non-operative management of pancreatic trauma with complete duct transection is associated with a higher risk of pseudocyst formation compared with operative management.*
- *Long-term comparative studies on outcomes of patients with pancreatic trauma and complete pancreatic duct transection are scarce, limited in time, and often retrospective.*

What is New:

- *Regardless of the initial management, children with grade III, IV, and V pancreas trauma are at risk to develop very long-term complications such as pancreatitis, pancreas atrophy, and exocrine insufficiency; clinical follow-up is therefore warranted.*

Keywords Pancreatic trauma · Blunt trauma · Children · ERCP · Pancreatic surgery · Pancreatic atrophy · Pancreatitis · Exocrine insufficiency

Introduction

Pancreatic trauma is a rare condition in children accounting for 3–12% of abdominal injuries, with 15.3–44% of cases involving injuries to other organs [1]. The severity of pancreatic injury is classified into five grades according to the American Association for the Surgery of Trauma (AAST) Organ Injury Scale. Grades III to V are associated with pancreatic duct lesions [2].

The optimal management strategy for AAST grades III–V pancreatic injuries is still being debated. Historically, surgery was the primary treatment approach until conservative management was recognized as a valuable alternative with the advancement of endoscopic techniques. A 2014 systematic review of available retrospective studies found that patients treated non-operatively had similar short- and

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mid-term complication rates (7% vs. 8%), as well as similar total parenteral nutrition (TPN) days and length of stay compared to patients managed surgically. However, conservative management was associated with a higher risk of pseudocyst development (18% vs. 4%) [3]. Recently, a prospective study of children with grade III or IV pancreatic trauma managed non-operatively further showed that following a predefined clinical pathway [4] could reduce TPN days and pseudocyst drainage—most of which could just be observed—compared to a historical cohort [5].

Few retrospective studies have examined the impact of initial management on long-term complications such as endocrine and exocrine insufficiency, pancreatitis, ductal strictures, and pancreatic atrophy. Existing studies are limited by small sample sizes and short follow-up periods [1, 6].

The present study aims to retrospectively and prospectively analyze the long-term outcomes of children with grade III to V pancreatic trauma who were managed at level-1 trauma centers in Belgium.

Material and methods

Study population

The Belgian Pancreatic Club invited its members, who are all part of level-1 trauma centers in Belgium, to submit data on children (under 18 years old) diagnosed with blunt pancreatic trauma and duct transection between January 2009 and December 2019. Pancreatic injuries were classified according to the guidelines of the AAST [2]. To ensure comprehensive capture of eligible patients, institutional clinical data warehouses were queried using diagnosis or procedural codes (ICD-9). The study was approved by the Cliniques universitaires Saint-Luc/UCLouvain Ethics Review Board (#2018/18OCT/394), following approval from the local ethics committees of all the participating centers (Ghent University Hospital, UZ Leuven, University Hospital Antwerp, UZ Brussel, HUB Erasme, CHC Liège and CHU Liège-Citadelle). It was conducted in compliance with the Declaration of Helsinki.

Retrospective review and prospective follow-up

The patients' medical records were reviewed and the following data was collected: age at the time of trauma, time elapsed between trauma and diagnosis of pancreatic injury, sex, mechanism of injury, AAST trauma grade, clinical symptoms, laboratory results, imaging studies and their findings, initial management (non-operative/conservative versus operative/surgical management), therapeutic interventions (e.g., somatostatin, octreotide, endoscopic ultrasound (EUS), endoscopic retrograde cholangiopancreatography (ERCP), surgery), and their indication, complications, readmissions, and length of stay for initial and further admissions. Endocrine function was assessed using fasting glucose, Hb1Ac and/or HOMA-OGTT, while exocrine function was assessed clinically and/or using serum trypsinogen, fecal elastase, and/or the coefficient of fat malabsorption on a 72-h stool collection. Clinical outcomes (e.g., need for reintervention, pancreatitis, exocrine and endocrine function, and pancreatic atrophy) were also retrieved. These outcomes were defined according to guidelines [7–9]. For atrophy, we evaluated the thickness of the parenchyma by deducting the main pancreatic duct directly before and after the traumatic area on successive MRI or CT images [10].

The decision to pursue initial operative management or patient observation was left to the discretion of each participating center and was mainly guided by local surgical and/or endoscopic expertise, and institutional protocols.

Statistical analysis

Statistical analyses were performed using GraphPad Prism Software (San Diego, CA, USA) and SPSS 24.0 (Chicago, IL, USA). Descriptive data for continuous variables were reported as either mean ± standard deviation and 95% confidence intervals or median with range, as appropriate. Continuous variables with a non-normal distribution according to the Anderson–Darling test were normalized using Box Cox transformation. Univariate and multivariate logistic regression and chi-squared tests with Cook's correction for small values were used to show potential correlations between trauma and outcomes.

Trauma grades IV and V were combined for analysis.

Results

Patient characteristics

Between January 2009 and December 2019, 31 patients were followed in one of seven level-1 pediatric trauma centers in Belgium. They had sustained grade III–V pancreatic trauma with duct transection. The median age at trauma diagnosis was 9.2 years (range: 2.8–17); the majority were boys ($n = 18/28$, 64.3%). Eighteen children (58.1%) had a grade III injury, eleven (35.5%) had a grade IV injury, and two (6.5%) had a grade V injury. The mechanism of injury included bicycle accidents ($n = 20$, 64.5%), motor vehicle collisions ($n = 5$, 16.1%), falls ($n = 4$, 12.9%), and sports injuries ($n = 2$, 6.5%). Twelve children (38.7%) had at least one associated organ injury (Table 1).

Table 1 Patient characteristics and management strategy

	Global cohort	Conservative	Surgery	*p*-value		95%CI
N	31	20	11			
Age at trauma (y) Median (range)	9.2 (2.8–17)	8.3 (2.8–15.8)	12.9 (7–17)	0.0011	Beta 8.36	2.67–26.15
Female	10/28 (35.7%)	6/19 (31.6%)	4/9 (44.4%)	0.53	OR 1.73	0.32–9.37
Isolated trauma	19 (61.3%)	13 (65%)	6 (54.5%)	0.59	OR 1.55	0.32–7.25
Grade of trauma						
III	18 (58.1%)	14 (70%)	4 (36.4%)			
IV + V	13 (41.9%)	6 (30%)	7 (63.6%)			
Length of stay (d) Median (range)	17 (2–86)	17 (2–75)	18 (12–86)	0.36	Beta 1.19	0.83–1.73
Duration						
NPO (d)	4 (0–14)	3.5 (0–14)	4 (2–14)	0.29	Beta 1.22	0.85–1.75
TPN (d)	0 (0–24)	0 (0–24)	5 (0–16)	**	**	**
Need readmission	13/27 (48.1%)	11/19 (57.9%)	2/8 (25%)	0.13	OR 0.24	0.03–1.49
Follow-up duration (y) Median (range)	8.4 (2.2–17.1)	8.1 (2.2–17.1)	11 (3.5–16.9)	0.21	Beta 2.95	0.58–14.9
Complications						
Pseudocyst	19 (61.3%)	17 (85%)	2 (18.2%)	0.0013	OR 0.05	0.007–0.34
Pancreatitis	6 (19.4%)	3 (15%)	3 (27.3%)	0.25	OR 3.25	0.4–23.6
ExoPI	2* (6.4%)	1 (5%)	1* (9%)	0.19	OR 0.21	0.03–6.9
EndoPI	1* (3.2%)	0	1* (9%)			
Atrophy	8/23 (34.8%)	7/16 (43.8%)	1/7 (14.3%)			

Beta beta-coefficient, *d* days, *OR* odds ratio, *PI* pancreatic insufficiency, *y* years

*patient underwent total pancreatectomy; ** beta coefficient cannot be calculated as the distribution is atypical

Initial pancreatic trauma management

Eleven patients ($n = 11/31$, 35.5%) were initially managed surgically (Table 1). Surgery was performed after a median of 20 h post-trauma (range: 2–118 h) and guided by hemodynamic instability ($n = 1$ grade V) or ductal injury characteristics ($n = 10$). For grade III trauma, the surgical strategy consisted of suture of the proximal duct with distal pancreatectomy ($n = 1$), drainage of the invisible distal duct on a Penrose drain ($n = 1$), or a two-step intervention with external drainage of the distal duct by a stent, followed a few weeks later by distal pancreatico-jejunostomy ($n = 2$). For grade IV trauma, the surgical strategy consisted of suture of the proximal duct with distal pancreatico-gastrostomy ($n = 2$), distal pancreatico-jejunostomy ($n = 2$), or a two-step intervention with external drainage of the distal pancreatic duct by a stent, followed a few weeks later by distal pancreatico-jejunostomy ($n = 1$). For grade V trauma, one patient required an emergency total pancreatectomy due to organ laceration and uncontrollable bleeding, while another underwent a pancreatico-jejunostomy at the neck site. Somatostatin (3.5 µg/kg/day intravenously) or octreotide (6 mg/day intravenously) was administered postoperatively to all children except those who underwent pancreatico-gastrostomy, for a median duration of 5 days (range: 1–25 days).

Twenty patients ($n = 20/31$, 64.5%) were managed conservatively (Table 1). Seven of these patients, all with grade III trauma, received somatostatin (3.5 µg/kg/day intravenously) or octreotide (6 mg/day intravenously) within the first 24 h post-trauma for a median duration of 8 days (range: 1–25 days). Seven patients underwent ERCP after a median time of 27 days (range: 9–53) from trauma. Two patients underwent sphincterotomy alone (grade III), and five patients underwent an attempt of duct recanalization ($n = 2$ with grade III, and $n = 3$ with grade IV). Unfortunately, duct recanalization failed in all patients due to anatomical particularity not recognized on MRCP ($n = 1$, ansa pancreatica) or due to the inability to cross the cephalic stenosis with a 0.018 mm guidewire ($n = 4$). None of the patients initially managed non-operatively required surgical intervention.

Pancreatic trauma outcomes

The median length of stay for the initial hospitalization was 17 days (range: 2–75 days) in conservative versus 18 days (range: 12–86 days) in surgical management and was significantly correlated in univariate analysis with trauma grade ($p = 0.015$) but not with the presence of polytrauma ($p = 0.097$) or therapeutic approach (conservative vs. surgical; $p = 0.36$) (results of multivariate analysis are provided in Supplementary data 1). Patients were kept nil per os for a

median of 3.5 days (range: 0–14) in the conservative group and 4 days (range: 2–14) in the surgical group; while median total parenteral nutrition was 0 days (range: 0–24) and 5 days (range: 0–16), respectively. Thirteen children ($n = 13/31$, 41.9%) had to be readmitted, of whom nine (69.2%) had grade III trauma (two in the operative group and seven in the non-operative group), and four (30.8%) had grade IV trauma (all in the non-operative group). In the non-operative group, the reasons for readmission were pain related to the development of a pseudocyst ($n = 4$; 2 with grade III and 2 with grade IV). Two patients with grade IV trauma were readmitted for an attempt of duct recanalization by ERCP, which was unsuccessful. Seven other patients were readmitted for elective procedures, including pancreatic stent removal ($n = 5$ with grade III trauma) or second-step surgery for distal pancreatico-jejunostomy ($n = 2$ with grade III trauma).

Short-term complications included hemodynamic instability in two patients with pancreatic laceration (grade IV, $n = 1$ and grade V, $n = 1$), whereas none experienced infectious complications.

Two patients ($n = 2$ grade III) developed a biochemical leakage (ISGPS classification [11]) after pancreatico-jejunostomy that resolved spontaneously.

The main mid-term complication was the development of a pseudocyst ($n = 19/31$ patients, 61.3%), requiring drainage ($n = 13/19$, 68%) and/or treatment with somatostatin/octreotide ($n = 2/19$, 10%). Pseudocysts occurred significantly more frequently in patients who were initially managed non-operatively ($n = 2/11$ operative vs. $n = 17/20$ non-operative; $p = 0.0013$). Symptomatic pseudocyst required EUS-guided drainage with plastic double pig-tail stents or lumen apposing metallic stents (LAMS). This procedure was successfully performed without complications in 13/19 patients (68%) at various times after trauma (range: 9–21 days, median: 14 days).

The median long-term follow-up time for our cohort was 8.4 years (range 2.2–17.1 years). Except for the patient who underwent total pancreatectomy due to grade V trauma, one patient with grade IV trauma managed conservatively exhibited borderline exocrine function, as evidenced by intermittent steatorrhea and low fecal elastase levels (Supplementary data 2). This patient required pancreatic enzyme supplementation with fatty meals (Fig. 1A–C). None of the patients exhibited clinical and/or biological signs of endocrine pancreatic insufficiency (Supplementary data 2). Furthermore, six patients experienced recurrent bouts of pancreatitis (median time to first episode of pancreatitis 5.1 years, range 3.6–6.7 years); all these patients had a history of grade IV trauma. Three of them initially underwent a pancreatico-jejunostomy, while the other three were managed non-operatively with a trial of duct recanalization by ERCP. An anastomotic or ductal stricture was demonstrated in all of them on MRCP at the time of the pancreatitis work-up (Fig. 1D–H).

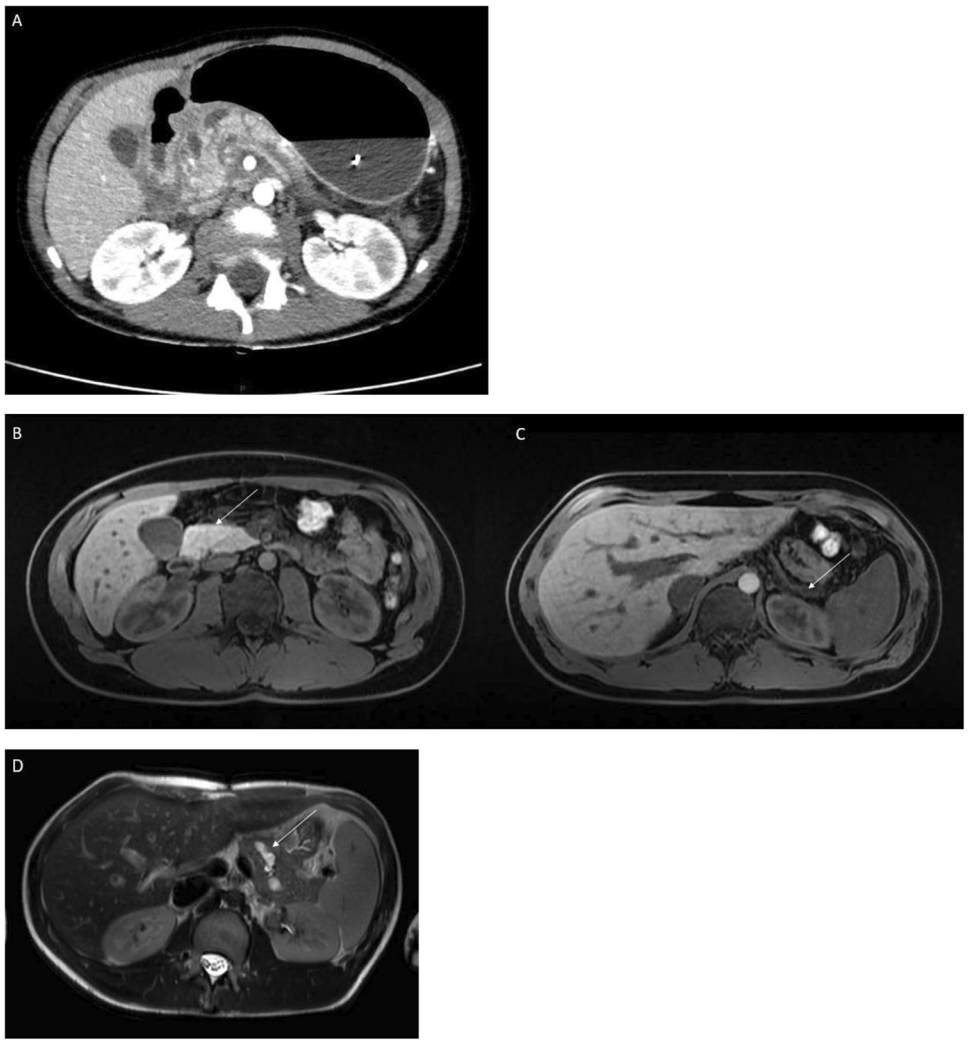
Pancreas atrophy was observed on follow-up imaging in 8/23 patients (34.8%; four grade III and four grade IV) after a median time of 18 months post-trauma (Supplementary data 2 and 3). Seven out of 8 patients had undergone initial non-operative management (Fig. 1A–C), and five of them had a history of ERCP. One patient had a history of anastomotic stricture after pancreatico-jejunostomy.

Discussion

In this study, we reviewed the short- and long-term outcomes for children with grade III–V pancreatic blunt trauma in a Belgian cohort. Initial surgical or observational management of pancreatic blunt trauma did not significantly impact length of stay or readmission rate. Furthermore, long-term complications such as endocrine or exocrine insufficiency and pancreatitis were similar between the two management approaches.

Children with grades III–IV abdominal trauma who were treated non-operatively were at an increased risk of developing pseudocysts. In the present study 68% of patients managed conservatively developed a symptomatic pseudocyst requiring EUS-guided drainage with plastic double pig-tail stents or lumen apposing metallic stents (LAMS). As shown in previous reports, pseudocyst formation is the main early complication of pancreatic trauma managed conservatively, affecting 30–45% of patients compared to 4% in children treated surgically [1, 12, 13]. Although only a limited proportion of patients ultimately require drainage [5], when performed by experienced endoscopists, pseudocyst drainage is a safe and low-risk procedure. Nevertheless, to prevent pseudocyst formation, some authors have attempted duct recanalization with some success. The technique can however be complex especially in younger children with small ducts, in the case of complete pancreatic duct transection or in the presence of anatomic variants (ansa, divisum). Performing ERCP earlier after trauma may improve success rates.

Very few studies have reported on the long-term (> 5 years) complications of severe pancreatic trauma. In this study, we demonstrated that 19.4% of children developed pancreatitis due to anastomotic or pancreatic duct strictures, regardless of their management. The management of these strictures, particularly those that occur following pancreatic diversion, is complex and requires reintervention or enteroscopy-guided ERCP. Enteroscopy-guided ERCP or EUS-guided gastro-pancreatico-jejunostomy for stricture dilation are safe procedures, but the expertise required is confined to a few specialized centers worldwide, and the procedure is limited by a lack of adequate equipment for young children. On the other hand, reintervention requires additional parenchymal resection, which ultimately affects pancreatic function



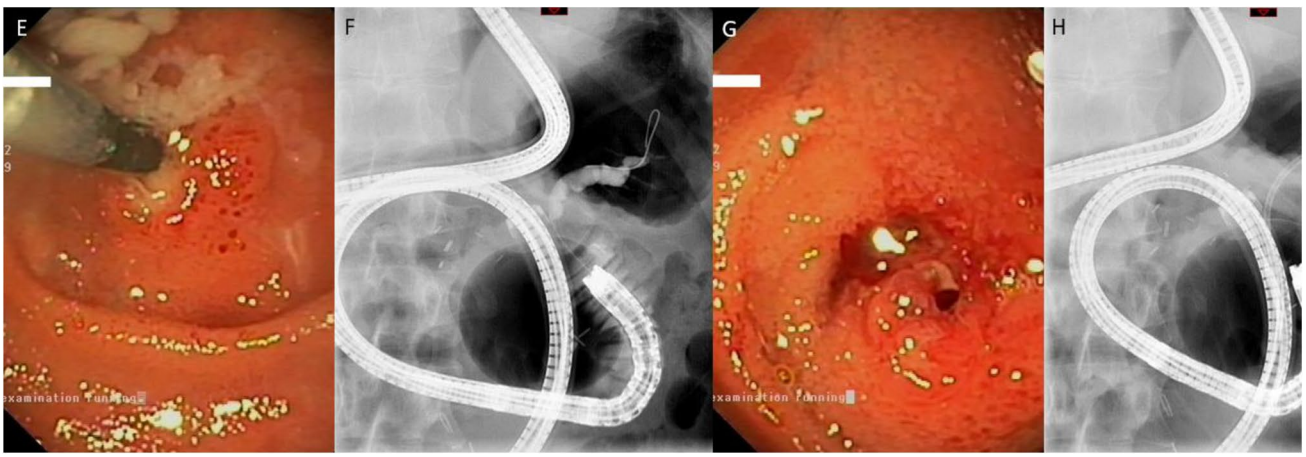


Fig. 1 **A** CT scan of an 11-year-old boy, grade IV pancreatic trauma with gland laceration secondary to bicycle handlebar impact on the abdomen. The patient was managed conservatively. **B**, **C** His evolution was marked by progressive pancreatic atrophy on magnetic resonance cholangiopancreatography (MRCP, 17 years old) and borderline pancreatic exocrine function. MRCP T1 FatSat sequences showing physiologic hypersignal of the pancreatic parenchyma in the pancreas head (**B**, arrow) and loss in the corporeo-caudal region (**C**, arrow) related to pancreatic atrophy beyond the site of disconnection (see also Supplementary data 3). **D** MRCP of a 27-year-old patient that sustained a grade IV trauma managed surgically by a pancreatico-jejunostomy at the age of 16 years. Dilated pancreatic duct suggestive of an anastomotic stricture (arrow). The stricture was dilated by enteroscopy-guided ERCP. Enteroscopic (**E**) and cholangiographic (**F**) view of the stricture before dilation, and thereafter (**G**, **H**)

Fig. 1 (continued)

and re-exposes the patient to complications of pancreatic surgery, such as fistulae or fluid collections. Pancreatitis may contribute to a further decline in both endocrine and exocrine pancreatic functions.

Another risk after pancreatic trauma is the development of pancreatic exocrine or endocrine insufficiency. Except for a child with total pancreatectomy, only one patient had borderline exocrine function; none developed

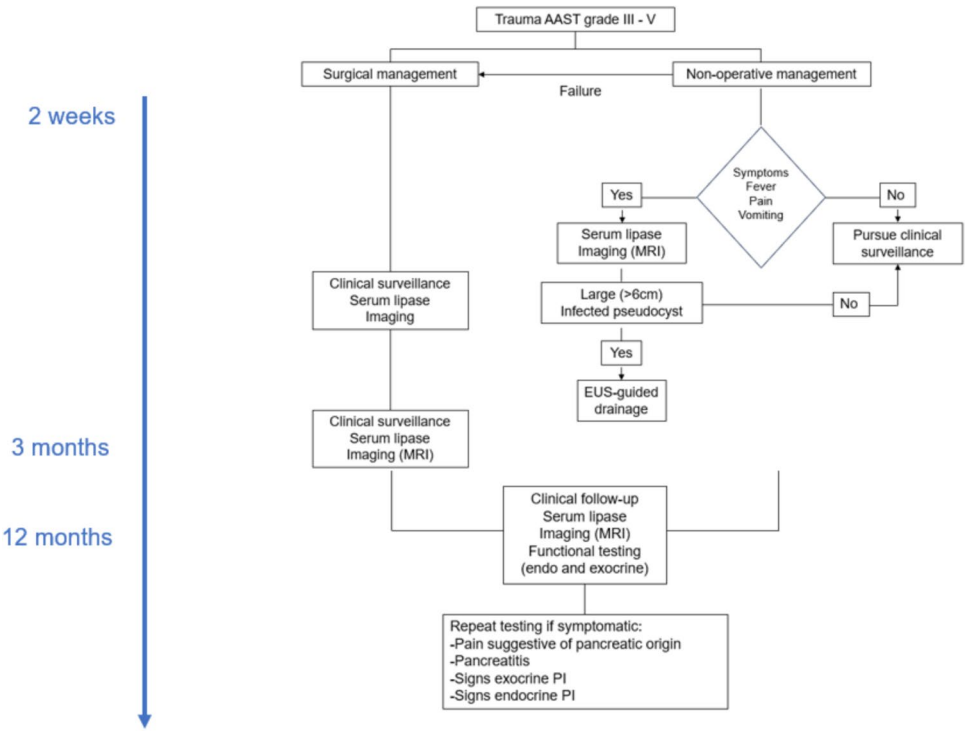


Fig. 2 Suggested long-term surveillance strategy after grade III–V pancreatic trauma. EUS: endoscopic ultrasound; PI: pancreatic insufficiency

endocrine insufficiency. Follow-up of these children may involve a search for pancreatic atrophy. Although there is no clear definition for this condition, evidence suggests that it reflects acinar loss and is correlated with functional decline of the pancreas. Indeed, Hirono et al. reported in an adult series on pancreatic resection with reconstruction by pancreatico-jejunostomy or pancreatico-gastrostomy, an occurrence of parenchymal atrophy and exocrine insufficiency of 40 and 60%, respectively [10]. Although our cohort is small, and not all children had long-term imaging of their pancreas, 30% of children with a pancreatico-jejunostomy and 43.8% of patients managed conservatively presented some extent of pancreatic atrophy on long-term follow-up imaging. Of note, MRI follow-up was not available to assess atrophy in children with pancreatico-gastrostomy. Until now, only one developed exocrine dysfunction but we cannot rule out that more children with parenchymal atrophy will evolve to exocrine or endocrine insufficiency over time. The risk of pancreatic atrophy has also to be balanced with the permanent loss of pancreatic tissue related to distal pancreatectomy. Based on the gathered knowledge, we suggest a long-term surveillance strategy (Fig. 2).

The main limitations of the present study are the relatively small size of the cohort which limited further comparison of patient outcomes, the retrospective nature of parts of the study, and the lack of a uniform management protocol between centers.

Conclusion

The results of this study demonstrate that patients with grade III and IV pancreatic trauma can be safely managed conservatively or surgically. Nevertheless, a majority of conservatively managed patients will require pseudocyst drainage, easily drained by endoscopic ultrasound (EUS). Long-term complications such as pancreatitis or pancreatic atrophy may develop over time, resulting in exocrine or endocrine dysfunction, which emphasizes the importance of patient follow-up to monitor those complications.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no competing interests.

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