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ORIGINAL ARTICLE

National trends in pancreaticoduodenal trauma: interventions and outcomes

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Abstract

Objectives: Pancreaticoduodenal trauma (PDT) is associated with substantial mortality and morbidity. In this study, contemporary trends were analysed using national data.

Methods: The Nationwide Inpatient Sample for 1998–2009 was queried for patients with PDT. Interventions including any operation (Any-Op) and pancreas-specific surgery (PSURG) were identified. Trends in treatment and outcomes were determined [complications, length of stay (LoS), mortality] for the Any-Op, PSURG and non-operative (Non-Op) groups. Analyses included chi-squared tests, Cochran–Armitage trend tests and logistic regression.

Results: A total of 27 216 patients (nationally weighted) with PDT were identified. Over time, the frequency of PDT increased by 8.3%, whereas the proportion of patients submitted to PSURG declined (from 21.7% to 19.8%; $P = 0.0004$) and the percentage of patients submitted to non-operative management increased (from 56.7% to 59.1%; $P = 0.01$). In the Non-Op group, mortality decreased from 9.7% to 8.6% ($P < 0.001$); morbidity and LoS remained unchanged at ~40% and ~12 days, respectively. In the PSURG group, mortality remained stable at ~15%, complications increased from 50.2% to 71.8% ($P < 0.0001$) and LoS remained stable at ~21 days. For all PDT patients, significant independent predictors of mortality included: the presence of combined pancreatic and duodenal injuries; penetrating trauma, and age >50 years. Having any operation (Any-Op) was associated with mortality, but PSURG was not a predictor of death.

Conclusions: The utilization of operations for PDT has declined without affecting mortality, but operative morbidity increased significantly over the 12 years to 2009. The development of an evidence-based approach to invasive manoeuvres and an early multidisciplinary approach involving pancreatic surgeons may improve outcomes in patients with these morbid injuries.

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Introduction

Pancreaticoduodenal trauma (PDT) in the setting of abdominal trauma is rare, representing 0.5–5.0% of all such traumas.[1,2] However, these injuries have historically carried a risk for mortality ranging from 10% to 40%.[1,3–6] Recent expert recommendations have urged the more conservative management of many intra-abdominal organ injuries, including PDT.[7] The current guidelines issued by the Eastern Association for the Surgery of Trauma

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Table 1 Cohort assembly: definitions used to define injury of the pancreas and/or duodenum (PDT), and to define any surgical intervention (Any-Op) and pancreas-specific interventions (PSURG)

	ICD-9 CM diagnoses and procedure codes
PDT	863.21, 863.31, 863.82, 863.84, 863.94, 863.92, 863.81, 863.83, 863.91, 863.93
Any-Op	
Non-PSURG	45.01, 45.02, 45.51, 45.6x, 52.13, 51.11, 51.10, 54.19, 54.11, 54.12, 88.95, 52.93
PSURG	52.52, 52.51, 52.53, 52.59, 52.6, 52.7, 52.95

recommend non-operative management for Grade I and II injuries, and operation (resection or drainage) for injuries of Grade III and higher.[7]

Both operative and non-operative protocols for the management of PDTs are among the most challenging clinical scenarios faced by surgeons. Prior research has focused on rates of mortality after PDT and thus little is known about the extent of complications in patients following PDT and whether surgical interventions exacerbate or alleviate the risk for complications.

This project was undertaken to study the changing patterns of intervention for PDT on a national basis over a period of 12 years, to investigate patterns of surgical intervention, and to establish whether new practice patterns have improved mortality and morbidity in patients with PDT.

Materials and methods

Data source

The US Nationwide Inpatient Sample (NIS) was queried for the 12-year period from 1998 to 2009 for all patients with pancreatic or duodenal trauma. The NIS, a part of the Healthcare Cost and Utilization Project (HCUP), is a national, all-payer discharge database containing information on a representative stratified sample of 20% of non-federal US community hospitals in participating states, including academic and specialty hospitals.[8] The NIS weighting strategy facilitates the drawing of population-based estimates at the national level.

Cohort assembly

Patients with PDT were identified if they had been admitted emergently or had a primary ICD-9 CM (International Classification of Diseases, Revision 9, Clinical Modification)[9] diagnosis code for injury to the pancreas or duodenum (codes 863.21, 863.31, 863.82, 863.84, 863.94. 863.92, 863.81, 863.83, 863.91 and 863.93) (Table 1). Patient data were then analysed to identify any surgical intervention (Any-Op), including exploratory laparotomy, small bowel resections, or pancreas-specific intervention using ICD-9 CM procedure codes 45.01, 45.02, 45.51, 45.6x, 52.13, 51.11, 51.10, 54.19, 54.11, 54.12, 52.52, 52.51, 52.53, 52.59, 52.6, 52.7, 52.95, 88.95 and 52.93. This surgical group was subdivided into two cohorts according to the presence or absence of pancreas-specific surgeries (PSURG) using ICD-9 CM procedure codes 52.52, 52.51, 52.53, 52.59, 52.6, 52.7 and 52.95. The non-operative (Non-Op) group included patients who did not undergo any of the surgical interventions defined here. Patients were excluded if they were aged $\leq$ 18 years or $\geq$ 95 years, had been admitted electively or had an invalid admission type.

Outcomes

The primary outcome measures were rates of surgical interventions in PDT patients over time. Secondary outcomes included mortality, length of stay (LoS), and the occurrence of major in-hospital complications, including cardiovascular or deep vein thrombosis (CV/DVT), gastrointestinal, pulmonary or urinary complications, infection and myocardial infarction, as defined by the present authors and others.[10–12]

Statistical analysis

All analyses were performed using SAS Version 9.2 (SAS Institute, Inc., Cary, NC, USA).[13] Univariate analyses were used to compare differences between subsets of treatment groups and included chi-squared tests of association for categorical variables. Trend tests for annual point estimates were performed using the Cochran–Armitage trend test for binary variables. A linear regression model was used to determine trends over time for continuous variables. *P*-values of < 0.05 were considered to indicate statistical significance. All data were weighted to nationally representative numbers using the validated weighting strategies provided by HCUP.[8]

Multivariable logistic regression models were constructed with the occurrence of mortality or a major in-hospital complication as the dependent variable (outcome). Independent variables with both statistical significance at the $P < 0.05$ level on univariate analyses or clinical relevance (established *a priori*) were included in multivariable models; these included race (White, Black, Hispanic, other/missing), age ($<$ 40 years, $\geq$ 40 years), sex, Elixhauser comorbidity score (0, 1, $\geq$2),[14] hospital characteristics including location (urban versus rural), region, size and teaching status, and type of insurance (Medicare, Medicaid, private, uninsured, other/missing). Adjusted odds ratios (AORs) were calculated to determine the effects of the covariates on outcomes of interest.

This study was determined to be exempt from requirements for ethical approval by the University of Massachusetts Medical School Institutional Review Board.

Results

Patient and hospital characteristics

During the study period, 27 216 nationally weighted patients with PDT were admitted. Nearly three-quarters of this cohort (73.6%) were male. The mean age of the patients was 37.7 years; the mean Elixhauser score was only 0.8. The majority of patients were treated at urban (93.1%), large (73.4%) and teaching (74.0%) hospitals (Table 2). From 1998 to 2009, the number of patients admitted with PDT increased by 8.3% from 2115 to 2290. Patients admitted more recently were older at presentation (37 years versus

Table 2 Patient and hospital characteristics

Variable	All PDT	Any-Op[a]	PSURG[a]	Non-Op[a]
Patients, *n*	27 216	11 011	5483	16 205
Proportion of all patients, %	100%	40.5%	20.1%	59.5%
Demographics				
Age, years, mean	37.7	35.7	35.9	39.0
Male, %	73.6%	79.5%	80.5%	69.7%
Race, %				
White	38.6%	33.5%	33.8%	42.1%
Black	19.3%	23.1%	24.0%	16.6%
Hispanic	12.3%	13.3%	13.8%	11.5%
Other/unknown	29.8%	30.0%	28.4%	29.7%
Mean Elixhauser comorbidity score, %				
0	51.6%	51.3%	51.7%	51.8%
1	27.2%	28.0%	28.1%	26.6%
≥ 2	21.2%	20.6%	20.3%	21.6%
Trauma type, %				
Pancreas alone	58.1%	65.0%	88.3%	53.4%
Duodenum alone	33.5%	23.8%	–	40.1%
Combined pancreas + duodenum	8.4%	11.2%	11.7%	6.5%
Hospital type, %				
Urban	93.1%	95.7%	95.5%	91.3%
Teaching	74.0%	79.3%	78.3%	70.5%
Hospital bed size, %				
Small	4.2%	3.3%	3.2%	4.9%
Medium	22.3%	22.2%	23.5%	22.3%
Large	73.5%	74.5%	73.4%	72.8%
Primary insurance, %				
Medicare	6.5%	5.6%	6.2%	7.1%
Medicaid	17.1%	21.0%	19.8%	14.4%
Private	39.7%	33.8%	32.5%	43.8%
Uninsured	23.9%	25.9%	27.5%	22.6%
Other/missing data	12.7%	13.6%	13.9%	12.1%

[a]The Any-Op group includes patients who underwent any abdominal operation; the PSURG group includes patients who underwent a pancreas-specific operation; the Non-Op group includes patients who were managed non-operatively.

40 years; $P = 0.0008$) and had more comorbidities (mean Elixhauser score: 0.5 versus 1.3; $P < 0.0001$).

Although the rate of isolated pancreatic injury, without concurrent duodenal injury, rose over the study period (from 58.2% to 64.2%), fewer isolated duodenal injuries were seen (32.9% versus 27.6%) and the combined injury rate remained stable at ~8%. The majority of PDT was caused by blunt injury. The mechanism of injuries changed over the course of the study, with increases in the proportions of injuries caused by motor vehicle accidents (from 29.9% to 34.0%; $P < 0.0001$) and falls (from 3.7% to 7.3%; $P < 0.0001$), and decreases in the proportions caused by penetrating traumas including stab wounds (from 8.8% to 7.7%) and gunshot wounds (from 21.2% to 16.7%).

Trends in location of injury

The distribution of pancreatic injuries by location was as follows: 50.5% were reported as affecting multiple locations; 17.3% pertained to the head of the pancreas, 9.6% to the pancreatic body, and 22.6% to the pancreatic tail.

From 1998 to 2009, the proportion of injuries affecting the head of the pancreas remained stable at ~15% ($P = 0.07$), the proportion of injuries to the body of the pancreas decreased from 11.3% to 8.0% ($P = 0.01$) and the proportion of injuries to the tail of the pancreas decreased from 26.3% to 21.2% ($P = 0.006$). The proportion of patients with multiple injuries to the pancreas increased from 48.2% to 53.8% ($P = 0.004$).

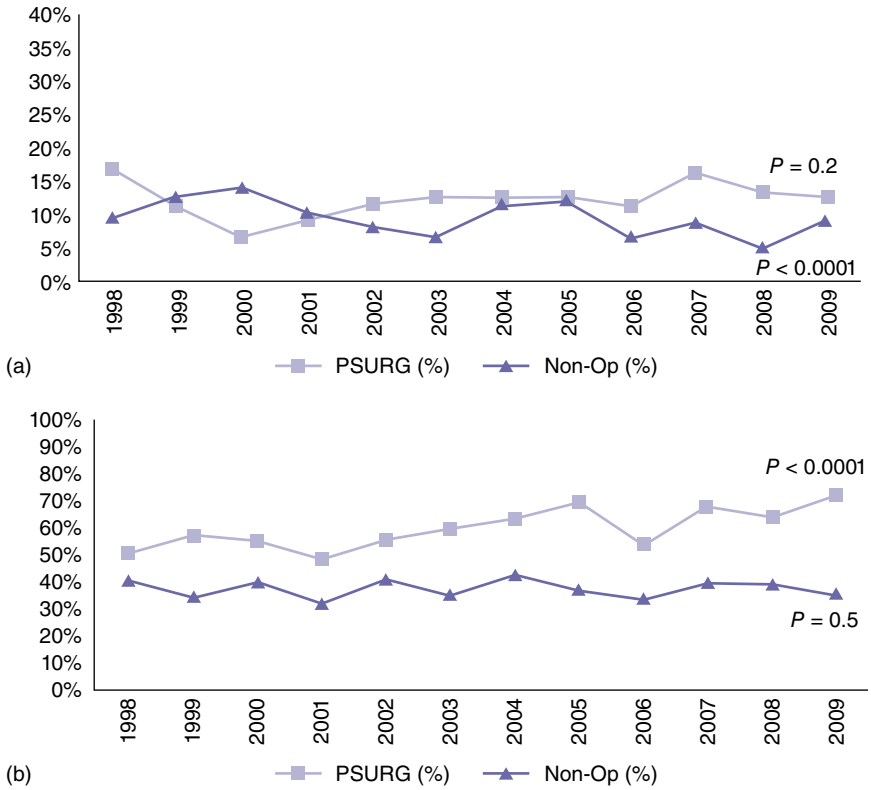

Figure 1 (a) Mortality and (b) morbidity in an extrapolated sample of 27 216 patients admitted for injury to the pancreas and/or duodenum during 1998–2009 by intervention type. Non-Op, non-operative group; PSURG, pancreas-specific surgery group

Trends in interventions

Across the entire cohort, 11 011 patients (40.5%) were submitted to surgery (Any-Op group) and 16 205 patients (59.5%) were managed non-operatively (Non-Op group). A total of 5483 patients (20.1%) underwent pancreas-specific surgery only (PSURG group). Fewer than 50% of operating room interventions warranted any pancreatic surgery. Only 1.5% of patients required endoscopic intervention (endoscopic retrograde cholangiopancreatography or stent placement).

Overall, within the PSURG group, 1976 patients (36.0%) underwent a primary repair procedure, 2681 (48.9%) underwent distal pancreatectomy, 162 (3.0%) underwent total pancreatectomy, 165 (3.0%) underwent radical pancreaticoduodenectomy or radical pancreatectomy, and 499 (9.1%) underwent partial or proximal pancreatectomy. Further analysis for trends referred to the collapsed PSURG group, rather than specific surgery types, as a result of NIS reporting requirements.

Because of the small sample numbers, data for patients treated with endoscopic procedures during 1998–2003 and 2004–2009, respectively, were collapsed to enable a comparison. The rate of endoscopic intervention did not change (~1.5%; $P = 0.9$).

From 1998 to 2009, the proportion of patients managed non-operatively increased from 56.7% to 59.1% ($P = 0.01$). The overall rate of Any-Op declined (from 43.3% to 40.9%; $P = 0.01$), as did the utilization of PSURG (from 21.7% to 19.8%; $P = 0.0004$).

Trends in short-term outcomes

Over the 12-year period of study, outcomes in patients with PDT improved. Mortality decreased from 12.7% to 11.0% ($P < 0.0.001$). Most of this decrease reflects a drop in mortality in the Non-Op group, from 9.7% to 8.6% ($P < 0.0001$). Mortality in the Any-Op group did not change significantly (16.9% versus 12.9%; $P = 0.2$) (Fig. 1).

A total of 46.6% of patients across the entire PDT cohort experienced major complications.

The most common complications were pulmonary compromise and infectious complications (Table 3). Patients who underwent an operation (Any-Op group) had increasingly higher rates of complications. This was especially significant in the PSURG group, among which the rate of complications increased from 50.2% to 71.8% ($P < 0.0001$). However, in the Non-Op group, the rate of complications was unchanged (40.8% versus 35.4%; $P = 0.5$). Similar trends were seen for LoS, which increased from 16.6 days to 21.5 days ($P = 0.007$) in the Any-Op group, and from 19.1 days to 22.9 days ($P = 0.0001$) in the PSURG group. In the Non-Op group, LoS remained stable (12.3 days versus 11.7 days; $P = 0.3$).

Predictors of complications and mortality

Multivariable logistic regression models were created to identify predictors of complications and mortality among patients with

Table 3 Major postoperative in-hospital complications and in-hospital mortality after pancreaticoduodenal trauma. Data refer to the Nationwide Inpatient Sample (NIS) for 1998–2009

Complication	Overall weighted *n*	Total	Any-Op [a]	PSURG [a]	Non-Op [a]
Patients in group, *n*	27 216	27 216	11 011	5483	16 205
Complications	12 672	46.6%	59.6%	59.8%	37.7%
Postoperative infection	3 507	12.9%	16.8%	17.7%	10.2%
Myocardial infarction	103	0.4%	[b]	[b]	0.34%
Aspiration pneumonia	267	1.0%	1.0%	[b]	1.0%
DVT/PE	656	2.4%	3.5%	4.0%	1.7%
Pulmonary compromise	5 460	20.1%	27.3%	26.9%	15.1%
Gastrointestinal haemorrhage	816	3.0%	4.6%	5.5%	1.9%
Reopening surgical site	1 453	5.3%	12.6%	7.9%	[b]
Perforation/laceration	7 037	25.9%	32.9%	35.3%	21.1%
Mortality	3 122	11.5%	14.5%	12.6%	9.5%

[a]The Any-Op group includes patients who underwent any abdominal operation; the PSURG group includes patients who underwent a pancreas-specific operation; the Non-Op group includes patients who were managed non-operatively.
[b]Data cannot be reported because of small cell numbers; agreements on the use of NIS data preclude the use of cells containing < 10 patients.
DVT, deep vein thrombosis; PE, pulmonary embolism.

PDT. After controlling for demographic and clinical variables, significant independent predictors of mortality for all PDT patients included: combined pancreaticoduodenal injury; penetrating trauma mechanism; age >40 years, and being uninsured. Having any surgery (Any-Op group) was associated with mortality, but PSURG was not a predictor of death (Table 4).

After controlling for demographic and clinical variables, significant predictors of complications included: penetrating trauma; combined pancreaticoduodenal injury; receipt of operation; age >40 years; a greater number of comorbidities, and having Medicaid insurance (Table 4).

Discussion

This study of recent national trends in the operative management of PDT found increasing rates of non-surgical management and improvements in overall mortality, but persistently high morbidity. Although the rate of complications in the Non-Op group remained unchanged, the rate of complications in the PSURG group rose by >20%. To the present authors' knowledge, this is the first study to examine national trends and outcomes in PDT over the last decade.

Historically, mortality for PDT has been as high as 40% because the condition is often associated with multi-organ injury.[5,15] More recently, in a retrospective examination of data from 11 trauma centres, Velmahos *et al.* found overall mortality of 11.7% and reported that the operative group fared slightly less well (15%) than the group managed conservatively (7%).[6] In a single-institution study, Antonacci *et al.* noted 22% mortality.[5] The present study, which analysed national data for a 12-year period, showed that the improvement in mortality occurred across the country, not just in individual high-volume trauma centres that had previously reported their outcomes.

When the results are stratified by intervention, the majority of the improvement in mortality is seen to be associated with non-operative management; there is no significant change in rates of mortality among patients undergoing surgery. Furthermore, a more detailed look at associated rates of complications shows a significant rise in morbidity associated with operative management, whereas outcomes in non-operatively managed patients remained unchanged. Some of these findings can be attributed to selection bias because the most severe cases of injury will require an operation. One possible explanation refers to the more widespread availability of angioembolization, which allows the non-operative management of some types of abdominal bleeding (spleen, renal, etc.) that in the past would have warranted abdominal surgery. This creates a new subset of patients in whom exploratory surgery is performed. Another possible explanation refers to the greater availability of better rescue therapies, as a result of which patients who in the past would have died, now survive, but have a prolonged recovery course with complications. Finally, some of the increase in complication rates can be attributed to a national recognition system and improvements in recording and reporting the occurrence of complications. However, there appears to be an inconsistent association between mortality and morbidity which suggests that other factors may contribute to this increase in the rate of complications. Further investigation of this subject is warranted.

Pancreaticoduodenal trauma patients are a very heterogeneous group. As injuries in recent years have tended to reflect blunt trauma, and seatbelt laws have become more stringent, the higher morbidity may be associated with a shift in the type of pancreatic injury, which cannot be quantified using a national database.

Pancreatic surgery is a technically complex procedure, even when performed by experienced pancreatic surgeons. Birkmeyer *et al.* showed that operative mortality in complex operations was

Table 4 Multivariable logistic regressions: adjusted odds ratios for mortality and morbidity during hospitalization for pancreaticoduodenal trauma

	Predictors of in-hospital mortality OR (95% CI)	Predictors of in-hospital complications OR (95% CI)
Age ≥ 40 years (versus < 40 years)	2.13 (1.75–2.59)	0.94 (0.82–1.07)
Male (versus female)	1.19 (0.94–1.51)	1.37 (1.18–1.59)
Race		
Black (versus White)	1.05 (0.84–1.33)	1.20 (1.00–1.45)
Hispanic (versus White)	1.10 (0.82–1.47)	1.15 (0.96–1.37)
Other/unknown (versus White)	1.25 (1.01–1.55)	1.02 (0.88–1.18)
Elixhauser comorbidity score		
1 (versus 0)	0.87 (0.70–1.08)	1.32 (1.14–1.54)
≥ 2 (versus 0)	0.62 (0.49–0.78)	1.89 (1.60–2.23)
Injury mechanism penetrating versus blunt	1.68 (1.31–2.16)	2.80 (2.36–3.34)
Unknown versus blunt	1.24 (1.0–1.55)	1.93 (1.66–2.25)
Injury type		
Duodenum alone versus pancreas	0.81 (0.66–0.99)	1.54 (1.34–1.77)
Pancreas + duodenum versus pancreas	1.66 (1.27–2.17)	1.77 (1.43–2.19)
Interventions		
Surgery versus no surgery	1.75 (1.42–2.16)	1.90 (1.60–2.25)
PD surgery versus no surgery	0.63 (0.48–0.82)	1.20 (0.99–1.45)
Hospital location		
Urban (versus rural)	2.46 (1.62–3.76)	2.22 (1.67–2.96)
Hospital bed size		
Medium (versus small)	1.56 (0.91–2.68)	1.46 (1.09–1.94)
Large (versus small)	1.62 (0.49–0.78)	1.81 (1.39–2.36)
Insurance		
Medicare versus private	1.79 (1.30–2.47)	1.17 (0.91–1.50)
Medicaid versus private	1.10 (0.82–1.48)	1.48 (1.24–1.76)
No insurance/self-pay versus private	1.48 (1.20–1.82)	0.91 (0.78–1.07)
Other/missing versus private	0.62 (0.42–0.91)	0.98 (0.81–1.18)

OR, odds ratio; 95% CI, 95% confidence interval; PD, pancreaticoduodenal.

inversely proportional to individual surgeon volume, with the greatest difference noted in pancreatic surgery.[16] In 2007, the present group showed that operations performed by surgeons who had carried out at least 60 pancreatic cancer surgeries as attending surgeons were associated with significant decreases in operating room time and intra-operative blood loss, a higher percentage of margin-negative resections, and a shorter associated LoS.[17] Pancreatic trauma is rare and is seen in only 0.5–5% of trauma cases, even at a Level I trauma centre. In addition, a large proportion of patients with pancreatic injury are managed non-operatively. In particular patients in whom pancreas-directed surgery, especially pancreatic resection, may be under consideration, the involvement of a dedicated pancreaticobiliary surgeon in the decision-making process may be helpful to the multidisciplinary team.

This study has several important limitations. The NIS is an administrative database and lacks certain clinical variables, including patient-level factors, such as injury severity score, imaging, laboratory values, operative data (blood loss, transfusions, operative time), and longterm follow-up and readmission information. Major postoperative complications were assessed using a validated set of ICD-9 codes; however, complication rates can be underestimated because individual medical records cannot be reviewed, and the NIS does not include complications that occur after the patient's discharge. Insufficient coding specifications in the NIS precluded the accurate assessment of the important complications of biliary stricture, duct injury, leak or fistula because the use of ICD-9 codes to evaluate bile duct injuries has been demonstrated to substantially underestimate their true incidence.[18,19] The database also does not allow for the assessment of perioperative variables that influence the surgeon's decision to take the patient to the operating room, which results in some selection bias.

Despite these limitations, this is the first national study to examine contemporary operative interventions for PDT, and to

both analyse mortality and comprehensively examine morbidity associated with PDT and its treatment. As PDT is rare, the use of a national database allows for a robust multivariable analysis that adjusts for the effect of multiple clinical and demographic variables in a manner that is not possible using a single-institution database.

Conclusions

During 1998–2009, the utilization of surgery for PDT declined, along with a minor decrease in mortality associated with non-operative management. However, in patients who underwent surgery, mortality was unchanged and the rate of complications increased significantly. The outcomes of PDT are impacted by many factors. An evidence-based approach to invasive manoeuvres and a multidisciplinary approach that enables the early involvement of team members with expertise in trauma and pancreatic surgery, interventional radiology and gastroenterology may improve outcomes in these morbid and costly injuries.

Conflicts of interest

None declared.

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