

Open or Not Open the Retroperitoneum: A Pandora's Box for High-grade Pancreatic Trauma?

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Research Article

Keywords: Pancreatic Trauma, Retroperitoneum, Management, Outcomes, Clavien-Dindo

Posted Date: January 3rd, 2022

DOI: <https://doi.org/10.21203/rs.3.rs-1217311/v1>

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Abstract

Background: The management strategy associated with the optimal clinical outcomes for patients with pancreatic trauma remains ambiguous. We sought to determine whether transitioning from initial laparotomy (LAP) to the nonoperative management strategy based on initial percutaneous drainage (PCD) without opening the retroperitoneum would improve clinical outcomes in patients with blunt high-grade pancreatic trauma.

Methods: We conducted a retrospective cohort study of pancreatic trauma at a single tertiary referral center. Blunt high-grade pancreatic trauma patients with stable hemodynamics and no diffuse peritonitis were enrolled consecutively in the study. The primary outcome measure was the incidence of severe complications (Clavien-Dindo classification \geq 3) for patients who underwent initial LAP vs PCD. To study effect modification by different initial strategies and to adjust for confounding, modified Poisson regression and sensitivity analysis based on propensity score matching and weighting were performed to estimate adjusted relative risks (aRR) and 95% confidence intervals (CIs).

Results: Among 119 patients with blunt grade 3/4 pancreatic trauma (107 male [89.9%] and 12 female [10.1%]; mean age, 35.7 [SD, 12.7] years), 29 underwent initial PCD and 90 underwent initial LAP (January 2009 through October 2021). Compared with initial LAP, patients underwent initial PCD were significantly lower risk of severe complications (9/29 [31.0%] vs 65/90 [72.2%]; aRR, 0.52 [95% CI, 0.30-0.90]). Consistent results are also observed in sensitivity analysis models. The relative risk of severe complications for the PCD group in propensity score matching model was 0.53 (95% CI, 0.28-0.99; P = 0.035), 0.37 (95% CI, 0.18-0.75; P = 0.006) in inverse probability of treatment weighting model, and 0.55 (95% CI, 0.31-0.99; P = 0.046) in overlap weighting model. In addition, the mean number of reinterventions per patient was 1.8 in the PCD group and 2.6 in the LAP group (P = 0.067).

Conclusions: For blunt high-grade pancreatic trauma patients with stable hemodynamics and no diffuse peritonitis, initial PCD strategy without open the retroperitoneum has a significantly lower rate of severe complications and does not increase reinterventions compared with initial LAP. Further randomized controlled trials are warranted to validate these results.

Trial Registration: ClinicalTrials.gov Identifier: NCT03681041(Sept. 21 2018).

Introduction

Pancreatic trauma is relatively uncommon, accounting for only 0.2%-0.3% of all traumas and 3-12% of patients with abdominal trauma but a high mortality rate of 17%-46% [1-4]. Diagnosis is hindered by its retroperitoneal position, nonspecific clinical features, limitations of laboratory tests, subtle imaging findings and multiorgan trauma, which undoubtedly lead to delays in the optimal timing of treatment [5, 6]. To make matters worse, these patients have a prolonged disease course with a high risk of severe complications and even death [7-9]. There are several classification systems, but the five-grade organ injury scale (OIS) proposed by the American Association for the Surgery of Trauma (AAST) is universally

accepted at present [10-12]. The key distinction between low-grade (grades I-II) and high-grade (grades III-V) injuries is involvement of the main pancreatic ductal (MPD). Furthermore, patients with higher injury grades are associated with worse outcomes and ultimately need to undergo multiple interventions [6, 7].

The management of pancreatic trauma depends on several factors, including the mechanism of injury (blunt vs penetrating trauma), AAST-OIS grade, hemodynamic status, and extent of concomitant organ injury [5, 13]. Particularly worth mentioning is that the outcomes related to high-grade injuries have not improved over the past many years as we intended [14-17]. This situation may be explained by differences in case-mix or by differences in management strategies and local expertise. Several changes in the management of patients with high-grade trauma have occurred over recent years. First, under the emergency setting of abdominal trauma, with priority given to controlling bleeding and intestinal content spillage, damage-control surgery is increasingly being performed on unstable patients [18, 19]. Second, nonpancreatectomy with drainage may be a feasible option [17, 20-22]. Third, nonoperative management (NOM) may be safe and effective in patients with stable hemodynamics and no associated organ injuries requiring laparotomy (LAP) [23-26]. Finally, as a part of the NOM strategy, the role of endoscopy and interventional radiology is well established in terms of initial interventions and treatment of subsequent complications [6, 17, 23, 27, 28].

Percutaneous drainage (PCD), without open the retroperitoneum, can be used as the initial management for pancreatic trauma patients with stable hemodynamics and no diffuse peritonitis caused by hollow organ injury. [23, 29] Subsequently, ERCP-guided stent placement was performed along the injured MPD for internal drainage [5, 17, 23, 30, 31]. NOM strategies combined with internal and external drainage is thought to be beneficial in the acute and delayed phase by inducing less surgical stress, thereby lowering the inflammatory cascade, especially in already critically ill patients with serious injury [25, 31, 32]. This, considering the fact that pancreatic trauma is a complex and rare disease, makes it unlikely that a trial with a sufficiently large sample size to study clinical outcomes will ever be performed [4, 22, 24, 26, 33, 34]. It therefore remains unclear if NOM strategies improve prognosis, especially in the context of other recent changes in the treatment. As a result, LAP is still a valid option [5, 13, 16, 17, 20, 22]. Combined with previous experience, we hypothesized that initial PCD without open the retroperitoneum might improve the clinical outcomes of blunt high-grade pancreatic trauma compared with initial LAP in selected patients.

Methods

Study design

We conducted a retrospective cohort study of consecutive patients with pancreatic trauma who were hospitalized in our center during a 13-year period (January 2009

through October 2021). The study design was predefined and prospectively registered (NCT03681041). The institutional review board of our centre approved the study protocols. We adhered to the STROBE (Strengthening the Reporting of Observational studies in Epidemiology) guidelines [35]. Original

individual patient data were collected in a standardized manner using an electronic case record form. Data were checked for consistency and plausibility.

Study population

Before 2017, all patients with highly suspected or diagnosed pancreatic trauma were treated with LAP. Beginning in 2017, we gradually transitioned from LAP to NOM based on PCD strategy with selective use of LAP. A rapid multidisciplinary evaluation, led by a trauma surgeon coordinating care with interventional radiologist, endoscopist, and intensive care specialist, is required from the moment our patients step into the hospital, especially in hemodynamic stable patients with blunt pancreatic trauma.

Inclusion criteria were blunt high-grade pancreatic trauma with stable hemodynamics, angioembolization was successfully performed after active bleeding of vascular or solid organs indicated by CT evidence, and direct admission between January 2009 and October 2021. Exclusion criteria included early deaths (< 48 hours), clinical or CT evidence of diffuse peritonitis, referral after LAP or PCD, previous history of malignancy, immune system and hematological diseases. The grade of pancreatic injury was according to the final diagnosis, and being judged by one or some imaging test (i.e., CT, MRI, ERCP) combined with intraoperative and/or pathological findings.

In the LAP group, the initial LAP was a transperitoneal approach, and the pancreas was completely exposed after opened the retroperitoneal space. The location and morphology of the injury, the status of MPD, operative methods, and drainage methods were recorded, as was the need for reinterventions, including surgical, endoscopic, or interventional radiological management. For the PCD group, in addition to the initial PCD under CT guidance, subsequent ERCP-guided stent placement and endoscopic transpapillary drainage were also applied. Similarly, reintervention measures were also recorded. After the percutaneous puncture of the sinus matures, the drainage tube is replaced with a closed suction drainage system. When the above measures failed or the progression of disease could not effectively be controlled, promptly convert to LAP.

Variables

The following baseline variables were collected: sex, age, Body Mass Index(BMI), AAST-OIS grade, vascular injury, isolated pancreatic injury, time to diagnosis (in hours), Acute Physiology and Chronic Health Evaluation II (APACHE-II) peak score before first intervention, Injury Severity Score(ISS), Sequential Organ Failure Assessment (SOFA) peak score before first intervention, Procalcitonin(PCT), C-reactive protein (CRP), Albumin, posttraumatic Acute Respiratory Distress Syndrome (ARDS), and organ failure before first intervention.

Outcomes

The primary outcome was the occurrence of severe complications graded by Clavien-Dindo classification (range I to V, with higher scores indicating more severe complication) after the implementation of two initial different strategies. Severe complications were defined as those with a Clavien-Dindo classification

\geq III_b between the day of the first intervention and the last discharge [36]. Multiple times or multiple grades of complications occurred in the same patient were calculated according to the highest grade. The secondary outcomes were occurrence of death, new-onset organ failure, hemorrhage grade B/C, pancreatic fistula grade B/C, pancreatic pseudocyst, other gastrointestinal fistulas, intra-abdominal abscess, sepsis, intra-abdominal hypertension (IAH), and abdominal compartment syndrome (ACS). Furthermore, number of reinterventions required to treat Clavien-Dindo classification \geq III complications under surgical, endoscopic, and interventional radiological procedures throughout the course of treatment were counted. Total length of stay (LOS) were also recorded. Further details on definitions of outcomes variables are provided in the **Table S1** (Additional file 1).

Statistical analysis

To evaluate the association between primary outcome and different initial interventions, we used modified Poisson regression with and without adjustment for the above baseline variables and calculated relative risks (RRs) and corresponding 95% confidence intervals (CIs) [37]. A univariable association was determined between severe complications and baseline characteristics. Factors with $p < 0.2$ were selected for multivariable modified Poisson regression analysis.

To study effect modification by different initial strategies and to adjust for confounding, we also performed sensitivity analysis based on propensity score matching and weighting. A non-parsimonious multivariable logistic regression model was developed to estimate a propensity score for the PCD and LAP groups. All covariates with $p < 0.2$ in univariable modified Poisson regression were included in this model. Propensity score matching (PSM) analysis means that patients who underwent initial PCD were matched 1:1 with patients undergoing initial LAP management using their propensity scores with the nearest neighbor matching algorithm without replacement (a caliper width equal to 0.2 of the SD of the logit score was used). We also used these estimated propensity score to calculate each patient's inverse probability of treatment weighting (IPTW) and overlap weighting (OW) [38, 39]. These weights were then included in a modified Poisson regression model with robust estimation of variance to estimate RR and corresponding 95% CIs for the primary outcome. Standardized mean differences (SMD) were assessed for covariate balance before and after propensity score matching and weighting [40]. The SMD of less than 10% indicates appropriate balance.

The Kolmogorov-Smirnov test was used to assess the normality of quantitative data. Mean with standard deviation (SD) and median with interquartile range (IQR) were used to describe continuous variables. T tests and Wilcoxon rank sum tests were used to compare normal or nonnormal continuous variables respectively. Frequency with percentage was used to describe categorical variables. Fisher's exact tests were used for comparing categorical variables. The level of significance was set as a two-sided P value less than 0.05. Analyses were conducted with SAS 9.4 (SAS Institute, Cary, North Carolina, USA) and R 4.0.3 (R Foundation for Statistical Computing).

Results

Patient Characteristics

We included 119 consecutive patients with blunt grade I/II pancreatic trauma (107 male [89.9%] and 12 female [10.1%]; mean age, 35.7 [SD, 12.7] years), of which 29 in the PCD group and 90 in the LAP group. **Figure 1** is the study flow-chart. Among them, 49 patients with grade I pancreatic injury and 70 patients with grade II. Median ISS was 16 (IQR, 13-20). Patients treated with initial PCD were significantly younger (mean [SD], 31.41 [11.74] vs 37.09 [12.78] years; $P = 0.036$) and had lower APACHE II peak scores before first intervention (median [IQR], 6 [3.5-7.5] vs 7 [4.75-10.25]; $P = 0.013$). The PCD group had more isolated pancreatic injury (55.2% vs 20.0%; $P = 0.001$), and with less concomitant vascular injury (3.4% vs 20.0%; $P = 0.040$). There was no statistically significant difference in patients who developed posttraumatic ARDS and organ failure before first intervention ($P = 0.05$). Baseline BMI (mean [SD], 21.51 [2.81] vs 22.17 [3.56]; $P = 0.363$), ISS (median [IQR], 16 [12-16] vs 16 [12.5-21.0]; $P = 0.337$), SOFA peak scores before first intervention (median [IQR], 2 [1-3] vs 3 [1-5]; $P = 0.061$), time to diagnosis (median [IQR], 24 [6-96] vs 12 [6-48] hours; $P = 0.655$), and **laboratory test index** (i.e., Albumin, PCT, CRP) were similar between the two groups (**Table 1**).

Severe Complications (Clavien–Dindo \geq III) as Primary Outcome

Clavien-Dindo classification of PCD vs LAP in different initial interventions at different injury grades can be seen in **Table 2**. In the PCD group, 12 patients underwent PCD alone, of which one third patients (4/12) were converted to LAP. Among 17 patients who underwent PCD+Stent, 29.4% of patients (5/17) developed severe complications. In the LAP group, the incidence of grade III injuries was 32.2% (29/90). For different operative methods specifically, 100% in patients who underwent operative drainage alone (13/13), 50.0% in patients underwent distal pancreatectomy (10/20), and a combined incidence of 75.0% in patients underwent pancreaticojejunostomy and open abdomen (6/8). The incidence of grade IV injuries was 40.0% (36/90). Similarly, 68.3% in patients who underwent operative drainage alone (28/41), and all occurred in patients underwent pancreaticojejunostomy and open abdomen. In summary, 31.0% of patients (9/29) in the PCD group suffered severe complications compared with 72.2% of patients (65/90) in the LAP group.

In univariate modified Poisson regression analysis: ISS, APACHE-II peak score, SOFA peak score, PCT, CRP, isolated pancreatic injury, posttraumatic ARDS, organ failure before first intervention, and different groups were associated with severe complications ($P < 0.05$). Notably, the PCD group was significantly less likely to develop into severe complications (Relative Risk [RR], 0.43; 95% CI, 0.25-0.75; $P = 0.003$). In adjusted multivariate analysis, APACHE II peak score, PCT and different groups were still associated with severe complications ($P < 0.05$). Compared with the LAP group, the adjusted relative risk (aRR) of severe complications for the PCD group was 0.52 (95% CI, 0.30-0.90; $P = 0.020$) (**Table 3**).

PSM, IPTW and OW were adopted to estimate efficacy in different groups in order to make the results robust. The absolute SMD of baselines characteristics before and after propensity score matching or weighting are presented in the **Table S2** (Additional file 2) and the balance were significantly improved

than before as shown in the **figure S1** (Additional file 3). Obviously, the results of three models of sensitivity analysis are consistent with modified Poisson regression (**Figure 2**). Compared with the LAP group, the relative risk of severe complications for the PCD group in PSM model was 0.53 (95% CI, 0.28-0.99; $P = 0.035$), 0.37 (95% CI, 0.18-0.75; $P = 0.006$) in IPTW model, and 0.55 (95% CI, 0.31-0.99; $P = 0.046$) in OW model.

No. of Reinterventions as Secondary Outcome

In the PCD group, 17.2% of patients ($n=5$) underwent reoperative, and 34.5% ($n=10$) underwent PCD procedure more than once. Another 6.9% ($n=2$) of patients underwent the above two reinterventions. For the LAP group, the rates corresponding to the type of reinterventions were 18.9% ($n=17$), 35.6% ($n=32$), 20% ($n=18$), respectively. The mean number of reinterventions per patient throughout the course of treatment was similar in the two groups (1.8 vs 2.6, $P = 0.067$) (**Table 4**).

As shown in **Table 5**, no in-hospital mortality occurred in the PCD group, and 12.2% of patients (11/90) in the LAP group died, but there was no statistically significant difference between the two groups. The incidence of new-onset renal failure, pancreatic fistula grade B/C, hemorrhage grade B/C, other gastrointestinal fistulas, and intra-abdominal abscess in the LAP group was significantly higher than that in the PCD group ($P < 0.05$). Compared with the LAP group, the incidence of pancreatic pseudocyst was higher with PCD group (20.7% vs 5.6%, $P = 0.024$). With regard to hospital resource use, there was a shorter LOS in the PCD group (median [IQR], 30 [22-54] vs 63.5 [39-85.75] days; $P < 0.001$).

Discussion

The management strategy associated with the optimal clinical outcomes for patients with pancreatic trauma remains ambiguous. Previous retrospective studies were mostly descriptive reports on the treatment process, and some comparative studies only focused on the operative methods of different injury grades. Our study, based on the relatively large sample size in a regional trauma center, differ from these earlier studies, and as a consequence the possibility to compare novelly the outcomes of PCD vs LAP as initial management strategies in blunt high-grade patients with stable hemodynamics and no diffuse peritonitis. This study firstly demonstrate that the initial PCD without open the retroperitoneum significantly reduces the incidence of severe complicates and does not require more invasive reinterventions compared with LAP.

Both of the Eastern Association for the Surgery of Trauma (EAST) and the results from an international conference consensus recommended OM for grade III/IV pancreatic injuries, because failure of NOM leads to treatment delays and increased complications.[22, 23] However, the only two consensus reports so far are based on weak evidence. In addition, the results of the conference consensus put forward the criteria of NOM was that patients be stable and without associated organ injuries requiring LAP, and they suggested that PCD and endoscopic management might be the treatment options in selected centers with advanced skills. Kong et al found that endoscopic management could improve success rate of NOM and lower the incidence of pancreatic-related complications in hemodynamically stable patients with

blunt pancreatic trauma, however, the premise was that strictly defined selection criteria should be used for NOM [41]. It's difficult to pool findings from these studies due to heterogeneity in study participants, interventions, and comparison groups. We clearly defined different groups, conducted a comparative analysis, and adjusted for the effects of confounding and selection bias. Our results extending previous research and indicating significant improvement in the clinical outcomes with the use of NOM strategy based on initial PCD.

The reduced risk of severe complications for PCD seen in this study is potentially attributable to several factors. First, it is well known that in various diseases, minimally invasive techniques bring less surgical stress than LAP, resulting in lower systemic proinflammatory responses [42]. Second, the more pronounced proinflammatory response invoked by LAP may cause organ failure or worsen pre-existing organ failure, especially in critically ill patients who are already suffering from a severe multiple organ injuries, and these patients have a series of complex pathophysiological conditions of serious posttraumatic internal environment disorders and hypoimmunity [43]. More importantly, external drainage of initial PCD combine with the internal drainage of subsequent ERCP-guided stent placement achieves the favorable drainage effect, which can reduce various complications [27, 29, 44]. The retroperitoneal space is like Pandora's box. Opening this space to expose the pancreas, the normal anatomy is destroyed, just like opening the magic box. Leakage of pancreatic juice and aseptic peripancreatic fluid collection are no longer limited to this space, which spreads to the abdominal cavity to form pancreatogenic ascites [45]. On this basis, LAP may increase the chance of infection, damaging the peritoneal defense barrier, and causing pancreatogenic peritonitis. Combined with the tissue erosion caused by activation of pancreatic enzymes, can lead to fatal complications. PCD as the first step, which can quickly relieve intra-abdominal hypertension, drain peripancreatic fluid collections and so on. In the meantime, it also avoids traditional surgical drainage and reduces the risk of systemic and local complications [46]. Subsequently, ERCP-guided stent placement can bridge the ductal disruption and reduce the incidence of fistula by decreasing intraductal pressure and promoting antegrade flow of pancreatic juice. It has been successfully used to heal MPD disruptions and treat the pancreatic-related complications in some reports [32, 47].

Our results suggest that patients with blunt high-grade pancreatic trauma who are haemodynamically stable and no diffuse peritonitis should undergo initial PCD instead of LAP. Although the LAP group had poor pathophysiological conditions in pre-intervention (i.e., higher Apache II peak score, more concomitant injuries, and older), we still saw that the LAP group had a high risk of worse outcomes than the PCD group after propensity score matching and weighting. Similar to the mortality was 9.2% (11/119) in our study, the Western Trauma Association (WTA) Multicenter Trials Group on Pancreatic Injuries found that the mortality was 7% (30/426) in high-grade injuries [17]. We did not find significant difference in mortality between the two groups. These patients, who are in a relatively stable clinical condition, seem capable of sustaining the larger surgical stress and proinflammatory hit induced by LAP. In addition, these patients might benefit from the improvement of care capacity for severe trauma and critical illness. Another explanation may be that, due to their lower a priori risk of death, the sample size in this study is not enough to detect the difference in death between the two groups.

Looking from an overall perspective, the mean number of reinterventions per patient did not differ between two groups. Moreover, the LAP group had a higher rate of reoperation compared with the PCD group (38.9% vs 24.1%) and more severe complications, which indirectly reflected that opening the retroperitoneum may lead to severe adverse events requiring invasive reinterventions. Addison et al compared 29 patients who underwent OM with 32 patients who underwent NOM, and found that patients who underwent OM were more severely injured, had higher mortality (27.6% vs 3.1%), and suffered more complications [33]. The incidence of renal failure was higher in the LAP group. The results of our previous study also showed that renal failure was significantly associated with the risk of mortality after undergoing LAP [48]. Furthermore, compared with the PCD group, the LAP group had a higher incidence of pancreatic-related complications (i.e., pancreatic fistula grade B/C, hemorrhage grade B/C, other gastrointestinal fistulas, and intra-abdominal abscess). Pancreatic leakage, caused by high-grade pancreatic trauma, can spread in the retroperitoneal space and along this space to the abdominal cavity [45]. In the process of multiple diffusion pathways, pancreatic enzyme corrosion and cross fascia diffusion of inflammation lead to a series of pancreatic-related complications. Unfortunately, opening the retroperitoneal space through LAP is likely to accelerate this process. Another notable difference between two groups was the significantly higher rates of pancreatic pseudocyst in the PCD group. This finding is consistent with those of some previous studies. Koganti et al found that the development of pseudocysts in haemodynamically stable patients is associated with the success of NOM [25]. Other studies have demonstrated shorter LOS in NOM patients, and we did find similar results in the PCD group [33]. The longer LOS in the LAP group is not surprising, since it was related almost exclusively to severe postoperative complications. The conversion rate of LAP was 24.1% (7/29) in the PCD group. Ando et al found that the conversion rate was 40% (4/10) after undergoing the initial PCD or stent placement [34]. We believe that this combination of percutaneous peripancreatic external drainage and the bridge stenting-based internal drainage facilitated the success of NOM, and can avoid LAP to a certain extent.

Given the expertise of NOM strategy based on initial PCD is absent and the patient is clinically unfit for transport to a tertiary referral centre, LAP may still be acceptable. In patients with grade III injuries, the incidence of severe complications was significantly higher in patients who underwent operative drainage alone than in patients who underwent distal pancreatectomy (100% vs 50%, $P=0.05$). Therefore, we suggested that distal pancreatectomy is a valid option for grade III injuries. This result validates the recommendations of most management strategies [14, 15, 22]. Patients with grade IV injuries who underwent operative drainage alone also had a higher incidence of severe complications (68.3%). Lin et al found that peripancreatic drainage can be used as an alternative measure for grade III injuries, however, drainage alone is not adequate and further stenting or reoperation is required due to the higher incidence of complications [49]. Regrettably, since partial pancreatectomy was not observed in grade IV injuries, we are unable to talk about this point and these constitute important aims for future study.

A varied number and combination of interventions were adopted in managing the 119 patients in this study. Of the patients requiring a second or third procedure in the form of LAP or PCD, the majority of cases were necessary reinterventions for complications. Our study focuses on the comprehensive PCD-

based strategy rather than on one specific interventions measures. Seven patients were converted to LAP due to failure of the initial PCD strategy. To avoid a selection bias, we chose to include them in the PCD group because we wanted to present the overall phenomenon of pancreatic trauma management in the NOM strategy. This gives what is essentially an intention-to-treat analysis of a PCD-based strategy. As we have discussed previously, patients with high-grade pancreatic trauma are a complex population, with no one-size-fits-all management strategy. It is therefore expected that in the evolution of treatment concept, a shift will occur from OM to NOM to an increase in the use of endoscopic and interventional radiological procedures for selected patients.

Limitations

This study has several limitations. It is possible that measurement errors and hidden or unknown confounding factors, which are not accounted for in our analyses, may have influenced results. Using per-protocol predefined case record forms for data extraction and well-defined patient inclusion criteria, however, reduced the risk of measurement errors to a minimum. For another, the included cohorts did not capture data on pretherapeutic imaging, which may influenced the decisions to perform PCD or LAP. Second, this is a single-center retrospective study spanning 13 years. Time periods is neither included in univariate nor in multivariate analysis. However, it may have been a factor to adjust for per se. Because the knowledge and practice of trauma care, imaging technology and lifesaving interventions have developed significantly during this period. The PCD group might have benefited from overall improvements in care, not specifically related to the management strategy. In addition, our LAP cohort represents a group of patients benefiting from years of experience with that technique, and the patients comprising the PCD group include our first patients treated with the techniques of PCD and ERCP-guided stent placement. This might have biased the comparison against the PCD group. Despite the inherent limitations exist in our study, it still provides a certain degree of evidence to guide clinical decision-making for this serious and complex disease.

Conclusion

For blunt high-grade pancreatic trauma patients with stable hemodynamics and no diffuse peritonitis, initial PCD strategy without open the retroperitoneum was associated with a significant reduction in the incidence of severe complications (Clavien-Dindo classification $\geq \text{III}$) and did not increase reinterventions compared with initial LAP. This could offer an effective option to intensify NOM, and may improve the clinical outcomes of pancreatic trauma. Further randomized controlled trials are warranted to validate these results.

Abbreviations

LAP: Laparotomy; PCD: Percutaneous Drainage; MPD: Main Pancreatic Ductal; NOM: Nonoperative Management; CIs: Confidence Intervals; PSM: Propensity Score Matching; IPTW: Inverse Probability of Treatment Weighting; OW: Overlap Weighting; SMD, Standardized Mean Differences; BMI: Body Mass

Index; ISS: Injury Severity Score; APACHE-II Score: Acute Physiology and Chronic Health Evaluation II score; SOFA Score: Sequential Organ Failure Assessment Score; ARDS: Acute Respiratory Distress Syndrome; PCT: Procalcitonin; CRP: C-reactive Protein; TTD: Time to Diagnosis; IQR: Interquartile Range; SD: Standard Deviation; AAST-OIS: American Association for the Surgery of Trauma Organ Injury Scale; EAST: Eastern Association for the Surgery of Trauma; WTA: Western Trauma Association.

Declarations

Details of ethics approval

We obtained the approval of the Institutional Review Board (Ethics committee of Jinling Hospital, Nanjing, China. No. 2021DZGZR-YBB-009), and all the analyses were performed in accordance with the committee's regulation.

Consent for publication

All the authors have reached the agreement for publication.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors report no conflict of interest.

Funding

This study was supported by Jinling Hospital Scientific Research Project (No. YYZD2021011) and National Natural Science Foundation of China (No. 81770532).

Authors' contributions

Kaiwei Li, and Wensong Chen contributed equally to this work. K.L and W.D contributed to the study concept and design. K.W, C.Y, Y.D, and X.W were involved in literature search and data extracting. K.L W.C and Y.L analyzed and interpreted the data. K.L and W.C drafted the manuscript; all authors were involved in quality assessing of the articles. Y.L, W.D and W.L supervised the study. All authors read and approved the final manuscript.

Acknowledgements

None.

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Tables

Table1. Characteristics of the Patients at Baseline.

Characteristic	PCD(n=29)	LAP (n=90)	PValue
Male sex, n (%)	26(89.7)	81(90.0)	1.000
Age, mean (SD)	31.41(11.74)	37.09(12.78)	0.036
BMI, mean (SD)	21.51(2.81)	22.17(3.56)	0.363
ISS, median (IQR)	16(12-16)	16(12.5-21.0)	0.337
APACHE II Peak Score, median (IQR)	6(3.5-7.5)	7 (4.75-10.25)	0.013
SOFA Peak Score, median (IQR)	2 (1-3)	3(1-5)	0.061
Albumin, mean (SD)	33.21(6.81)	30.94(5.62)	0.123
PCT, median (IQR)	0.36(0.16-1.57)	0.79(0.17-4.31)	0.096
CRP, median (IQR)	66.7(27.1-147.4)	115.6(45.2-184.1)	0.070
TTD, median (IQR)	24(6-96)	12(6-48)	0.655
AAST-OIS grade, n (%)			0.130
I	8(27.6)	41(45.6)	
II	21(72.4)	49(54.4)	
Isolated pancreatic injury, n (%)			0.001
No	13(44.8)	72(80.0)	
Yes	16(55.2)	18(20.0)	
Vascular injury, n (%)			0.040
No	28(96.6)	72(80.0)	
Yes	1(3.4)	18(20.0)	
Posttraumatic ARDS, n (%)			0.077
No	26(89.7)	65(72.2)	
Yes	3(10.3)	25(27.8)	
Organ Failure before first intervention , n(%)			0.070
No	28(96.6)	73(81.1)	
Yes	1(3.4)	17(18.9)	

LAP, laparotomy; PCD, percutaneous drainage; BMI, body mass index; ISS, Injury Severity Score; TTD, Time to Diagnosis; ARDS, Acute Respiratory Distress Syndrome; APACHE-II Score, Acute Physiology and Chronic Health Evaluation II score; SOFA Score, Sequential Organ Failure Assessment Score; PCT, Procalcitonin; CRP, C-reactive protein; IQR, interquartile range; SD, Standard Deviation.

Table 2. No. of patients with Clavien-Dindo classification of PCD vs LAP at different injury grades.

Initial Interventions	AAST Grade I (n=49)		AAST Grade II (n=70)	
	CD ≤ III _a	CD ≥ III _b	CD ≤ III _a	CD ≥ III _b
PCD group				
PCD alone	6	1	2	3
PCD + Stent	1	0	11	5
LAP group				
Operative drainage alone	0	13	13	28
Distal pancreatectomy	10	10	0	0
Pancreaticojejunostomy	2	1	0	3
Open Abdomen	0	5	0	5

CD: Clavien-Dindo classification, in this category include those that resulted in surgical, endoscopic, or interventional radiological intervention (Clavien-Dindo classification III), without general anesthesia (III_a), and required general anesthesia (III_b); required care in the intensive care unit (Clavien-Dindo classification IV); or resulted in death (Clavien-Dindo classification V).

Table 3. Primary outcome based on the modified Poisson regression model.

Characteristic	Univariate modified Poisson			Multivariate modified Poisson		
	Relative Risk	95% CI	P Value	Relative Risk	95% CI	P Value
Male sex	1.06	0.66-1.71	0.821	-	-	-
Age (Years)	1.01	1.00-1.02	0.082	1.00	0.99-1.01	0.973
ISS	1.02	1.01-1.04	0.008	1.01	0.99-1.03	0.264
APACHE II Peak Score	1.05	1.03-1.08	<0.001	1.04	1.01-1.07	0.015
SOFA Peak Score	1.08	1.05-1.12	<0.001	0.96	0.90-1.02	0.171
Log PCT *	1.16	1.08-1.24	<0.001	1.11	1.01-1.23	0.028
Log CRP *	1.20	1.01-1.44	0.042	1.01	0.83-1.22	0.943
Albumin	0.98	0.96-1.01	0.228	-	-	-
Log TTD *	1.07	0.97-1.17	0.199	1.04	0.94-1.16	0.442
BMI	1.02	0.99-1.06	0.201	-	-	-
AAST-OIS grade						
0	Ref					
1	1.09	0.81-1.45	0.577	-	-	-
Isolated pancreatic Injury						
No	Ref					
Yes	0.64	0.42-0.95	0.028	0.83	0.56-1.23	0.360
Vascular Injury						
No	Ref					
Yes	1.23	0.90-1.68	0.198	1.00	0.76-1.33	0.982
Posttraumatic ARDS						

No	Ref					
Yes	1.37	1.06-1.79	0.018	0.85	0.63-1.14	0.266
Organ Failure before first intervention						
No	Ref			Ref		
Yes	1.67	1.36-2.05	<0.001	1.21	0.95-1.53	0.118
Group						
LAP	Ref			Ref		
PCD	0.43	0.25-0.75	0.003	0.52	0.30-0.90	0.020

LAP, laparotomy; PCD, percutaneous drainage; BMI, Body Mass Index; ISS, Injury Severity Score; APACHE-II Score, Acute Physiology and Chronic Health Evaluation II score, SOFA Score, Sequential Organ Failure Assessment Score; ARDS, Acute Respiratory Distress Syndrome; PCT, Procalcitonin; CRP, C-reactive protein; TTD, Time to Diagnosis; IQR, interquartile range; SD, Standard Deviation; Ref, Reference. *To correct for non-normal distribution, PCT, CRP, and TTD variables were log-transformed.

Table 4. Summary of Reinterventions.

	PCD (n=29)	LAP (n=90)	PValue
Type of Reinterventions, n (%)	17(58.6)	67(74.5)	0.158
LAP, n (%)	5(17.2)	17(18.9)	0.842
PCD ± Stent, n (%)	10(34.5)	32(35.6)	0.916
Both of the above, n (%)	2(6.9)	18(20.0)	0.152
No. of Reinterventions			
1, n (%)	7(24.1)	22(24.4)	0.973
2+, n (%)	10(34.5)	45(50.0)	0.145
Mean No. of Reinterventions Per Patient	1.8	2.6	0.067

Table 5. Post-intervention Complications of PCD vs LAP.

Complications	PCD(n=29)	LAP(n=90)	PValue
New-onset organ failure, n (%)	2 (6.9)	20 (22.2)	0.097
Circulatory failure	2 (6.9)	13 (14.4)	0.335
Respiratory failure	0	8 (8.9)	0.197
Renal failure	0	13 (14.4)	0.036
In-hospital mortality, n (%)	0	11(12.2)	0.064
Hemorrhage grade B/C, n (%)	2 (6.9)	23 (25.6)	0.036
Pancreatic fistula grade B/C, n (%)	9 (31)	53 (58.9)	0.011
Sepsis, n (%)	4 (13.8)	17 (18.9)	0.780
Pancreatic pseudocyst, n (%)	6 (20.7)	5 (5.6)	0.024
Other gastrointestinal fistulas, n (%)	2 (6.9)	27 (30)	0.012
Intra-abdominal abscess, n (%)	1 (3.4)	22 (24.4)	0.013
IAH/ACS, n (%)	0	4 (4.4)	0.571
LOS, median (IQR)	30(22-54)	63.5 (39-85.75)	0.001

IAH, intra-abdominal hypertension; ACS, abdominal compartment syndrome; LOS, Length of Stay; IQR, interquartile range.

Figures

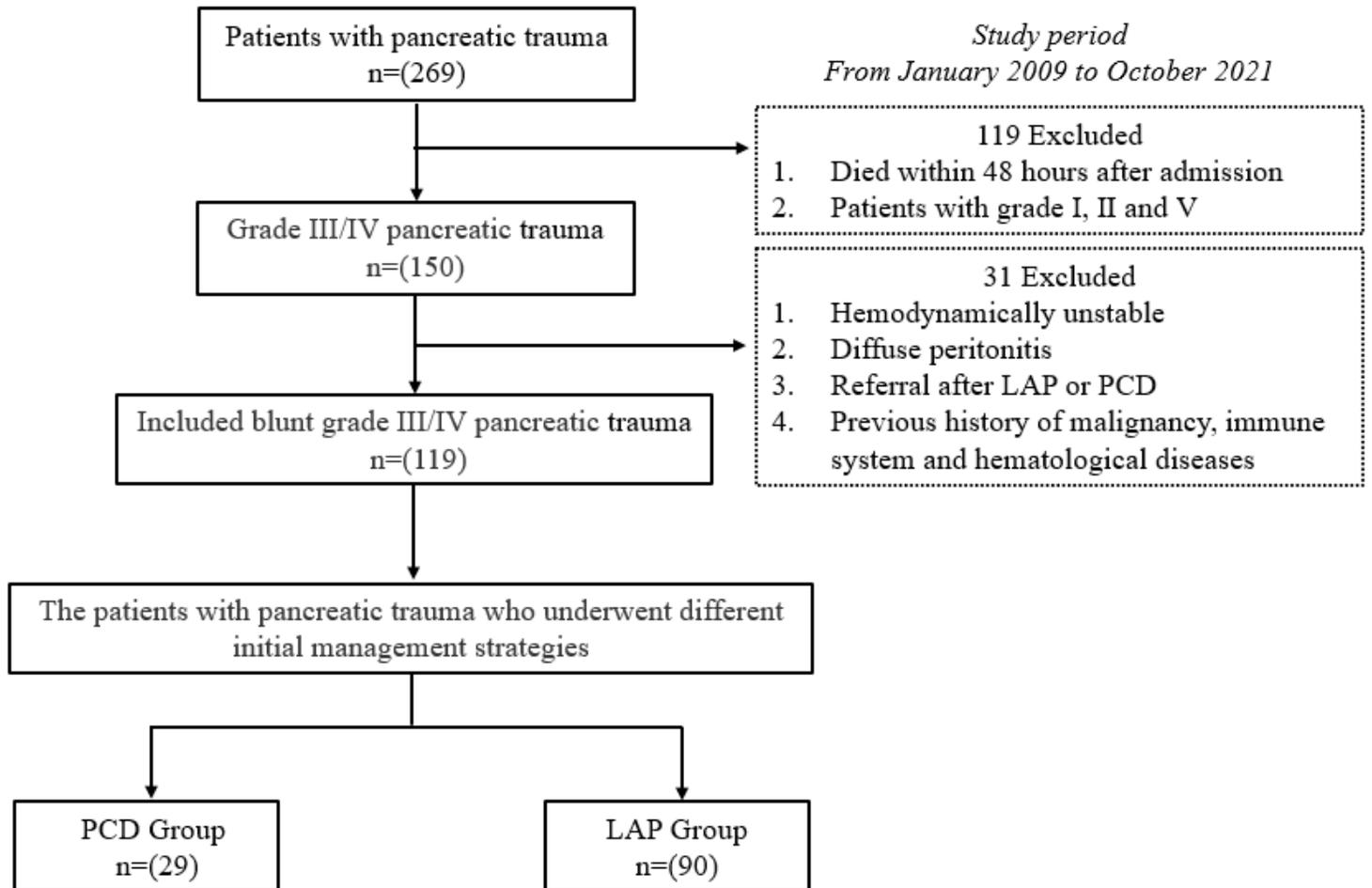


Figure 1

Study Flow-Chart.

Pancreatic trauma grade according to AAST-OIS (American Association for the Surgery of Trauma Organ Injury Scale). Abbreviations: LAP, laparotomy; PCD, percutaneous drainage.

Figure 2

Events of severe complications for PCD vs LAP and sensitivity analysis results.

Unadjusted, univariate modified Poisson regression model; Adjusted, multivariate modified Poisson regression model; PSM, propensity score matching; IPTW, inverse probability of treatment weighting; OW, overlap weighting. Events of severe complications associated with different management strategies are measured as those with a Clavien-Dindo classification of \geq IIIb.

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