An AAST-MITC analysis of pancreatic trauma: Staple or sew? Resect or drain?

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INTRODUCTION: Pancreatic trauma results in high morbidity and mortality, in part caused by the delay in diagnosis and subsequent organ dysfunction. Optimal operative management strategies remain unclear. We therefore sought to determine CT accuracy in diagnosing pancreatic injury and the morbidity and mortality associated with varying operative strategies.

METHODS: We created a multicenter, pancreatic trauma registry from 18 Level 1 and 2 trauma centers. Adult, blunt or penetrating injured patients from 2005 to 2012 were analyzed. Sensitivity and specificity of CT scan identification of main pancreatic duct injury was calculated against operative findings. Independent predictors for mortality, adult respiratory distress syndrome (ARDS), and pancreatic fistula and/or pseudocyst were identified through multivariate regression analysis. The association between outcomes and operative management was measured.

RESULTS: We identified 704 pancreatic injury patients of whom 584 (83%) underwent a pancreas-related procedure. CT grade modestly correlated with OR grade (r^2 0.39) missing 10 ductal injuries (9 grade III, 1 grade IV) providing 78.7% sensitivity and 61.6% specificity. Independent predictors of mortality were age, Injury Severity Score (ISS), lactate, and number of packed red blood cells transfused. Independent predictors of ARDS were ISS, Glasgow Coma Scale score, and pancreatic fistula (OR 5.2, 2.6–10.1). Among grade III injuries (n = 158, 22.4%), the risk of pancreatic fistula/pseudocyst was reduced when the end of the pancreas was stapled (OR 0.21, 95% CI 0.05–0.9) compared with sewn and was not affected by duct stitch placement. Drainage alone in grades IV (n = 25) and V (n = 24) injuries carried increased risk of pancreatic fistula/pseudocyst (OR 8.3, 95% CI 2.2–32.9).

CONCLUSION: CT is insufficiently sensitive to reliably identify pancreatic duct injury. Patients with grade III injuries should have their resection site stapled instead of sewn and a duct stitch is unnecessary. Further study is needed to determine if drainage alone should be employed in grades IV and V injuries. (*J Trauma Acute Care Surg.* 2018;85: 435–443. Copyright © 2018 American Association for the Surgery of Trauma. All rights reserved.)

LEVEL OF EVIDENCE: Epidemiologic/Diagnostic study, level III.

KEY WORDS: Pancreas; staple; sew; leak; drainage; resection.

The diagnosis, classification, and treatment of pancreatic injury remain a challenge. Diagnosis is difficult because of the retroperitoneal location leading to delayed diagnosis based on physical examination, laboratory, and radiographic data. These factors contribute to a delay in treatment, which is associated with worse outcomes. Additionally, pancreatic injury only occurs in 1–5% of blunt abdominal trauma and less frequently in penetrating abdominal trauma adding to the diagnostic and therapeutic complexity.[1] When the diagnosis is delayed, mortality is much higher than the commonly quoted range of 17% to 21%.[1–3] Concomitant injury to nearby structures contributes to the increased morbidity and mortality with up to 30% of deaths caused by sepsis and multiple organ system failure.[4]

Overall morbidity ranges from 11% to 62%.[1,4–7] The most common pancreas-related complications are pancreatic fistula (8–19%), intra-abdominal abscess (9–22%), wound infection (11–19%), pancreatitis (10%), and pseudocyst formation (9–19.5%).[1,3,6–8] These complications carry a significant resource use burden with prolonged hospital stay, chronic nutritional support, interventional radiologic procedures, and possibly reoperation, which have effects on patient quality of life.[4,5,9,10]

To assist in identification and determining the appropriate treatment approach, several classification systems have been developed to categorize pancreatic injury. The American Association for the Surgery of Trauma (AAST) developed the most widely used and validated classification system grading injury from I to V based on the extent of contusion, laceration, pancreatic duct involvement, location of injury, and disruption of the pancreatic head (Table 1).[11] Interestingly, pancreas-related complications may be an interplay between grade and intervention because complications have been reported to be higher in grade III injuries (present in over 60%) compared with other grades.[7]

Consensus regarding the indications for resection and/or drainage and endoscopic stenting are lacking. In patients with abdominal trauma who do not require immediate laparotomy, one must rely on physical examination, laboratory, and radiographic data to determine the treatment approach. Most studies indicate that the presence of main pancreatic ductal injury and the location of the injury predict outcome and therefore the need for surgery. Historically, distal main duct disruption (injury grade III) would mandate distal pancreatectomy.[1,2,4,9,12] Pancreaticoduodenectomy is indicated only if the pancreatic head injury involves the major pancreatic duct and ampulla (grade V).[1,4] However, recent investigations suggest that nonoperative management or closed drainage alone rather than resection may provide acceptable outcomes. Additionally, the role of endoscopic stenting in reducing morbidity has not been well characterized until Kong et al. retrospectively determined criteria to promote success in endoscopic management of pancreatic injury.[1,2,4,12,13] Their criteria were threefold: (1) hemodynamically

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TABLE 1. AAST Pancreatic Injury Grading System

Grade		Injury Description
I	Hematoma	Minor contusion without ductal injury
	Laceration	Superficial laceration without ductal injury
II	Hematoma	Major contusion without ductal injury or tissue loss
	Laceration	Major laceration without ductal injury or tissue loss
III	Laceration	Distal transection or pancreatic parenchymal injury with ductal injury
IV	Laceration	Proximal transection or pancreatic parenchymal injury involving the ampulla
V	Laceration	Massive disruption of the pancreatic head

unstable patients or signs of peritonitis should undergo laparotomy, (2) endoscopic management should be reserved for those patients at high risk of failure from nonoperative management such as suspicious findings on CT, and (3) delayed endoscopic management can be reserved to salvage patients who are stable but have persistently elevated amylase levels or known duct injury.[13]

Given the impact of a delay in diagnosis, the rarity of the injury as well as the evolving treatment for pancreatic injury, we sought to measure the accuracy of CT scan as well as the outcomes related to treatments for higher grade injuries in a multicenter study.

METHODS

Data Collection

We performed a retrospective, multi-institutional study after Institutional Review Board approval from all participating sites. Each center provided de-identified data regarding patients admitted for traumatic pancreas injuries from 1/1/2005 through 12/31/12 who met the following inclusion criteria:

1. Age ≥18
2. Admission for blunt or penetrating trauma with ICD9 codes of 863.80–863.84, 863.89–863.94, 863.99. These codes correspond to injuries of the pancreas as well as to nonspecified gastrointestinal tract injuries. Those nonspecified injuries who were found to not have pancreatic injury were excluded
3. Survival >48 hours

Exclusion criteria:

1. Age <17
2. Death within 48 hours of arrival
3. Known previous history of pancreatic surgery

Patient demographics, mechanism of injury, injury severity, admission physiology, diagnostic modalities, treatments, and outcomes were collected for each patient. Complications included pancreatitis, wound infection, deep space infection, ICU-related infections, fistula, abscess, hemorrhage, pseudocyst, anastomotic leak, length of stay, and overall hospital cost. All abdominal operative reports were reviewed and pertinent data were abstracted by the primary site. CT scan images were uploaded in DICOM format to the web portal for independent review by three radiologists at the primary site. The grade of the pancreatic injury was defined by operative report description whenever available but otherwise was based upon radiographic data.

Statistical Analysis

Patients were stratified by injury grade as defined by radiographic (when available) and operative data. Radiologists at the primary site were blinded to all clinical data and treatment decisions. In cases where there was a discrepancy between the radiographic and operative grade, the operative grade was used for analyses. In cases where there was a discrepancy between the grade assigned by the three radiologists, these cases were reviewed jointly and a grade assignment was made after agreement between the three radiologists. Correlation coefficient where both radiologic and operative grading were present was measured using Spearman's rho.

Patients were stratified into those who underwent urgent/emergent laparotomy and those who were managed nonoperatively. Student's t test was used to assess differences in means for continuous variables and Pearson's χ^2 was used to assess for differences in proportions in categorical variables. Mortality, ARDS, organ space infection, and pseudocyst/pancreatic fistula were analyzed using multivariate logistic regression analyses. Regression models were developed using backwards stepwise method maintaining confounders if they resulted in more than a 10% change in the odds of association with the outcome of interest, had a p value of <0.1, or were thought to be clinically relevant. Receiver operating curves with their 95% CIs for the models as well as Hosmer–Lemeshow test for goodness of fit were performed to assess model calibration. Outcomes for grades III, IV, and V injuries were analyzed separately.

RESULTS

There were 704 pancreatic trauma patients of whom 585 (83.1%) underwent laparotomy. Overall mortality rate was 7.5% (53/704) and was 7.5% (44/585) in the operative group and 7.6% (9/119) in the nonoperative group. More than half of the patients (n = 430, 61.1%) were bluntly injured and all but one of the patients in the nonoperative group had a blunt mechanism. Overall Injury Severity Score (ISS) was similar between the operative and nonoperative groups, but the abdominal abbreviated injury score was higher in the operative group. Admission vital signs and lactate (n = 454) were similar between operative and nonoperative groups. The initial FAST examination results (n = 366) were positive in 9/62 (14.5%) bluntly injured patients and 164/304 (54%) penetrating trauma patients. A preoperative CT scan was obtained in 29.7% of cases. The operative group was younger, predominantly male, had a higher incidence of penetrating injury, had an increased need for packed red blood cells (pRBCs), had a higher pancreatic grade injury, and had a lower systolic blood pressure (SBP) on admission compared with the nonoperative group.

Main Pancreatic Duct Injury Diagnosis

The primary diagnostic modality for ductal injury was surgery (61.2%, n = 430) followed by CT (25.8%, n = 181). A total of 585 patients underwent laparotomy of which 574 operative reports contained a sufficient description to categorize the operation and the extent of injury by AAST grade. There were 182 patients (31.7%) with a ductal injury diagnosed at surgery. Of those with ductal injury diagnosed at surgery, 61 had preoperative CT scans. CT scan identified 48/61 (78.7%) of these

patients as having a main ductal injury. The 13 patients who were thought to have no duct injury on CT were identified as having a grade III injury in nine cases and a grade IV injury in one case.

Of those who did not have a main ductal injury at surgery (grade I or II injuries), 138 had preoperative CT scans. The CT was interpreted as having a main ductal injury in 38.4% (53/138). Therefore, CT had a sensitivity of 78.7% and a specificity of 61.6% in classifying main pancreatic ductal injury. Spearman's rho was calculated at 0.39 (95% CI, 0.25, 0.53) for the correlation between operative and CT grade.

In terms of concordance among the radiologists, all three radiologists agreed regarding the presence or absence of ductal injury in 75.1% (n = 160) of cases; two radiologists agreed in the remaining 24.9% (n = 53) cases in which the three radiologists needed to come together to reach consensus.

Predictors of Outcome

In univariate analysis age, ISS, SBP, heart rate, GCS, lactate, hematocrit, need for transfusion of pRBCs, and development of postoperative bleeding predicted mortality whereas gender, injury mechanism, pancreatic fistula, anastomotic leak, pancreatic abscess, and AAST pancreatic injury grade did not. Penetrating injury as well as combining oversewing and stapling of the pancreas was associated with a higher rate of pancreatic fistula or pseudocyst. Higher penetrating abdominal trauma index (PATI) was associated with a higher incidence of ARDS (Table 2). In multivariate analysis, the independent predictors of mortality were age, ISS, SBP, heart rate (HR), lactate, and need for transfusion of pRBCs (Table 3). The model's area under the curve (AUC) was 0.86 (95% CI 0.81–0.91, Hosmer–Lemeshow $\chi^2 = 7.2$, $p = 0.51$). Independent predictors of ARDS were age, ISS, GCS score, lactate, need for pRBC transfusion, and the development of a pancreatic fistula (model AUC = 0.82, 95% CI 0.76–0.87, Hosmer-Lemeshow $\chi^2 = 12.1$, $p = 0.15$) (Table 3).

Among grade III injuries, independent predictors for the development of pseudocyst/pancreatic fistula were HR, postoperative bleeding, and stapling the transected end of the pancreas (stapling was protective—OR 0.21, 95% CI 0.05–0.88). Oversewing (OR 0.51, 95% CI 0.1–2.7) or placing a duct stitch (OR 0.65, 95% CI 0.2–1.9) was not associated with a reduced rate of pseudocyst/fistula formation (Table 3). The model's AUC was 0.74 (95% CI 0.64–0.83, Hosmer–Lemeshow $\chi^2 = 5.54$, $p = 0.70$).

Operative Management

The most common procedure performed for pancreatic injury was wide external drainage (n = 282, 48.2%) followed by distal pancreatectomy (n = 161, 27.5%). Grade III injuries were most frequently managed by distal pancreatectomy (133/158, 84.2%), wide external drainage for grade IV for injuries (6/9, 66.7%), and Whipple for grade V injuries (11/15, 73%) (Table 4).

Grade III injuries managed by distal pancreatectomy (133/158) had a 6% mortality rate compared with 16% for those without resection (25/158) ($p = 0.08$). The rates of pancreatic abscess (10.5% vs. 8.0%, $p = 0.70$), pseudocyst (5.3% vs. 12%, $p = 0.21$), and pancreatic fistula (29.3% vs. 36.0%, $p = 0.51$), return to the operating room for bleeding (6.0% vs. 15.8%, $p = 0.71$), bleeding from pseudoaneurysm (3.0% vs. 4.0%, $p = 0.80$), mean hospital length of stay (24.9 vs. 26.8), and mean hospital charges ($299,000 vs. $269,000, $p = 0.60$) were similar. The two groups were similar in injury severity with the exception of a higher Abbreviated Injury Scale head score for the drainage group compared with the distal pancreatectomy group (1.5 vs. 0.6, $p = 0.01$), admission vital signs, lactate, number of pRBCs needed in the first 24 hours, age, and penetrating mechanism.

In the 133 patients who underwent distal pancreatectomy, information regarding the stapler thickness used was provided in the operative reports of only 47 patients: 16 (34%) were stapled with a 4.8-mm stapler, 16 (34%) with a 3.5-mm stapler, 14 (29.8%) with a 2.5-mm stapler, and 1 (2.1%) with a stepped stapler with a staple height range from 3 to 4.5 mm. The rates of either pseudocyst or pancreatic fistula formation for these stapler types were 5/16 (31.3%), 1/16 (6.3%), 6/14 (42.9%), and 1/1 (100%), respectively. Unfortunately, none of the operative reports mentioned the thickness of the pancreas itself.

In the 118 patients who developed a pancreatic fistula, the mean in situ drain time was 44.2 days with 62.7% of patients requiring a drain for more than 4 weeks. The mean drain time was

TABLE 2. Outcomes Stratified by Patient Characteristics and Management of Distal Pancreas

Outcome	Age (SD)	Male	Penetrating	Blunt	PATI (SD)	Stapled†	Sewn†	Stapled and Sewn†
Dead (n = 53)	50.6 (21.5)	41 (77.4%)	14/274	39/430	13.2 (2.4)	5/84	2/31	5/59
Alive (n = 651)	34.4* (14.5)	503 (77.3%)	(5.1%)	(9.1%)	11.5 (8.1)	(6.0%)	(6.5%)	(8.5%)
ARDS								
Yes (n = 58)	35.5 (14.2)	49 (84.5%)	25/273	33/430	15.8 (5.2)	8/83	5/31	8/59
No (n = 645)	35.6 (15.9)	494 (76.6%)	(9.2%)	(7.7%)	11.2* (8.1)	(9.6%)	(16.1%)	(13.6%)
Pancreatic abscess								
Yes (n = 31)	33.8 (12.4)	26 (83.9%)	21/273	10/429	11.0 (5.7)	7/84	4/31	3/59
No (n = 671)	35.7 (15.9)	516 (76.9%)	(7.7%)	(2.3%)	11.6 (8.2)	(8.3%)	(12.9%)	(5.1%)
Fistula/pseudocyst								
Yes (n = 128)	33.4 (14.2)	97 (75.8%)	71/273	57/427	12.8 (5.9)	18/83	11/31	19/59
No (n = 572)	36.0 (16.0)	444 (77.6%)	(26.0%)*	(13.4%)*	11.2 (8.6)	(21.7%)	(35.5%)	(32.2%)*

*Significant difference ($p < 0.05$).
†Among patients who had a distal pancreatectomy.
PATI, penetrating abdominal trauma index score; ARDS, adult respiratory distress syndrome.

TABLE 3. Predictors for Mortality, ARDS, and Pancreatic Pseudocyst/Fistula

Predictor	Mortality	ARDS	Pseudocyst/Fistula*
Age	**1.07 (1.05, 1.10)**	1.0 (0.98, 1.02)	1.02 (0.99, 1.06)
Gender	0.7 (0.3, 1.8)	0.7 (0.3, 1.6)	0.4 (0.1, 1.5)
ISS	**1.05 (1.02, 1.09)**	**1.027 (1.001, 1.054)**	1.01 (0.96, 1.05)
Admit SBP	1.0 (0.99, 1.01)	1.00 (0.99, 1.01)	0.99 (0.97, 1.00)
Admit HR	1.01 (0.99, 1.02)	1.00 (0.99, 1.02)	1.02 (1.00, 1.04)
Admit GCS	0.93 (0.87, 1.01)	**0.92 (0.86, 0.98)**	0.93 (0.85, 1.02)
Admit lactate	1.03 (0.98, 1.10)	1.02 (0.95, 1.08)	0.93 (0.85, 1.02)
Number of pRBCs in 24 h	1.04 (1.005, 1.08)	1.02 (0.98, 1.05)	1.00 (0.95, 1.05)
AAST injury grade	1.1 (0.7, 1.6)	0.9 (0.7, 1.3)	N/A
Postop bleed	1.3 (0.4, 4.2)	1.3 (0.5, 3.5)	**5.5 (1.6, 19.3)**
Stapled end*	—	—	**0.21 (0.05, 0.88)**
Oversewn end*	—	—	0.51 (0.10, 2.73)
Duct stitch*	—	—	0.65 (0.22, 1.93)

Boldface indicates statistical significance.
*Among patients who underwent distal pancreatectomy.
ARDS, adult respiratory distress syndrome; ISS, Injury Severity Score; SBP, systolic blood pressure; HR, heart rate; GCS, Glasgow Coma Scale; AAST, American Association for the Surgery of Trauma; pRBC, packed red blood cells.

not statistically significantly different between the stapled and sewn groups (35 days in the staple group compared with 21 days in the sewn group, $p = 0.26$). The presence of a pancreatic fistula was associated with a twofold increase in hospital length of stay (18 days vs. 37 days, $p < 0.05$).

Endoscopic retrograde cholangiopancreatography (ERCP) stent placement was infrequently used postoperatively. Despite the development of pseudocyst/fistula in 128/704 (18.2%), ERCP was employed for stent placement in only 8 (1.1%) patients. Of these patients, six were in patients who had a laparotomy (one grade I injury, two grade II injuries, two grade III injuries, and one grade IV injury).

When comparing grade III injury patients who underwent distal pancreatectomy, there were 61/155 (39.4%) who had the end stapled, 23/155 (14.8%) sewn, 53/155 (34.2%) stapled and sewn, and 18/155 (11.6%) had neither. Comparing those who had their pancreas stapled as opposed to oversewn showed no significant difference in age, PATI score, ISS, number of pRBCs in the first 24 hours or admission lactate, HR, blood pressure, or GCS score; however, those who underwent stapling of their distal end were significantly more likely to have had a penetrating mechanism (Table 5).

The number of patients in the grades IV and V injury groups were too small to make any definitive statements about outcomes relative to the type of procedure performed; however, combining grades IV and V injuries and comparing resection versus drainage procedures showed that drainage alone carried increased risk of pancreatic fistula/pseudocyst (OR 8.3, 95% CI 2.2, 32.9).

DISCUSSION

This multicenter, retrospective study assessed the current trends in pancreatic trauma management with a focus on grade III injuries and management of the pancreatic stump. Overall, 585 of 704 (83.1%) patients underwent surgical management, which is slightly higher than published by Ragulin-Coyne and colleagues in 2013 in their U.S. national survey discussing national trends in pancreatic management. Their study demonstrated an increasing trend of nonoperative management and slightly improved survival in the nonoperative group over the study period, likely reflecting an improvement in critical care, nutrition, and infection management. The mortality rate did not change for the operative group (decreased from 16.9% to 12.9, p = NS). They concluded that nonoperative management had increased over their study period, that complications increased slightly with operative management, and that a multidisciplinary approach should be used in the care of pancreatic

TABLE 4. Operative Procedures by AAST Pancreatic Injury Grade

Operative Procedure	I (n = 219)	II (n = 173)	III (n = 158)	IV (n = 9)	V (n = 15)
Exploration only	64 (29.2%)	15 (8.7%)	7 (4.4%)	0	0
Wide external drainage	143 (65.3%)	116 (67.1%)	16 (10.1%)	6 (66.7%)	1 (6.7%)
Distal pancreatectomy	1 (0.5%)	24 (13.9%)	133 (84.2%)	2 (22.2%)	0
Midsegment pancreatectomy	0	0	0	1 (11.1%)	0
Whipple	0	0	0	0	11 (73.3%)
Suture repair and drainage	11 (5.0%)	18 (10.4%)	2 (1.3%)	0	3 (20.0%)

AAST, American Association for the Surgery of Trauma.

TABLE 5. Patient Characteristics Comparing Stapled, Sewn, or Both in Those Who Had Distal Pancreatectomy

Characteristic	Stapled (n = 61)	Sewn (n = 23)	Stapled and Sewn (n = 53)
Age	31.7 (14.8)	31.9 (14.6)	32.9 (15.4)
Male gender	53 (86.9%)	18 (78.3%)	45 (84.9%)
Penetrating mechanism	38 (62.3%)	7 (30.4%)*	35 (66.0%)
PATI	14.7 (SD = 4.8, n = 38)	13.1 (SD = 2.5, n = 7)	15.3 (SD = 3.5, n = 35)
ISS	27.2 (12.7)	27.7 (13.1)	26.9 (11.7)
Number of pRBCs in 24 h	10.1 (SD = 13.6, n = 60)	8.0 (10.9)	7.5 (10.0)
Admit lactate (mg/dL)	6.6 (n = 46)	5.6 (n = 15)	5.6 (n = 33)

Continuous variables are described as means (SD).
PATI, penetrating abdominal trauma index score; ISS, Injury Severity Score; pRBC, packed red blood cells.
*$p < 0.05$, remaining comparisons are nonsignificant.

trauma.[14] Mortality rate in our series was only 7.5% and was similar in the operative and nonoperative. Our lower mortality rate may reflect the fact that our series was more recent than Ragulin-Coyne's National Inpatient Sample analysis reflecting further improvements in care over time or it may reflect differences in care from high-volume centers in our series relative to overall care delivered across the nation.[14] The possibility that pancreatic trauma outcomes may be influenced by trauma center volume and experience should be further studied.

Non-operative management of pancreatic injury has also proven controversial. Increasingly low-grade injuries (grade I and II) are managed conservatively, particularly in pediatric populations, whereas high-grade injuries involving the duct (grade III through grade V) are managed operatively. The study from 2013 by Beres et al. assessed the trends in management at two Level 1 trauma centers. After controlling for confounders, they determined that nonoperative management of higher-grade injuries (grades III through V) had an increase in complication rate and need for total parenteral nutrition.[15] In our series, all but three patients with grades III–V injuries underwent surgery making it impossible to determine the impact of nonoperative management on outcomes for these injuries.

In our series, 15 patients were operated on for grade V injury with 11 (73.3%) receiving a Whipple procedure. In a recent National Trauma Data Bank Study comparing those undergoing Whipple with those who did not in the setting of grade V injuries, outcomes were not improved with pancreaticoduodenectomy, suggesting conservative measures may be more appropriate for high-grade injuries.[16] Our study had too few patients with injury grades IV and V injuries to make any definitive statements, but there were trends toward increased pancreatic fistula and pseudocyst rates when pancreaticoduodenectomy was not performed. Further studies will need to be done to determine whether resection versus drainage alone is most appropriate for these high-grade injuries. With appropriate patient selection, it has been shown that up to 84% of patients undergoing a trauma pancreaticoduodenectomy may survive. Specific parameters have been shown to determine which patients would survive this radical resection and frequently required combined hepatobiliary and trauma surgery expertise.[17]

With respect to grade III injuries, our study shows that resection was associated with lower mortality and similar pancreas-related complication rates compared with those managed without resection. The question of how to manage the remnant duct remains a debate. Iacono et al. provides a surgeon's perspective on pancreatic injury and a management algorithm based on extent of parenchymal damage and site of ductal injury stating that "the duct is ligated separately whenever possible".[18] Ahmed et al. also suggested that the pancreatic gland be evaluated and if a duct injury is present it should be ligated.[1] Our study questions this surgical dogma. Pancreatic fistula and pseudocyst development was associated with oversewing the pancreatic remnant or placing a pancreatic duct stitch compared with stapling the transected end. According to Malgras et al., closure with suture or staples was not associated with outcome. They did, however, stated that there was concern for parenchymal necrosis with suture closure and increased risk of infectious complications with permanent suture. In Degiannis' study of pancreatic and duodenal injuries, the pancreatic duct was routinely ligated with a 5-0 vascular stitch and the pancreatic stump was closed with overlapping interrupted mattress sutures of polypropylene or silk material. They state that they had used a stapling technique but were not satisfied with the closure and reinforced the staple line frequently, but no statistical comparisons were made between the two techniques.[4] In a study by Sharpe et al., 17 patients had staple closure with a 12% fistula rate. Interlocking u-stitches were used in 44 patients with a fistula rate of 11%.[10] Vasquez et al. described their experience in which there was no difference in pancreatic fistula or intra-abdominal abscess rate when comparing pancreatic duct or stump closure with suture or stapler techniques. Most of these trauma studies either did not compare staple with sewing of the pancreatic remnant or were too small to exclude the possibility of type II error.

The majority of our knowledge regarding pancreatic fistula or pseudocyst formation after pancreatic transection comes from patients who underwent elective resection. A review article from Schoellhammer in 2014 indicates that leakage after pancreaticoduodenectomy (13%) is lower than that for distal pancreatectomy (30%).[19] Various surgical techniques for creating a pancreaticojejunostomy anastomosis have been described and will not be expounded upon save for that trauma surgeons involved in the reconstruction of patients after traumatic pancreaticoduodenectomy should be aware that creation of the pancreaticojejunostomy with a duct to mucosa anastomosis has not consistently been associated with lower leak rates. Furthermore, the binding technique reported by Peng et al. was associated with a 0% leak rate in two separate studies.[20–26]

Given that distal pancreatectomy caries a higher leak rate and was the predominant resection procedure performed in our

series, the management of the remnant deserves special consideration. In elective resection, the main question has been whether to staple or sew the pancreatic stump as well as whether to specifically ligate the duct. In a series of 126 elective distal pancreatectomies, suture closure of the duct was associated with a fivefold reduction in leak rate.[27] In a meta-analysis of six studies that compared stapled versus sewing of the pancreatic stump, there was a trend toward a lower pancreatic fistula rate with stapling.[28] The DISPACT trial randomized over 350 elective distal pancreatectomy patients to stapled versus sewing of the stump and showed no difference in pancreatic fistula rate between the two groups.[29] These results are in sharp contrast to the results of our study. Possible explanations for this difference include an unmeasured confounder in our analysis biasing our results toward improved outcomes for stapling of the stump. Our unadjusted analysis demonstrates that the injury severity and physiology between our stapled and sewn groups were similar, making this less likely to be the reason. An alternative explanation is the lack of uniformity in the manner of suturing the distal end in our series compared with the rigorously performed DISPACT trial. This might explain the slightly higher leak rate in our series compared with the DISPACT trial (DISPACT = 28%, our series = 35.5%). The greatest contributor, however, is likely to be the difference in the two patient populations given that the patients in our series were physiologically compromised at the time of their operation. Pancreatic edema and perfusion are likely to be at play in closure durability. The application of results from elective resection series to our series may, therefore, not be appropriate. For example, debate still exists as to whether stapled or hand-sewn anastomosis in traumatized bowel resection cases yields different outcomes. Such a difference may certainly be magnified in the setting of traumatic pancreatic resection.

Another consideration regarding the management of the pancreatic stump is the size of the gland relative to the stapler thickness used. Unfortunately, none of the operative reports mentioned gland thickness and only a small proportion stated the stapler thickness used. These small numbers make it impossible to draw any firm conclusions about stapler thickness and the risk for pancreatic leak from the stump; however, those stapled with a 3.5-mm-thick stapler appeared to have the lowest leak rate, which should prompt further study in this area.

Other techniques to reduce the risk of pancreatic fistula after distal pancreatectomy have included the use of ampullary stents and reinforcement of the stump with bioabsorbable mesh and fibrin glue or sealants. The use of a stent in the ampulla of Vater has yet to be shown to be effective in reducing pancreatic fistula after distal pancreatectomy as evidenced by a series in which there was almost a twofold higher incidence of leak in the stented group.[30] Buttressing the stapled closure with bioabsorbable mesh or sleeves has been associated with lower rates of postoperative fistula that range from 0% to 3.5% in retrospective studies, which is considerably lower than the typical leak rate observed.[31–39] A number of studies have assessed the efficacy of fibrin glue and other sealants on subsequent pancreatic fistula formation with mixed results. A meta-analysis of nearly 900 patients from seven studies showed no reduction in leak rate when sealants were used.[40] In our series, sealants were described in only five operative reports making comments on its efficacy impossible. Trauma surgeons should, however, be aware that bioabsorbable mesh or sealants may have a role in reducing pancreatic fistula and should be the focus of future studies in the trauma setting.

Given that fistula formation is associated with ARDS, our results suggest that stapling is the best way to manage the transected end of grade III injuries as this may reduce the risk of ARDS. Pancreatic fistula or pseudocyst formation was seen in 128/704 (18.2%) of patients in this study. Multiple options exist for management of these pancreas-related complications including nonoperative, operative, and endoscopic treatments. Interestingly, only 8/128 (1.1%) patients underwent ERCP for stent placement in our study. Not only can ERCP be used for management of pancreas related complications but it can also aid in the diagnosis and location of ductal injuries.[9,41] ERCP has some limitations including general anesthesia and patient positioning, which may be difficult in the patient with multiple injuries. False-negative results do occur and various procedure-related complications such as pancreatitis can occur in 3–5% of cases.[9] Transampullary stent placement or sphincterotomy is thought to reduce the intraductal pressure, which can assist in decreasing the amount of pancreatic drainage from a ductal injury or fistula/pseudocyst.[12] Several small series show successful management of pancreas injury with ERCP either as primary management or for treatment of pancreas-related complications.[41–44] Multiple algorithms have also been devised to include the use of ERCP to facilitate nonoperative management or treatment of complications.[12,13] With the low number of ERCP patients in our study, it is not possible to draw any conclusions related to this modality and this will need further study.

Preoperative CT scans were compared with operative findings to determine the sensitivity and specificity of CT and diagnosing ductal injury. This study found a sensitivity of 78.7% and specificity of 61.6% in identifying pancreatic ductal injury, which is within the reported range of other studies.[1,2,4,9,12,45] Specifically, our sensitivity was higher, but specificity was lower for pancreatic ductal injury compared with Phelan's AAST multicenter study published in 2009.[46] A possible explanation for our improved sensitivity is that a greater proportion of our sites (8 out of 18) were using 64-slice or greater scanners compared with Phelan's sites. The drop in specificity may be the price that is paid for this improved technology because the improved technology may be identifying subtle changes in the pancreas more readily that suggest a duct injury when in fact there is no injury present. The sensitivity and specificity for CT were less than ideal and trauma surgeons need to be aware that the absence of a pancreatic ductal injury on CT may be inaccurate, which may lead to delay in care contributing to morbidity and mortality.

This study has several limitations that should be mentioned. First, this is a retrospective study with all of the limitations inherent to retrospective reviews. Second, data were collected at each individual institution based on its own trauma registry and chart abstraction. Our intent was to be exhaustive with regards to diagnostic and patient data, but data quality is limited to each institution's trauma registry and research personnel's accuracy. Third, patient care and decision-making was not standardized, which may lead to unaddressed confounding. Last, we did not standardize the definition of pancreatic fistula. If the caring provider diagnosed a pancreatic fistula, then we

coded it as such. This clearly would have implications on the magnitude of clinical impact based upon how each provider defined the fistula. We did, however, attempt to determine the degree of impact pancreatic fistula had based upon the duration that drains remained in place for these fistulae.

CONCLUSIONS

The sensitivity and specificity of CT to identify a main pancreatic ductal injury remains suboptimal. Operative management of grade III injuries should include resection and stapling of the remnant may be superior to suture; however, given the retrospective nature of our study, we cannot say for certain that this technique is responsible for the lower fistula rate observed. Drainage rather than resection remains debatable for patients with grade IV or grade V injuries but was associated with a higher risk of pancreatic fistula/pseudocyst formation, raising concerns regarding its use in severe injuries.

AUTHORSHIP

N.B., M.H., and N.W. conducted the literature search and collected the data. M.H. and N.W. analyzed and interpreted the data. N.B. and M.H. wrote the manuscript. N.B. revised the manuscript.

DISCLOSURE

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