

Does drainage or resection predict subsequent interventions and long-term quality of life in patients with Grade IV pancreatic injuries: A population-based analysis

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BACKGROUND:	Clinical equipoise remains significant for the treatment of Grade IV pancreatic injuries in stable patients (i.e., drainage vs. resection). The literature is poor in regards to experience, confirmed main pancreatic ductal injury, nuanced multidisciplinary treatment, and long-term patient quality of life (QOL). The primary aim was to evaluate the management and outcomes (including long-term QOL) associated with Grade IV pancreatic injuries.
METHODS:	All severely injured adult patients with pancreatic trauma (1995–2020) were evaluated (Grade IV injuries compared). Concordance of perioperative imaging, intraoperative exploration, and pathological reporting with a main pancreatic ductal injury was required. Patients with resection of Grade IV injuries were compared with drainage alone. Long-term QOL was evaluated (Standard Short Form-36).
RESULTS:	Of 475 pancreatic injuries, 36(8%) were confirmed as Grade IV. Twenty-four (67%) underwent a pancreatic resection (29% pancreatoduodenectomy; 71% extended distal pancreatectomy [EDP]). Patient, injury and procedure demographics were similar between resection and drainage groups ($p > 0.05$). Pancreas-specific complications in the drainage group included 92% pancreatic leaks, 8% pseudocyst, and 8% walled-off pancreatic necrosis. Among patients with controlled pancreatic fistulas beyond 90 days, 67% required subsequent pancreatic operations (fistulo-jejunostomy or EDP). Among patients whose fistulas closed, 75% suffered from recurrent pancreatitis (67% eventually undergoing a Frey or EDP). All patients in the resection group had fistula closure by 64 days after injury. The median number of pancreas-related health care encounters following discharge was higher in the drainage group (9 vs. 5; $p = 0.012$). Long-term (median follow-up = 9 years) total QOL, mental and physical health scores were higher in the initial resection group ($p = 0.031, 0.022$ and 0.017 respectively).
CONCLUSION:	The immediate, intermediate and long-term experiences for patients who sustain Grade IV pancreatic injuries indicate that resection is the preferred option, when possible. The majority of drainage patients will require additional, delayed pancreas-targeted surgical interventions and report poorer long-term QOL. (<i>J Trauma Acute Care Surg.</i> 2021;91: 708–715. Copyright © 2021 Wolters Kluwer Health, Inc. All rights reserved.)
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Traumatic injury to the pancreas continues to present numerous diagnostic and therapeutic challenges for all surgeons. High-grade injuries are particularly interesting given their definitional trauma to the main pancreatic duct.¹ More specifically, while Grade III injuries are described by either a distal pancreatic transection or parenchymal trauma with an associated main duct injury, Grade IV (“proximal transection or parenchymal injury involving the ampulla”) and Grade V (“massive disruption of the pancreatic head”) injuries are focused on substantial trauma to the right of the superior mesenteric/portal vein.¹ They are also intimately related to Grade V duodenal injuries (significant disruption of the pancreatoduodenal complex). Although significant variability persists in the care of all pancreatic trauma,^{2–5} management of Grade III and V injuries generally entails resection with a distal pancreatectomy and pancreatoduodenectomy, respectively.^{2–7} It must also be mentioned that these procedures (particularly pancreatic head resections) are best completed by experienced surgeons in the context of patient stability.^{5,8} If hemodynamic instability and/or physiologic exhaustion persists, then simple

drainage of *any* pancreatic injury (and associated vascular hemorrhage control), with a plan to return to the operating room for a secondary resection/reconstruction as necessary, is the preferred procedure of choice.^{9–12}

Unlike the traditional pathways described above, Grade IV pancreatic injuries represent a more intriguing cohort given the possibility of initial drainage versus resection/reconstruction options.^{2–7,9–19} Not only does this particular grade include a wide variety of morphologic injuries (e.g., ampullary vs. pancreatic head),¹ the limited experience of trauma surgeons with both Grade IV injury volumes, as well as complex pancreatic head resections (i.e., pancreatoduodenectomy, extended distal pancreatectomy with duct closure, duodenal-preserving pancreatic head resection, central pancreatectomy with reconstruction), makes the surgical management of this scenario strongly debated with both opinion and passion. The alternative, nonresectional treatment is described by simple drainage of the pancreatic head. Although drainage-only strategies have not been prospectively studied in the context of confirmed main pancreatic duct injuries, some authors have described a potential for lower short-term morbidity.^{14,15} More recently, however, a large multicenter trial suggested that higher morbidity rates are associated with drainage compared with resection.²

A secondary issue of critical importance also surrounds the long-term outcomes of patients who are treated with drainage versus resection. To date, there is a paucity of objective data within this important quality of life domain beyond anecdotal comments by pancreatic surgeons that many of these patients suffer long-term symptoms created by persistent fistulae, main ductal strictures, and chronic pancreatitis. The primary aims of this study were, therefore, to evaluate both the initial management

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and outcomes of patients with Grade IV pancreatic injuries, as well as their reported longer-term quality of life.

METHODS

All adult (≥ 16 years of age) patients who were severely injured (defined by the Canadian National Standard: Injury Severity Score [ISS] ≥ 12), and sustained a pancreatic injury between January 1, 1995 and September 30, 2020 were evaluated. The Foothills Medical Center is a regional tertiary care, Level I trauma referral center with a catchment approximating 3 million citizens from Southern Alberta, Southwestern Saskatchewan and Southeastern British Columbia. All trauma team leaders, and hepatopancreatobiliary (HPB) physicians are fellowship-trained surgeons with high-volume clinical experience. The electronic patient medical record captures all inpatient medical admissions and procedures for all Alberta residents. This population-based document also includes the vast majority of outpatient subspecialty care visits in southern Alberta (i.e., all pancreas related visits).

Patients with Grade IV injuries (defined by the AAST Pancreas Injury Scale) were compared.¹ Despite debate within the trauma surgical community at large, our study group interpreted a Grade IV injury to be defined by a “proximal (to the right of the portal vein/superior mesenteric vein) pancreatic transection” (transection of varying degrees as long as a confirmed synchronous injury to the main pancreatic duct was included) and/or “ampullary injury.” Concordance of perioperative imaging (computed tomography [CT] and/or magnetic resonance imaging [MRI]), intraoperative explorative findings, and/or pathological reporting was required for inclusion. All imaging confirming Grade IV injuries (CT or MRI) was rereviewed by a study panel (pancreas and trauma surgeons) to ensure that a Grade IV injury was truly present. When discrepancies in injury grade existed between evaluation tools, a study committee resolved all conflicts by consensus. Patients with Grade IV pancreatic injuries who underwent resection (i.e., extended distal pancreatectomy vs. pancreatoduodenectomy) were compared with those who received drainage of their pancreas/peripancreatic regions alone. An extended distal pancreatectomy was defined as a distal pancreatectomy that extended to the right of the portal vein and, therefore, into the head of the gland to incorporate the injury itself. This technique involves resection within the head of the pancreas (+/- specific ligation of the main duct within the head). As injuries extend deeper into the head and/or uncinate of the gland, extended distal pancreatectomies become unacceptably high risk for postoperative pancreatic leaks, and a transition is made to a formal pancreatoduodenectomy (vs. drainage). Although this is our dominant approach to Grade IV injuries, specific volumes of injury and/or resection were not recorded. Patient and injury demographics, flow of care, specific interventions, and patient outcomes were evaluated. All subsequent pancreas-directed interventions (inpatient and outpatient) and admissions were also captured and evaluated from a population-based, provincial electronic medical record. Long-term outcomes and quality of life were assessed using the Standard Short Form-36 (SF-36) questionnaire distributed via mail as part of this study.²⁰ The SF-36 includes eight multiple item subscales that evaluate physical function (limitations in physical activities because of health problems), social

function (limitations in social activities because of physical or emotional problems), role physical (limitations in usual role activities because of physical health problems), role emotional (limitations in usual role activities because of emotional problems), mental health (psychological distress and well-being), vitality (energy and fatigue), bodily pain, and general health perception (SF-36 scores range: 0 to 100; with higher scores indicating better results).²⁰

Postoperative pancreatic fistula was defined using the International Study Group (ISGPS) on Pancreatic Fistula recommendations.²¹ Pancreatic exocrine insufficiency was defined as the presence of diarrhea, steatorrhea, and weight loss, as well as corollary improvement with oral pancreatic enzyme supplementation. Pancreatic endocrine insufficiency was defined as new-onset diabetes or worsening of diabetes. Additional pancreas-specific complications (delayed gastric emptying [DGE], postoperative hemorrhage) were also defined by the validated ISGPS classification.²² The term pancreatic “leak” refers to persistent lipase/amylase-rich fluid drainage for the first 4 weeks. Beyond 4 weeks (i.e., epithelialization of the drain tract), the term “fistula” is appropriate. Similarly, “acute pancreatic/peripancreatic fluid collection” refers to a pancreatic leak-related collection prior to 4 weeks.^{23,24} Beyond 4 weeks, a fluid-only collection is referred to as a “pseudocyst” (i.e., relatively rare). If the delayed collection has any necrosis (pancreatic or peripancreatic), the term “walled off pancreatic necrosis” (WOPN) is considered accurate.^{23,24} A controlled pancreatic leak is defined as pancreatic secretions evacuated via a closed suction or gravity drain. Operative technique (e.g., pancreatoenteric reconstitution (pancreatojejunostomy vs. pancreatogastrostomy); parenchymal transection method; number of peripancreatic drains) was surgeon-dependent and variable. Relevant postexploration interventions included *pancreas-directed* diagnostic and therapeutic (pancreatic duct stent) endoscopic retrograde cholangiopancreatography (ERCP), endoscopic ultrasound-guided transgastric necrosectomy/drainage, percutaneous drainage of pancreatic collections (confirmed by elevated lipase/amylase fluid level), reoperation (completion distal pancreatectomy, pancreatoduodenectomy, Roux-en-Y fistulostomy, transgastric necrosectomy),^{25,26} and outpatient long-acting octreotide use.

Data are presented as means or medians (with interquartile ranges) for normally and nonnormally distributed continuous variables, respectively. Frequencies were used for categorical data. Differences in demographic data and secondary measures between patient groups were assessed using a χ^2 analysis and Student *t* tests as appropriate. An α significance level of 0.05 was set a priori. All statistical testings were performed using Stata/IC version 16.0 (Stata Corp., College Station, TX).

RESULTS

Of 475 pancreatic injuries over a 25-year interval, 36 (8%) were confirmed as Grade IV and survived beyond 72 hours (three additional patients with Grade IV injuries died within 72 hours of admission secondary to hepatic ischemia [1], physiologic exhaustion [1], and catastrophic traumatic brain injury [1]). All 36 patients who survived beyond 72 hours also survived to discharge. Twenty-four (67%) underwent a pancreatic resection. Of these, seven (29%) received a pancreatoduodenectomy.

The remaining patients (71%) underwent an extended distal pancreatectomy. Half of all resections were performed during the index laparotomy, whereas the others (50%) were completed at the second or third operations. All patients undergoing resection received at least one closed suction surgical drain (pancreatoduodenectomy: four single drain, three double drains; extended distal pancreatectomy: 12 single drain, 5 double drains). All but one patient who underwent a pancreatoduodenectomy was reconstructed with a partially invaginated end-to-side pancreaticojejunostomy (i.e., vs. one pancreaticogastrostomy) and an indwelling pancreatic ductal stent (5 Fr). Pancreatic parenchymal division employed Bovie electrocautery (35 Spray setting). Among the extended distal pancreatectomies, attempts were made to oversee all main pancreatic ducts within the head of the gland. When comparing the patients who had a resection with those who did not, patient, injury, and procedure demographics were similar (Table 1). The median time between arrival and transfer to the operating room was similar between groups (3.7 vs. 2.8 hours; $p = 0.498$). Hemodynamically unstable patients underwent rapid transfer to the operating room, however (median interval, 16 minutes). Among patients who did not undergo resection (12), 10 received closed suction peripancreatic drainage, whereas two did not receive any initial exploration/laparotomy. Of these two patients, one developed a large lesser sac collection (i.e., pancreatic leak) that required subsequent percutaneous drainage and eventual ERCP-guided pancreatic duct stent placement. The other patient underwent an early ERCP pancreatic duct stent insertion, but eventually developed a pseudocyst that required long-term intervention.

Main Pancreatic Duct Injury Diagnosis

Main duct injuries were initially confirmed in 31 (86%) patients. The majority (77%) were identified within the operating

room (16 based on surgeon inspection and 8 on surgeon-performed intraoperative ultrasound of pancreas anatomy). Intraoperative ultrasound was used more frequently in the last 10 years of the study interval. The remaining patients were confirmed with cross-sectional imaging (MRCP/CT [6] or ERCP [1]). Of the five patients who did not have *a priori* confirmation of a main duct injury, all were confirmed following resection of the pancreas specimen.

Immediate Pancreas-Focused Outcomes

Pancreas-specific complications in the nonresection group included 11 (92%) pancreatic leaks, 10 (83%) pancreatic fistulas (i.e., 10/11 leaks evolved into fistulas because they did not close within 4 weeks), 1 (8%) true pseudocyst, and 1 (8%) WOPN. All 10 nonresection patients with a persistent pancreatic fistula underwent ERCP with pancreatic ductal stenting. The patients with a pseudocyst and WOPN underwent eventual endoscopic transgastric drainage and open necrosectomy (with concurrent resection of the colon due to a dehiscence colonic suture line secondary to pancreatic leak erosion of the preceding repair) respectively. Among the 24 patients who underwent resection, eight (33%) had a biochemically confirmed postoperative pancreatic leak, with five (21%) displaying a persistent fistula. Of these five (four extended distal pancreatectomies and one pancreatoduodenectomy), two required ERCP-guided pancreatic duct stent placement. All five fistulas subsequently closed without further intervention. While no patients within the resection group developed either a pseudocyst or WOPN, two patients developed Grade I DGE following pancreatoduodenectomy.

Long-Term Pancreas-Focused Outcomes

Among the 10 patients with controlled pancreatic fistulas (i.e., ERCP pancreatic stenting), four closed and six remained persistent beyond 90 days from the injury. Of these six patients, four underwent a subsequent operative roux-en-Y pancreatic fistulo-jejunostomy, while two received a technically challenging extended distal pancreatectomy. Of the four patients whose fistulas closed, three suffered from recurrent episodes of pancreatitis with two eventually undergoing an operative intervention (one Frey procedure and one extended distal pancreatectomy). All patients in the resection group had fistula closure by 64 days after injury. No patient in either cohort displayed pancreatic exocrine insufficiency on a clinical basis, whereas one patient in each of the nonresection and resection cohorts displayed pancreatic endocrine instability (1 nonresection patient with subsequent chronic pancreatitis developed insulin dependent diabetes and one patient who underwent an extended distal pancreatectomy developed diabetes 7 years following their injury). The median number of overall pancreas-related health care encounters following initial discharge after the index injury treatment (i.e., population-based analysis) was higher in the nonresection group (9 vs. 5; $p = 0.012$).

Long-Term Quality of Life Outcomes

Long-term quality of life analysis displayed a median follow-up of 9 years. A total of 28 (78%) patients returned the SF-36 questionnaire (9 of 12 without an initial resection and 19 of 24 with an initial resection). In reference to the eight domains, the total quality of life, mental health and physical health scores were higher in the initial resection group ($p = 0.031$,

TABLE 1. Patient and Injury Demographics for Grade IV Pancreas Injuries

	Resection	Drainage	<i>p</i>
Total number	24	12	
Median age—yr (IQR)	32 (23–48)	34 (21–43)	0.521
Sex—male (%)	18 (75)	8 (67)	0.599
Median ISS (IQR)	27 (19–31)	29 (17–38)	0.746
Blunt mechanism (%)	19 (79)	8 (67)	0.414
Hemodynamic instability (%)	6 (25)	4 (33)	0.600
Blood transfusion (%)	9 (38)	5 (42)	0.809
Associated abdominal injuries (%)	21 (88)	11 (92)	0.708
Damage-control surgery (%)	5 (21)	5 (42)	0.188
Median number of operations (IQR)	2 (1–4)	2 (0–4)	0.893
Hospital length of stay—days (IQR)	12 (4–41)	16 (7–82)	0.201
ICU length of stay—median days (IQR)	2 (0–21)	3 (0–34)	0.326
Pancreas-specific morbidity (%) (including controlled leak)	10 (42)	11 (92)	0.004*
Pancreas-specific morbidity (%), (excluding controlled leak)	2 (8)	2 (17)	0.453
Mortality beyond 72 h (%)	0 (0)	0 (0)	NA
Home discharge destination (%)	20 (83)	9 (75)	0.551

* $p < 0.05$.

ICU, intensive care unit; IQR, interquartile range.

0.022 and 0.017, respectively) (Fig. 1). More specifically, role physical, bodily pain, vitality, and mental health scores were lower in the drainage cohort (Fig. 1). Long-term quality of life did not have any statistical relationship with preceding injury pattern or burden (ISS) ($p > 0.05$).

DISCUSSION

The frequency of, and therefore, surgeon experience with, Grade IV pancreatic injuries remains low across all peer-reviewed publications. In our series, 8% of patients had Grade IV injuries, which is similar to both the American College of Surgeons Trauma Quality Improvement program (7%)³ and Canadian national report (8%).⁴ A large multinational description focused exclusively on high-grade pancreatic injuries reported a 17% rate of Grade IV pancreatic trauma.² This can also be loosely compared with a large 25-year, single-center report from South Africa limited to pancreatic injuries that underwent resection at 3%.⁵ Interestingly, 67% of the patients within our series underwent a resection (vs. drainage). This rate compares favorably to the Canadian national data (50%),³ but is moderately higher than that found in both Trauma Quality Improvement program (38%)⁴ and the multinational series focused on high-grade injuries (39%).² While the resection rate was slightly higher, the proportion of patients within our series undergoing a pancreatoduodenectomy (vs. extended distal pancreatectomy) (29%) was similar to other series (27% “proximal” pancreatectomy).^{2,3,5} These comparative data are interesting from both a rate and selection point of view. More specifically, in published series where trauma and HPB services are in close alignment and work together on most pancreatic trauma cases, the resection rates for high-grade injuries (III, IV, V) are routinely reported to be higher.^{2,5,10} The proportion of definitive proximal resections is also increased.^{2,5,10} This observation of more aggressive surgery in collegial trauma-HPB working groups and high-volume centers is an interesting trend

that warrants deeper discussion. Although rarely required given the relatively low incidence, strong familiarity, and ease of performance with extended distal pancreatectomies diving into the head of the gland, as well as high-volume pancreatoduodenectomy, likely influences both surgeon comfort and the application of these procedures. Similarly, the nuanced understanding of potential long-term pancreatic specific complications (i.e., persistent pancreatic fistula, recurrent pancreatitis secondary to main ductal strictures, delayed necrosis) may bias these hybrid teams toward performing a more definitive single-stage resection in the initial phase of care, when safe.^{2,3,5,10}

It is also critical to reflect upon the patients who did not undergo a resection during their initial inpatient stay. More specifically, all 12 patients developed a high-volume pancreatic leak (confirmed via biochemical fluid analysis). While the majority (83%) underwent operative exploration and received closed suction peripancreatic drainage with an average of two drains, even the two patients who did not display pancreatic secretions leakage required a major intervention (two ERCP stents; one percutaneous drain).

Importance of Diagnosing a Main Pancreatic Duct Injury

A critical, but rarely reported, anatomic variable is the absolute *confirmation* of a transection to the main pancreatic duct in a series that report Grade IV injuries. Upon careful evaluation of the AAST pancreas injury scale, the lack of an explicit definitional requirement for a concurrent main pancreatic duct injury within Grades IV and V is cause for pause.¹ While we suspect that most clinicians apply a Grade IV, and especially Grade V, injury definition to pancreatic trauma that has a high likelihood of possessing a main pancreatic duct injury, the possibility of including injuries that may *appear* to have a potential main duct lacerations/transections, but not actually possess one, is high (i.e., a Grade II injury within the head of the gland). We believe that this potential reality is a likely etiology for the unusually low number of Grade IV injuries reported across most series (i.e., higher Grades III and V injury rates).^{2,5,10} Similarly, this challenge may also explain the poor summative treatment data and optimal pathways for addressing Grade IV injuries within the literature.^{6,7,10,16} To better address these concerns, we evaluated the main pancreatic duct integrity for each confirmed Grade IV injury. Although the tools used to ensure the concurrent diagnosis of a main duct injury varied across patient cases and eras (intraoperative assessment with surgeon inspection [44%] or surgeon-performed pancreatic ultrasonography [22%]; preoperative cross-sectional imaging [MRCP/CT] [17%]; postresectional “back table” evaluation [14%]; ERCP [3%]), it remained a requirement to confirm this reality to use the Grade IV definition. Given the challenge in confirming main duct integrity in some pancreatic injuries,^{10,19,27–37} we suspect that much of the literature is mixed with true Grade IV and “pseudo-Grade IV” trauma that dilute our anatomical understanding of pancreas-specific complications and subsequent successful treatment options.

Immediate Pancreas-Specific Outcomes

The evaluation of pancreas-specific complications in both the resection and nonresection patients is essential to optimizing our understanding of potential treatments. It is not surprising



PF = physical function
RP = role physical*
BP = bodily pain*
GH = general health
VT = vitality*
SF = social functioning
RE = role emotional
MH = mental health*

* = $p < 0.05$

Figure 1. Quality of life after Grade IV pancreas injury resection and drainage (mean values in the eight SF-36 domains).

from a pancreas anatomy and ductal hydraulics point of view that any transectional injury to the proximal (i.e., right side/head of gland) main pancreatic duct will lead to high output, enzyme rich leakage.^{24,25} This has long been clear in cases of traumatic injury, acute pancreatitis, and high-volume elective pancreatic surgery. Integrity of the main pancreatic duct also forms the foundation for complex pancreatic care (surgical, endoscopic, radiologic). The data in our series confirm this reality. In retrospect, all patients with a true Grade IV injury (i.e., concurrent main duct transection) who did not undergo a resection developed a pancreatic juice leak. While most of these leaks were detected relatively early in the patient's postoperative course, one patient did present with pain and pseudo-obstruction related to a large pseudocyst. The important summary message is that if the clinician decides to avoid resection for a true Grade IV injury (i.e., physiologic exhaustion; concurrent life threatening injuries; inexperience with resectional techniques),³⁸ then a subsequent pancreatic leak is inevitable. This leak will be enzyme-rich and high-volume based on proximal ductal disruption. In other words, the goal of nonresectional interventions (surgical or not) must be to control the predictable leak in its entirety to prevent injury to adjacent organs, sepsis, and hemorrhage. If this is the stated goal of the surgeon, then a controlled pancreatic fistula (i.e., via a percutaneous or surgical drain) should be considered a success, as opposed to a "complication." This control will avoid potential catastrophic pancreas-specific complications, such as hemorrhage, sepsis, and peripancreatic/pancreatic necrosis.

Within the resectional cohort, postoperative leaks (i.e., controlled by postoperative drains) were present in 33% of all patients. This value is higher than usually accepted for elective resections (extended distal pancreatectomy and pancreatoduodenectomy),

but typical for trauma-related resections.^{3,5,10,39} A similarly higher rate of DGE was also noted following pancreatoduodenectomy.²² Closure of these fistulas was achieved by a combination of adequate recovery time, optimal nutrition, and/or ERCP-guided pancreatic ductal stent insertion, depending on the case. This pathway to closure also reemphasizes the importance of adequate collaboration with our high-volume pancreas surgery colleagues and experienced interventional gastroenterologists. Optimal pancreatic care requires multidisciplinary input, regardless of the underlying etiology (Fig. 1).^{8,24,37}

Longer-Term Pancreas-Specific Outcomes

Although the pancreas-specific complications and main duct status for Grade IV injuries is challenging to confirm within the literature, there is a complete paucity of reported long-term outcomes following pancreatic injuries. Beyond 90 days, it became evident in our series that the vast majority of nonresected patients with controlled pancreatic fistulas (80%) required an eventual secondary operative intervention to address either the persistent fistula or delayed main duct stricture leading to recurrent pancreatitis (four roux-en-Y pancreatic fistulogastrojejunostomies, three extended distal pancreatectomies, one Frey procedure).^{25,40} In comparison, all postresectional fistulas closed within 64 days. The difference in pancreas fistula treatment and trajectory between the nonresected and resected patient cohorts highlights the reality of a proximal pancreatic fistula as a result of main duct disruption. Based on this comprehensive and population-based data, it can be surmised that the goal of the surgeon in the initial acute postinjury period is to address the Grade IV pancreatic injury, and predictable high-volume pancreatic leak, with either resection at the index operation (if patient physiology and

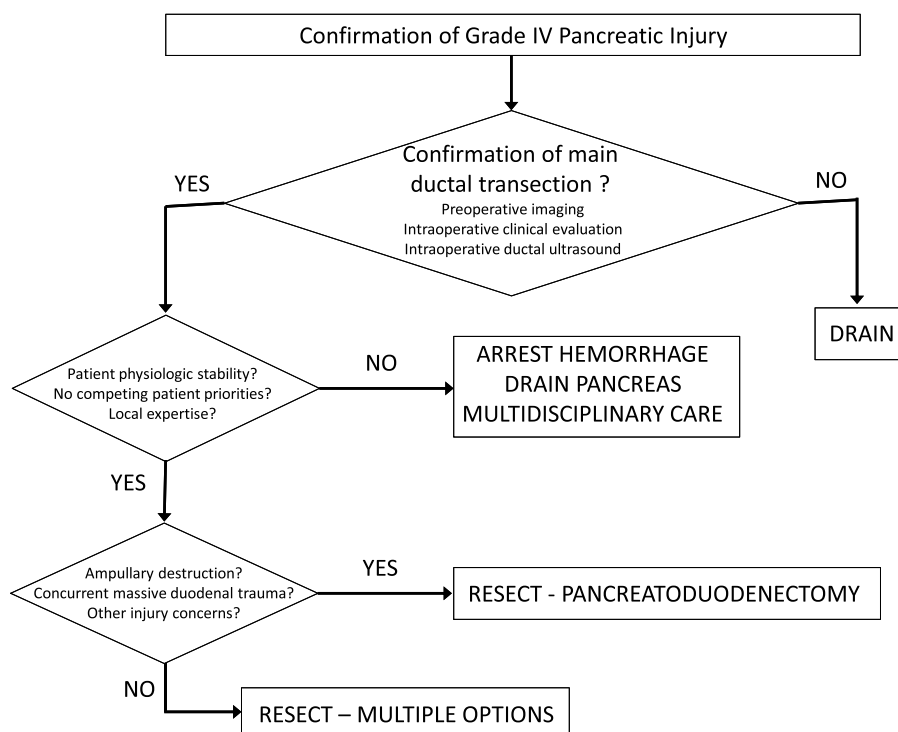


Figure 2. Suggested management of Grade IV pancreatic injuries.

competing priorities allow, as well as surgeon expertise available), or by controlling the fistula via adequate drainage, optimal nutrition and excellent rehabilitation with a high associated likelihood of the patient requiring a second delayed operative procedure to internalize a persistent fistula (or address recurrent pancreatitis following the development of a pancreatic ductal stricture). It was also reassuring to note that minimal pancreatic endocrine and exocrine insufficiency was evident in either group following Grade IV injuries, which fits well with the initial short-term data currently available.⁴¹

Long-Term Quality of Life Outcomes

The final piece to the Grade IV pancreatic injury puzzle is outlined by the impact of these injuries on patients' long-term quality of life. Patients who did not undergo an initial resection were more likely to report lower role physical, bodily pain, vitality and mental health scores, in addition to display lower total quality of life, mental health, and physical health scores. This observation is not overly surprising given similar observations in patients who possess chronic health challenges (e.g., chronic pancreatitis, autoimmune disorders).⁴² Certainly, the prolonged and complicated treatment course in patients who underwent drainage only for their Grade IV pancreatic injuries is a likely cause of these decreased reported quality of life scores. Elements, such as repeated operations, additional procedures (surgical or endoscopic), intermittent returns to the health care system for assessments and treatment, and chronic pain, would each potentially contribute to a poorer quality of life. This pattern is confirmed by the increased need for pancreas-related visits/assessments within the health care system for nonresection patients. If worse quality of life is the price of survival at the index injury procedure, however, most patients (89%) reported that they would gladly pay it forward.

Limitations inherent within this study are multifold. The retrospective methodology (except the SF-36) introduces the possibility of both initial treatment bias, as well as survival bias. Although each case was confirmed to be a Grade IV pancreatic injury, elements of the operative and/or pathology reports could potentially possess errors. All cross-sectional images were rereviewed by a combined trauma and HPB team, however, to eliminate potential errors in the radiology reporting. The addition of concurrent major visceral vascular injuries to pancreatic trauma is known to increase both morbidity and mortality.^{43,44} Despite aligning well with preceding publications outlining Grade IV pancreatic injuries, the number of patients with synchronous vascular injuries in our series remained low and, therefore, limited our ability to comment on the long-term outcomes and quality of life associated with this cohort. The small study group numbers, in general, are also subject to data fragility realities. While 78% of all patients responded to the SF-36 quality of life questionnaire, the missing patients may have offered a differing experience (three patients were also deceased at the time of the SF-36). The advantage of a population-based comprehensive electronic medical record allows the study investigators to track the location and health care interactions (and deaths) associated with each patient, unless they move out of the province of Alberta (i.e., rare).

In summary, the immediate, intermediate, and long-term experiences for patients who sustain Grade IV pancreatic injuries indicate that resection is the preferred option, when possible

(Fig. 2). Given initial realities, such as patient physiologic exhaustion, competing treatment priorities, and limited local experience in pancreatic assessments and resection strategies, damage control of Grade IV pancreatic trauma (and its associated high-volume pancreatic leak secondary to proximal main pancreatic duct transection), may be required. The majority of these patients will require additional, delayed pancreas-targeted surgical interventions and report poorer long-term quality of life scores, however.

AUTHORSHIP

C.B. participated in the study design, data analysis and author of the abstract and article. W.B. participated in the data analysis, author of the article. K.V. participated in the study design, data analysis, author of the abstract and article. M.H. participated in the study design, data analysis, author of the abstract and article. N.P. participated in the study design, data analysis, author of the abstract and article. A.K. participated as author of the abstract and article. M.K. participated as author of the abstract and article.

DISCLOSURE

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REFERENCES

- Moore EE, Cogbill TH, Malangoni MA, Jurkovich GJ, Champion HR, Gennarelli TA, McAninch JW, Pachter HL, Shackford SR, Trafton PG. Organ injury scaling, II: pancreas, duodenum, small bowel, colon, and rectum. *J Trauma*. 1990;30(11):1427–1429.
- Biffl WL, Zhao FZ, Morse B, et al. A multicenter trial of current trends in the diagnosis and management of high-grade pancreatic injuries. *J Trauma Acute Care Surg*. 2021;90(5):776–786.
- Joos E, de Jong N, Ball CG, et al. Canadian Collaborative on Urgent Care Surgery (CANUCS). Time to operating room matters in modern management of pancreatic injuries: a national review on the management of adult pancreatic injury at Canadian level 1 trauma centers. *J Trauma Acute Care Surg*. 2021;90(3):434–440.
- Mohseni S, Holzmacher J, Sjolín G, Ahl R, Sarani B. Outcomes after resection versus non-resection management of penetrating grade III and IV pancreatic injury: a trauma quality improvement (TQIP) databank analysis. *Injury*. 2018;49(1):27–32.
- Krige JE, Jonas E, Thomson SR, Kotze UK, Setshedi M, Navsaria PH, Nicol AJ. Resection of complex pancreatic injuries: benchmarking postoperative complications using the accordion classification. *World J Gastrointest Surg*. 2017;9(3):82–91.
- Ho VP, Patel NJ, Bokhari F, et al. Management of adult pancreatic injuries: a practice management guideline from the Eastern Association for the Surgery of Trauma. *J Trauma Acute Care Surg*. 2017;82(1):185–199.
- Biffl WL, Moore EE, Croce M, et al. Western Trauma Association critical decisions in trauma: management of pancreatic injuries. *J Trauma Acute Care Surg*. 2013;75(6):941–946.
- Krige J, Nicol A, Navsaria P. Managing grade 5 pancreatic injuries—think smart, act smart, and call in the pancreatic cavalry early. *J Trauma Acute Care Surg*. 2017;82(6):1187–1188.
- Roberts DJ, Bobrovitz N, Zygun DA, Kirkpatrick AW, Ball CG, Faris PD, Stelfox HT, for the Indications for Trauma Damage Control Surgery International Study Group. Evidence for use of damage control surgery and damage control interventions in civilian trauma patients: a systematic review. *World J Emerg Surg*. 2021;16(1):10.
- Streith L, Silverberg J, Kirkpatrick AW, Hameed SM, Bathe OF, Ball CG. Optimal treatments for hepato-pancreato-biliary trauma in severely injured patients: a narrative scoping review. *Can J Surg*. 2020;63(5):E431–E434.
- Roberts DJ, Zygun DA, Faris PD, Ball CG, Kirkpatrick AW, Stelfox HT, Indications for Trauma Damage Control Surgery International Study Group. Opinions of practicing surgeons on the appropriateness of published indications for use of damage control surgery in trauma patients: an international cross-sectional survey. *J Am Coll Surg*. 2016;223(5):515–529.
- Biffl WL. Duodenum and pancreas. In: Moore EE, Feliciano DV, Mattox KL, eds. *Trauma*. McGraw-Hill Education; 2017.

13. Pata G, Casella C, Di Betta E, Grazioli L, Salerni B. Extension of nonoperative management of blunt pancreatic trauma to include grade III injuries. A safety analysis. *World J Surg*. 2009;33(8):1611–1617.
14. Patton JH Jr., Lyden SP, Croce MA, Pritchard FE, Minard G, Kudsk KA, Fabian TC. Pancreatic trauma: a simplified management guideline. *J Trauma*. 1997;43(2):234–239; discussion 239–41.
15. Sharpe JP, Magnotti LJ, Weinberg JA, Zarzaar BL, Stickley SM, Scott SE, Fabian TC, Croce MA. Impact of a defined algorithm on outcome after traumatic pancreatic injury. *J Trauma Acute Care Surg*. 2012;72(1):100–105.
16. Coccolini F, Kobayashi L, Kluger Y, et al, WSES-AAST Expert Panel. Duodeno-pancreatic and extrahepatic biliary tree trauma: WSES-AAST guidelines. *World J Emerg Surg*. 2019;14:56.
17. Jurkovich GJ. Pancreatic trauma. *J Trauma Acute Care Surg*. 2020;88(1):19–24.
18. Lin BC, Wong YC, Chen RJ, Liu NJ, Wu CH, Hwang TL, Hsu YP. Major pancreatic duct continuity is the crucial determinant in the management of blunt pancreatic injury: a pancreatographic classification. *Surg Endosc*. 2017;31(10):4201–4210.
19. Schellenberg M, Inaba K, Bards JM, Cheng V, Matsushima K, Lam L, Benjamin E, Demetriades D. Detection of traumatic pancreatic duct disruption in the modern era. *Am J Surg*. 216(2):299–303.
20. Sullivan M, Karlsson J, Taft C. *SF-36 Halsoenkät: Svensk Manual och Tolkningsguide, 2a: a upplagan (Swedish Manual and Interpretation Guide, 2nd edition)*. Gothenburg: Sahlgrenska University Hospital; 2002.
21. Bassi C, Marchegiani G, Dervenis C, et al, International Study Group on Pancreatic Surgery (ISGPS). The 2016 update of the International Study Group (ISGPS) definition and grading of postoperative pancreatic fistula: 11 years after. *Surgery*. 2017;161(3):584–591.
22. Wente MN, Bassi C, Dervenis C, et al. Delayed gastric emptying (DGE) after pancreatic surgery: a suggested definition by the International Study Group of Pancreatic Surgery (ISGPS). *Surgery*. 2007;142(5):761–768.
23. Dellinger EP, Forsmark CE, Luyer P, Lévy P, Maraví-Poma E, Petrov MS, Shimosogawa T, Siriwardena AK, Uomo G, Whitcomb DC, Windsor JA, Pancreatitis Across Nations Clinical Research and Education Alliance (PANCREA). Determinant-based classification of acute pancreatitis severity: an international multidisciplinary consultation. *Ann Surg*. 2012;256(6):875–880.
24. Ball CG, Hameed SM, Dixon E, Lillemoie KD. Severe acute pancreatitis for the acute care surgeon. *J Trauma Acute Care Surg*. 2016;80(6):1015–1022.
25. Murage KP, Ball CG, Zyromski NJ, Nakeeb A, Ocampo C, Sandrasegaran K, Howard TJ. Clinical framework to guide operative decision making in disconnected left pancreatic remnant (DLPR) following acute or chronic pancreatitis. *Surgery*. 2010;148(4):847–856; discussion 856–7.
26. Driedger M, Zyromski NJ, Visser BC, et al. Surgical transgastric necrosectomy for necrotizing pancreatitis: a single-stage procedure for walled-off pancreatic necrosis. *Ann Surg*. 2020;271(1):163–168.
27. Wong YC, Wang LJ, Fang JF, Lin BC, Ng CJ, Chen RJ. Multidetector-row computed tomography (CT) of blunt pancreatic injuries: can contrast-enhanced multiphasic CT detect pancreatic duct injuries? *J Trauma Acute Care Surg*. 2008;64(3):666–672.
28. Phelan HA, Velmahos GC, Jurkovich GJ, et al. An evaluation of multidetector computed tomography in detecting pancreatic injury: results of a multicenter AAST study. *J Trauma*. 2009;66(3):641–646; discussion 646–7.
29. Gordon RW, Anderson SW, Ozonoff A, Rekhi S, Soto JA. Blunt pancreatic trauma: evaluation with MDCT technology. *Emerg Radiol*. 2013;20(4):259–266.
30. Dreizin D, Bordegaray M, Tirada N, Raman SP, Kadakia K, Munera F. Evaluating blunt pancreatic trauma at whole body CT: current practices and future directions. *Emerg Radiol*. 2013;20(6):517–527.
31. Nirula R, Velmahos GC, Demetriades D. Magnetic resonance cholangiopancreatography in pancreatic trauma: a new diagnostic modality? *J Trauma*. 1999;47(3):585–587.
32. Fulcher AS, Turner MA, Yelon JA, McClain LC, Broderick T, Ivatury RR, Sugerman HJ. Magnetic resonance cholangiopancreatography (MRCP) in the assessment of pancreatic duct trauma and its sequelae: preliminary findings. *J Trauma*. 2000;48(6):1001–1007.
33. Aydelotte JD, Ali J, Huynh PT, Coopwood TB, Uecker JM, Brown CVR. Use of magnetic resonance cholangiopancreatography in clinical practice: not as good as we once thought. *J Am Coll Surg*. 2015;221(1):215–219.
34. Rogers SJ, Cello JP, Schecter WP. Endoscopic retrograde cholangiopancreatography in patients with pancreatic trauma. *J Trauma*. 2010;68(3):538–544.
35. Thomson DA, Krige JE, Thomson SR, Bornman PC. The role of endoscopic retrograde pancreatography in pancreatic trauma: a critical appraisal of 48 patients treated at a tertiary institution. *J Trauma Acute Care Surg*. 2014;76(6):1362–1366.
36. Kim S, Kim JW, Jung PY, Kwon HY, Shim H, Jang JY, Bae KS. Diagnostic and therapeutic role of endoscopic retrograde pancreatography in the management of traumatic pancreatic duct injury patients: single center experience for 34 years. *Int J Surg*. 2017;42:152–157.
37. Ball CG, Clements TS, Kirkpatrick AW, Vogt K, Biffi W, Hameed SM. Inviting a friend to evaluate potential grade III pancreatic injuries: are they truly occult, or simply missed on CT? *Can J Surg*. 2021; Online ahead of print.
38. Byrge N, Heilbrun M, Winkler N, et al. An AAST-MITC analysis of pancreatic trauma: staple or sew? Resect or drain? *J Trauma Acute Care Surg*. 2018;85(3):435–443.
39. Rozich NS, Morris KT, Garwe T, et al. Blame it on the injury: trauma is a risk factor for pancreatic fistula following distal pancreatectomy compared with elective resection. *J Trauma Acute Care Surg*. 2019;87(6):1289–1300.
40. Baltatzis M, Jegatheeswaran S, Siriwardena AK. Reporting of longitudinal pancreatojejunostomy with partial pancreatic head resection (the Frey procedure) for chronic pancreatitis: a systematic review. *Hepatobiliary Pancreat Dis Int*. 2021;20(2):110–116.
41. Mansfield N, Inaba K, Berg R, Beale E, Benjamin E, Lam L, Matsushima K, Demetriades D. Early pancreatic dysfunction after resection in trauma: an 18-year report from a level I trauma center. *J Trauma Acute Care Surg*. 2017;82(3):528–533.
42. van Loo ES, van Baal MC, Gooszen HG, Ploeg RJ, Nieuwenhuijs VB. Long-term quality of life after surgery for chronic pancreatitis. *Br J Surg*. 2010;97(7):1079–1086.
43. Krige JEJ, Jonas EG, Kotze UJ, Setshedi M, Navsaria PH, Nicol AJ. The consequences of major visceral vascular injuries on outcome in patients with pancreatic injuries: a case-matched analysis. *S Afr J Surg*. 2019;57(3):30–37.
44. Seamon MJ, Kim PK, Stawicki SP, Dabrowski GP, Goldberg AJ, Reilly PM, Schwab CW. Pancreatic injury in damage control laparotomies: is pancreatic resection safe during the initial laparotomy? *Injury*. 2009;40(1):61–65.