Original Contribution

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Long-Term Outcomes of Pancreatic Function Following Pancreatic Trauma

TOSHIO MORITA, OSAMU TAKASU, TERUO SAKAMOTO, SHINJIROU MORI*, ATSUO NAKAMURA, MASAKAZU NABETA, NOBUHISA HIRAYU, MARIKO MOROKI AND NORIO YAMASHITA

*Department of Emergency and Critical Care Medicine, Kurume University School of Medicine and *Advanced Emergency Medical Service Center, Kurume University Hospital, Kurume 830-0011 Japan*

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Summary: The objective of this study is to retrospectively assess long-term outcomes and late complications of pancreatic trauma. We studied 14 patients with pancreatic trauma who were treated at the Advanced Emergency Medical Service Center, Kurume University Hospital, between 1981 and 2012 and discharged alive. Relevant data were extracted from patient records and a retrospective patient questionnaire and blood test were completed to evaluate pancreatic function. The median patient age at the time of the survey was 49 years; the median post-injury period was 23 years and 5 months. The comorbidity rates for pancreatic endocrine and exocrine dysfunctions were 35.7% and 33.3%, respectively. No new-onset diabetes mellitus (DM) was seen within 3 years of trauma, except in 1 patient who underwent pancreaticoduodenectomy. DM developed >15 years after trauma in 2 patients each in the pancreatectomy and non-pancreatectomy groups. Diarrhea exacerbated by fat intake was seen in 3 and 1 patient in the pancreatectomy and non-pancreatectomy groups, respectively. Both complications were more common in the pancreatectomy group, but without statistical significance. Although post-surgical pancreatic dysfunction may be absent at discharge, treatment for pancreatic trauma should take into account the possibility that pancreatectomy may accelerate DM onset.

Key words pancreatic trauma, pancreatic function, pancreatic injury, long-term outcomes, post-trauma new-onset DM, exocrine dysfunction

INTRODUCTION

Pancreatic trauma reportedly accounts for 0.2% of all types of trauma and 5%-7% of abdominal trauma, with trauma-related organ damage being extremely rare [1,2]. Thus, very few detailed reports exist on the long-term outcomes of pancreatic trauma, particularly in terms of functional outcomes, such as endocrine and exocrine function. Once pancreatic endocrine dysfunction, particularly diabetes mellitus (DM), occurs, patients become more susceptible to serious complications such as retinopathy and nephropathy. In addition, decreased exocrine function can cause malnutrition and diarrhea from fat malabsorption, resulting in reduced quality of life. Studying and clarifying the effects of differences in the type and severity of pancreatic injury and in the treatment of pancreatic trauma on pancreatic function, long-term outcomes, and life-

Corresponding Author: Toshio Morita, Department of Emergency and Critical Care Medicine, Kurume University School of Medicine, Kurume, Fukuoka 830-0011, Japan. Tel: +81-942-31-7732 Fax: +81-942-35-3920, Email: mickey_mickey_1118@med.kurume-u.ac.jp

Abbreviations: DM, diabetes mellitus; AIS, abbreviated injury score; ISS, injury severity score; JAST type 2008, the Japanese Association for the Surgery of Trauma Classification for Pancreatic Injury 2008; PNI, Onodera's prognostic nutritional index; DP, distal pancreatectomy; PD, pancreaticoduodenectomy; DR, drainage; RP, repair of the parenchyma.

style are, therefore, an important challenge.

We conducted a retrospective case study to determine whether late complications and long-term outcomes differ by the characteristics and treatment of pancreatic trauma.

MATERIALS AND METHODS

The study was approved by the Ethics Committee of Kurume University (research number: 13279). In total, 6,993 patients were managed for trauma at the Advanced Emergency Medical Service Center of Kurume University Hospital during the 32-year period from 1981 to 2012. Of these, 69 had been diagnosed with pancreatic trauma and 62 were discharged alive. We obtained voluntary consent to participate, both over the phone and in writing, from 14 patients. We then retrospectively reviewed the medical records of these patients and conducted interviews and hematological tests. The flowchart showing the enrollment of patients in the study is presented in Figure 1.

Retrospective Survey of Medical Records

Medical records were used to extract data regarding age, sex, mechanism of trauma, abbreviated injury score (AIS), injury severity score (ISS), the Japanese Association for the Surgery of Trauma Classification for Pancreatic Injury 2008 (JAST type 2008; Table 1) [3], concomitant injury, use of surgery, surgical method, pancreatic complications, length of hospitalization, and outcomes.

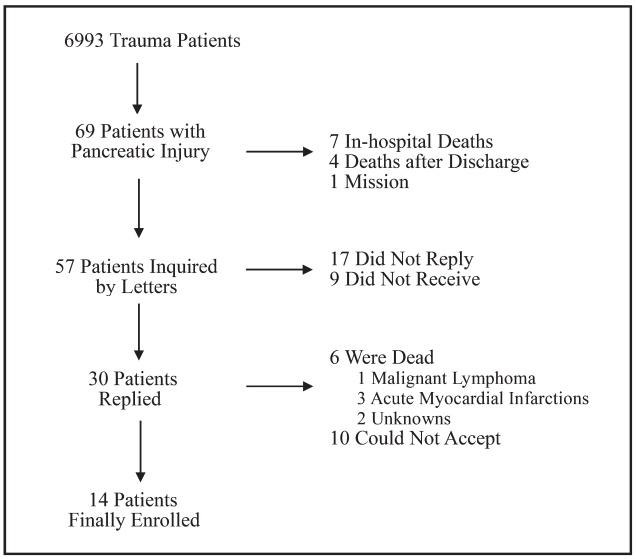

Fig. 1. Flowchart showing the enrollment of patients in the study.
A total of 6,993 patients had been managed for trauma at the Advanced Emergency Medical Service Center of Kurume University Hospital during a 32-year period. Of these, 69 had been diagnosed with pancreatic trauma and 62 were discharged alive. Eventually, 14 patients who provided voluntary consent to participate, both over the phone and in writing, were enrolled in the study.

Interview and Hematological Test

After giving their consent to participate in the study, the patients answered a written questionnaire before undergoing an outpatient examination and blood test. To assess endocrine dysfunction, the presence of post-trauma new-onset DM requiring treatment was surveyed by the questionnaire, and HbA1c levels were measured by hematological testing. In addition, to assess exocrine dysfunction, the same questionnaire was used to check for the presence of diarrhea after fat intake, chronic diarrhea, or use of oral pancreatic enzyme preparations. Amylase, lipase, and trypsin levels were determined by hematological testing. To assess nutritional status, the presence of obvious weight loss was checked and the body mass index (BMI) was calculated from the height and weight recorded at the time of the survey. Serum albumin levels, total lymphocyte count, and total cholesterol levels were also measured, and Onodera's prognostic nutritional index (PNI) was calculated [4].

Presentation of Results and Statistical Processing

After testing the data for normality, any values outside the normal distribution were expressed as median (interquartile range). Intergroup comparisons were performed using the Wilcoxon test, and ratios were tested using the chi-square test and Fisher's exact test. The statistical software used was JMP Pro 11.0.0 (SAS Institute Inc., Cary, NC, USA).

TABLE 1.
JAST 2008 Type

Type	Injury description
I	Subcapsular injury
II	Superficial injury
III	Deep injury
a	Simple deep injury
b	Complex deep injury

Type IIIa (simple deep injury) is defined as pancreatic injury of greater than one-half of the gland without main pancreatic duct disruption. Type IIIb (complex deep injury) is defined as pancreatic injury with main pancreatic duct disruption.
JAST, Japanese Association for the Surgery of Trauma Classification for Pancreatic Injury

RESULTS

Characteristics of Participants

The characteristics of the participants are listed in Table 2. The median age at the time of trauma was 28.5 years (range: 18.5-39 years), and there were more males than females. All cases involved blunt trauma, and the most common mechanism of trauma was steering wheel injury. JAST (2008) type Ⅲ injuries accounted for the majority of injuries [10/14 (71.4%) patients].

Of the 14 participants, 12 (85.7%) had undergone surgery, with 5 patients undergoing distal pancreatectomy (DP) and 1 patient undergoing pancreaticoduodenectomy (PD). Only 1 patient had suffered isolated pancreatic trauma, whereas the other 13 patients had suffered additional organ damage. In the order of frequency, concomitantly injured organs were the liver [8/14 (57.1%) patients], spleen [4/14 (28.6%)], and duodenum [3/14 (21.4%)]. The median length of hospitalization was 48.5 days (range: 27.5-80.5 days). The

TABLE 2.
Characteristics of Patients

Patient no.	Age, y	Gender	ISS	Accident situation	Patient situation		JAST type	Associated injuries	Pancreas-specific surgery	Complications	LOS in hospital, d	Follow-up period
1	19	F	16	MVA	driver	seat belt	Ⅲa	liver	NOM	Pseudocyst	30	3y6m
2	22	M	21	MBA	rider	pole	Ⅲb	liver, scapula	NOM	Pseudocyst	49	4y2m
3	29	F	24	MVA	co-driver	seat belt	Ⅲb	liver, spleen, stomach, Rt. kidney, small bowel, colon, cervical spine	DR	Non	184	9y11m
4	34	M	16	MVA	driver	steering wheel	Ⅱ	duodenum	DR	Abdominal abscess	51	28y7m
5	19	F	5	MVA	driver	steering wheel	Ⅱ	non	RP	Pancreatic fistula, pancreatitis, abdominal abscess	80	14y4m
6	48	M	9	MVA	driver	steering wheel	Ⅱ	duodenum, mesentery, stomach, SMV	RP	Non	25	24y5m
7	35	M	16	MVA	driver	steering wheel	Ⅲb	liver, spleen, SMV	RP	Pancreatic fistula, abdominal abscess	82	26y9m
8	36	M	4	MVA	driver	steering wheel	Ⅱ	liver	RP	Non	34	29y1m
9	49	M	9	Work related	worker	iron plate 2t	Ⅲa	liver, spleen, Lt. kidney, heart	DP	Non	28	6y6m
10	53	M	45	MBA	rider	handle	Ⅲb	liver, spleen, diaphragm, lung, pelvis, tibia	DP	Non	48	10y2m
11	16	M	9	MBA	rider	handle	Ⅲb	mesentery	DP	Pancreatic fistula, abdominal abscess	64	22y3m
12	16	M	29	MBA	rider	handle	Ⅲa	spleen	DP	Non	17	26y1m
13	17	F	21	MBA	rider	handle	Ⅲb	renal artery, splenic artery, clavicle	DP	Abdominal abscess	93	26y2m
14	28	M	30	MVA	driver	steering wheel	Ⅲb	duodenum, face, lower leg	PD	Non	26	26y11m

d, days; DP, distal pancreatectomy; DR, only drainage; F, female; ISS, injury severity score; JAST, Japanese Association for the Surgery of Trauma Classification for Pancreatic Injury; LOS, length of stay; Lt., left; M, male; m, months; MBA, motor bike accident; MVA, motor vehicle accident; NOM, non-operative management; PD, pancreaticoduodenectomy; Rt., right; RP, repair of parenchyma; SMV, superior mesenteric vein; y, years

TABLE 3.
Summary of the Questionnaire

Patient no.	BMI	Pre-trauma DM	Post-trauma DM	Therapy for DM	Diarrhea	Steatorrhea	Oral pancreatic enzymes	Body weight loss	Chronic pancreatitis	Others
1	19. 1	−	−	−	−	−	−	−	−	
2	18.6	−	−	−	−	−	−	−	−	Fatty liver
3	22.9	−	−	−	−	−	−	−	−	
4	16.8	−	+	Insulin with medication	−	−	−	−	−	AMI, brain infarction
5	23.4	−	−	−	−	+	−	−	−	
6	22.7	−	−	−	−	−	−	−	−	Multiple myeloma, CKD
7	18.1	−	−	−	−	−	−	−	−	Fatty liver
8	23.2	−	+	Medication	−	−	−	−	−	Fatty liver
9	23.3	−	−	−	−	−	−	−	−	
10	23.9	−	−	−	−	−	−	−	−	
11	25.3	−	+	Medication	−	+	−	−	−	Fatty liver
12	23.4	−	+	Medication	−	+	−	−	−	
13	28.2	−	−	−	−	−	−	−	−	
14	21.8	−	+	Insulin with medication	−	+	+	−	−	

− = negative response; + = positive response
AMI, acute myocardial infarction; BMI, body mass index; CKD, chronic kidney disease; DM, diabetes mellitus

most common complication related to pancreatic injury was pancreatic fistula [3/14 (21.4%)], followed by pancreatic pseudocyst [2/14 (14.3%) patients] and pancreatitis [1/14 (7.1%)].

Questionnaire Results

The questionnaire results are presented in Table 3. The median age of the 14 patients at the time of the survey was 49 years (range: 37-62.3 years), and the median post-injury period was 23 years 5 months (range: 9 years 1 month to 26 years 11 months). Of the 14 patients, 5 (35.7%) developed new-onset DM, with 2 receiving insulin therapy; all 5 patients had undergone surgery. In addition, 4 (33.3%) of the 14 patients developed diarrhea exacerbated by fat intake. No extreme obesity or malnutrition was evident in any of the patients from their BMI.

Timing of DM Onset

Insulin-based glycemic control was necessary only for Patient 14 after PD, and he has continued insulin therapy. No new-onset DM was seen within 3 years of trauma in any of the other patients; however, DM developed in 4 patients more than 15 years after the trauma (Patients 4, 8, 11, and 12). Patient 4 was a 34-year-old man who had undergone drainage (DR) by laparotomy and developed DM at 50 years of age. Patient 8 was a 36-year-old man who had undergone repair of the parenchyma (RP) by laparotomy and developed DM at 60 years of age. Patients 11 and 12 were both 16-year-old males who had undergone DP and developed DM at 35 and 40 years of age, respectively.

Hematological Test Results

The hematological test results are presented in Table 4. No patient exhibited clearly low serum albumin or lipid levels. PNI was low in Patient 14 (who required insulin therapy and suffered from daily diarrhea) and Patient 6 (who had chronic kidney disease). Patient 9 had no history of DM treatment but had an elevated HbA1c level of 6.7%.

Comparison between Pancreatectomy and Non-pancreatectomy Groups

To study the effects of parenchymal volume reduction on long-term outcomes, an intergroup comparison was conducted between pancreatectomy and non-pancreatectomy groups (Table 5). The pancreatectomy

TABLE 4.
Laboratory Data

Patient no.	Albumin g/dl	eGFR ml/ min./1.73 m^2	Amylase U/l	Lipase U/l	Total cholesterol mg/dl	HbA1c (NGSP) %	TLC	Trypsin ng/ml	PNI
1	4.49	120.7	75	5	163	6	1411.2	233	52
2	4.44	94.6	94	7	178	5.5	1539.2	131	52.1
3	4.27	63.1	116	33	207	6.3	2028	387	52.8
4	4.46	76.8	65	8	203	6.3	917	79	49.2
5	5.1	138.2	49	10	166	5.4	2197.8	248	62
6	3.18	26.9	89	25	134	6.1	1530	797	39.5
7	4.46	100.6	53	13	199	5.7	1446.9	316	51.8
8	3.96	81.4	70	31	181	7	1147	577	45.3
9	4.29	65.7	89	16	227	6.7	2027.6	350	53
10	4.29	80.9	63	34	201	5.7	3268.8	491	59.2
11	4.65	121.6	59	8	260	8.4	2912	429	61.1
12	4.53	90.9	66	26	169	7	3708	439	63.8
13	4.44	86.8	68	20	243	5.4	1907.4	382	53.9
14	3.42	75.3	68	2	107	8	1259.9	50	40.5

PNI = (10*albumin) + (0.005*TLC)
eGFR, estimated glomerular filtration rate; HbA1c, glycated hemoglobin; NGSP, National Glycohemoglobin Standardization Program; PNI, prognostic nutritional index; TLC, total lymphocyte count

group comprised patients who had undergone pancreatic parenchymal resection, such as DP or PD (i.e., Patients 9-14). The non-pancreatectomy group comprised patients who had not required pancreatectomy, such as RP or DR (i.e., Patients 3-8), and those who had not undergone surgery (i.e., Patients 1 and 2).

Post-trauma new-onset DM occurred in 3/6 (50%) patients in the pancreatectomy group and in 2/8 (25%) patients in the non-pancreatectomy group. Chronic diarrhea was seen only in 1 patient in the pancreatectomy group (Patient 14) who had undergone PD and had been regularly using oral pancreatic enzyme preparations. Steatorrhea after fat intake was seen in 3/6 (50%) patients in the pancreatectomy group and in 1/8 (12.5%) patients in the non-pancreatectomy group. A statistically significant difference was only seen for BMI in the intergroup comparison.

DISCUSSION

A search of PubMed revealed only two reports on pancreatic functional outcomes after pancreatic trauma. One was by Cogbill et al. [5], who examined endocrine function (impaired glucose tolerance) after DP, and the other was by Al-Ahmadi et al. [2], who conducted phone interviews of 19 patients with pancreatic injury at a single facility over a 5-year period. Cogbill et al. saw no impairment in glucose tolerance requiring insulin in DP patients even after 80% distal pancreatectomy and reported that there was no onset of exocrine dysfunction in an evaluation of pancreatic enzyme usage. However, their survey was conducted at discharge and the long-term outcomes of the patients were not reported. In contrast, Al-Ahmadi et al. reported that endocrine dysfunction occurred in 15.8% of patients over a 5-year period at a single facility, but they found no cases of exocrine dysfunction. However, follow-up in that study was limited to a maximum of 5 years. Considering the present findings, we believe that 5 years may not be sufficiently long to examine pancreatic functional outcomes.

Pancreatic endocrine and exocrine functions are believed to depend on the absolute amount of pancreatic parenchymal cells. However, a negative correlation exists between insulin secretory capacity and age in healthy individuals [6]. Thus, when the absolute amount of parenchymal cells decreases following trauma-related PD or DP, dysfunction at a later stage is conceivable despite the absence of dysfunction at discharge. In fact, a study on non-traumatic benign or low-grade tumors that examined the effects of DP on pancreatic endocrine function and onset of DM found that new-

TABLE 5.
Comparison between the Pancreatectomy and Non-pancreatectomy Groups

	Pancreatectomy (n = 6)	Non-pancreatectomy (n = 8)	*p* value
Males, %	83.3	62.5	N.S.
Age, y	22.5 (16–50)	31.5 (19.75–35.75)	N.S.
ISS	25 (9–33.75)	16 (6–19.75)	N.S.
LOS in hospital, d	38 (23.75–71.25)	50 (31–81.5)	N.S.
Operative management	6	6	N.S.
JAST 2008 type, no.			
I	0	0	
II	0	4	
IIIa	2	0	
IIIb	4	4	
Complications, no. (%)			
Pancreatitis	0	1	
Pseudocyst	0	2	
Pancreatic fistula	1	2	
Follow-up period	24y2m (9y3m to 26y11m)	19y5m (5y8m to 28y0m)	N.S.
BMI	23.6 (22.9–26.0)	20.9 (18.3–23.1)	*0.024*
Pre-trauma DM	0	0	N.S.
Post-trauma new-onset DM	3	2	N.S.
Medications for DM	3	1	N.S.
Insulin for DM	1	1	N.S.
Oral pancreatic enzymes	0	0	N.S.
Diarrhea	1	0	N.S.
Steatorrhea after fat intake	3	1	N.S.
Chronic pancreatitis	0	0	N.S.
Body weight loss	0	0	N.S.
Amylase, U/l	67 (62–73.2)	72.5 (56–92.75)	N.S.
Lipase, U/l	18 (6.5–28)	11.5 (7.3–29.5)	N.S.
Trypsin, ng/ml	405.5 (275–452)	282 (156.5–529.5)	N.S.
HbA1c (NGSP), %	6.9 (5.6–8.1)	6.05 (5.55–6.3)	N.S.
eGFR, ml/min./1.73 m^2	83.9 (72.9–98.6)	88 (66.5–115.7)	N.S.
Albumin, g/dl	4.37 (4.07–4.56)	4.45 (4.04–4.48)	N.S.
Total cholesterol, mg/dl	214 (153.5–247.3)	179.5 (163.8–202)	N.S.
TLC	2469.8 (1745.5–3378.6)	1488.5 (1213.1–1905.8)	N.S.
PNI	56.6 (49.9–61.8)	51.9 (46.3–52.7)	N.S.

BMI, body mass index; d, days; DM, diabetes mellitus; eGFR, estimated glomerular filtration rate; HbA1c, glycated hemoglobin; ISS, injury severity score; JAST, Japanese Association for the Surgery of Trauma Classification for Pancreatic Injury; LOS, length of stay; m, months; NGSP, National Glycohemoglobin Standardization Program; N.S., no significant difference; PNI, prognostic nutritional index; TLC, total lymphocyte count; y, years

onset DM occurred in 20 of 52 (38.5%) patients during a 12-month postoperative follow-up period; they also found simultaneous elevations in fasting blood glucose and HbA1c levels within 3 months of surgery, but not immediately after surgery [7]. This supports the clinical importance of examining outcomes for pancreatic trauma over a long period, rather than only at discharge.

In contrast, when abnormalities in endocrine function, particularly DM, occur during the long-term course after trauma, it is extremely difficult to determine whether they are related to the trauma. In this study, patients were divided into a pancreatectomy group (PD or DP) and a non-pancreatectomy group (DR alone, RP alone, or no surgery). We then attempted to examine whether there were any differences in the incidence of pancreatic endocrine and exocrine dysfunction between the 2 groups.

We first looked at the incidence of DM in relation to endocrine function and found that the incidence of DM was higher in the pancreatectomy group (50% in the pancreatectomy group vs 25% in the non-pancreatectomy group). However, due to the small sample size (5 patients), we were unable to demonstrate a statistically significant difference in the incidence of DM. In contrast, an examination of the timing of onset revealed that only 1 of the 5 (20%) patients had DM at discharge, whereas 4 of the 5 (80%) patients developed DM 15 years after trauma.

Retrospective studies in patients who have undergone DP for pancreatic tumors or pancreatic disease have reported incidences of endocrine dysfunction ranging from 4.8% to 8% [8-10]. However, the follow-up period in all these studies was less than 21 months after discharge, perhaps because cases of malignancy were included in all reports. Meanwhile, in a retrospective study of 90 patients with chronic pancreatitis who had undergone DP, it was reported that the rate of DM onset was 23% over a 34-month follow-up period [11]. Two other retrospective studies in patients who had undergone DP for pancreatic tumors reported incidences of DM of 14%-19% over follow-up periods of at least 60 months [12,13]. In the present study, 4 of the 5 (80%) patients were diagnosed with DM at least 15 years after trauma. Although a causal relationship with trauma cannot be necessarily inferred, given that the 2 patients who had undergone DP showed DM onset at a relatively young age (35 and 40 years), a correlation between pancreatectomy and DM cannot be entirely ruled out.

In contrast to the data for endocrine dysfunction, incidences of exocrine dysfunction following DP vary greatly (1.6%–61%) [9,11-13]. Although these discrepancies in the literature could be due to differences in the background of the participants, the diagnostic criteria for dysfunction may also be a likely cause. Falconi et al. reported an incidence of exocrine dysfunction of 18%, which is higher than that in other reports [11]. In their study, steatorrhea was diagnosed by the fecal chymotrypsin test; however, this test is no longer used in Japan. Shikano et al. diagnosed exocrine dysfunction in cases where diarrhea was a symptom or where diarrhea was improved by pancreatic enzyme intake and reported an incidence of 2.8%, which is lower than that in other reports [13]. In the present study, in which chronic diarrhea or diarrhea and steatorrhea exacerbated by fat intake were grounds for diagnosis, exocrine dysfunction developed at a rate of 33.3%. Other studies have reported pancreatic steatorrhea at a rate of approximately 10%, without the presence of diarrhea [14], suggesting the presence of ambiguity in their diagnosis. The Van de Kamer method [15], which is considered the gold standard for the evaluation of exocrine function, can evaluate steatorrhea quantitatively but is troublesome because all stool needs to be collected for 3 days after ingesting 100 grams of fat-restricted diet for 5 days. Consequently, we did not use this diagnostic method in the present study. Future long-term follow-up studies for suspected exocrine dysfunction would need to consider the use simpler pancreatic function tests, such as those evaluating fecal elastase-1 [16-18] or 13C compounds [19].

Study Limitations

In this study, we extracted the data from a sample of all patients with trauma over a 32-year period and invited patients with pancreatic trauma to participate. However, only 22.6% of the patients with pancreatic injury consented to participate, reducing the statistical power of our findings. Furthermore, there was variation in the follow-up periods and differences in the regularity of follow-up. Thus, our results may not sufficiently reflect the long-term outcomes of pancreatic injury. Therefore, future prospective studies will be needed to clarify the long-term outcomes following pancreatic injury.

Conclusions

We studied late complications and long-term outcomes following pancreatic trauma in 14 patients who had been managed at our facility. The comorbidity rates for pancreatic endocrine and exocrine dysfunctions were 35.7% and 33.3%, respectively. In patients requiring surgery, late complications occurred even when no pancreatic dysfunction had been seen at discharge, suggesting the need for long-term follow-up of such patients. Our findings suggest that management policies for pancreatic trauma should take into account the possibility that the onset of DM may be accelerated by pancreatectomy.

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REFERENCES

1. Borkon MJ, Morrow SE, Koehler EA, Shyr Y, Hilmes MA et al. Operative intervention for complete pancreatic transection in children sustaining blunt abdominal trauma: revisiting an organ salvage technique. Am Surg 2011; 77:612-620.
2. Al-Ahmadi K and Ahmed N. Outcomes after pancreatic trauma: experience at a single institution. Can J Surg 2008; 51:118-124.
3. Japanese Association for the Surgery of Trauma Classification committee. Classification of Pancreatic Injury 2008 (in Japanese). J Jpn Assoc Surg Trauma 2008; 22:264.
4. Onodera T, Goseki N, and Kosaki G. Prognostic nutritional index in gastrointestinal surgery of malnourished cancer patients (in Japanese with English abstract). Nihon Geka Gakkai Zasshi 1984; 85:1001-1005.
5. Cogbill TH, Moore EE, Morris JA, Hoyt DB, Jurkovich GJ et al. Distal pancreatectomy for trauma: a multicenter experience. J Trauma 1991; 31:160-1606.
6. Iozzo P, Beck-Nielsen H, Laakso M, Smith U, Yki-Järvinen H et al. Independent influence of age on basal insulin secretion in nondiabetic humans. European Group for the Study of Insulin Resistance. J Clin Endocrinol Metab 1999; 84:863-868.
7. Shirakawa S, Matsumoto I, Toyama H, Makoto Shinzeki, Tetsuo Ajiki et al. Pancreatic volumetric assessment as a predictor of new-onset diabetes following distal pancreatectomy. J Gastrointest Surg 2012; 16:2212-2219.
8. Lillemoe KD, Kaushal S, Cameron JL, Sohn TA, Pitt HA et al. Distal pancreatectomy: indications and outcomes in 235 patients. Ann Surg 1999; 229:693–698; discussion 698-700.
9. Shoup M, Brennan MF, McWhite K, Leung DH, Klimstra D et al. The value of splenic preservation with distal pancreatectomy. Arch Surg 2002; 137:164-168.
10. King J, Kazanjian K, Matsumoto J, Reber HA, Yeh MW et al. Distal pancreatectomy: incidence of postoperative diabetes. J Gastrointest Surg 2008; 12:1548-1553.
11. Hutchins RR, Hart RS, Pacifico M, Bradley NJ, and Williamson RCN. Long-term results of distal pancreatectomy for chronic pancreatitis in 90 patients. Ann Surg 2002; 236:612-618.
12. Falconi M, Mantovani W, Crippa S, Mascetta G, Salvia R et al. Pancreatic insufficiency after different resections for benign tumors. Br J Surg 2008; 95:85-91.
13. Shikano T, Nakao A, Kodera Y, Yamada S, Fujii T et al. Middle pancreatectomy: safety and long-term results. Surgery 2010; 147:21-29.
14. DiMagno EP, Go VL, and Summerskill WH. Relations between pancreatic enzyme ouputs and malabsorption in severe pancreatic insufficiency. N Engl J Med 1973; 288:813-815.
15. Van de Kamer JH, ten Bokkel Huinink H, and Weyers HA. Rapid method for the determination of fat in feces. J Biol Chem 1949; 177:347-355.
16. Stein J, Jung M, Sziegoleit A, Zeuzem S, Caspary FW et al. Immunoreactive elastase I: clinical evaluation of a new noninvasive test of pancreatic function. Clin Chem 1996; 42:222-226.
17. Leeds JS, Oppong K, and Sanders DS. The role of fecal elastase-1 in detecting exocrine pancreatic disease. Nat Rev Gastroenterol Hepatol 2011; 8:405-415.
18. Löser C, Möllgaard A, and Fölsch UR. Faecal elastase 1: a novel, highly sensitive, and specific tubeless pancreatic function test. Gut 1996; 39:580-586.
19. Hiele M, Ghoos Y, Rutgeerts P, and Vantrappen G. Starch digestion in normal subjects and patients with pancreatic disease, using a 13CO2 breath test. Gastroenterology 1989; 96:503-509.