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ORIGINAL ARTICLE

Schematic Pancreatic Configuration: A Risk Assessment for Postoperative Pancreatic Fistula After Pancreaticoduodenectomy

Motokazu Sugimoto · Shinichiro Takahashi · Naoto Gotohda · Yuichiro Kato · Takahiro Kinoshita · Hidehito Shibasaki · Masaru Konishi

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Abstract
Introduction Postoperative pancreatic fistula (POPF) remains a serious complication after pancreaticoduodenectomy (PD). Preoperative risk assessment of POPF is desirable in careful preparation for operation. The aim of this study was to assess simple and accurate risk factors for clinically relevant POPF based on a schematic understanding of the pancreatic configuration using preoperative multidetector computed tomography.
Methods Three hundred and eighteen consecutive patients who underwent PD in the National Cancer Center Hospital East between November 2006 and March 2013 were investigated. Pre-, intra-, and postoperative clinicopathological findings as well as pancreatic configuration data were analyzed for the risk of clinically relevant POPF. POPF was defined according to the International Study Group of Pancreatic Fistula classification. POPF grade A occurred in 52 patients (16.4 %), grade B in 84 (26.4 %), and grade C in 6 (1.9 %).
Conclusions Independent risk factors for POPF grade B/C included main pancreatic duct diameter (MPDd) < 2 mm ($P = 0.001$), parenchymal thickness ≥ 8 mm ($P = 0.018$), not performing portal vein/superior mesenteric vein resection ($P = 0.004$), and amylase level of drainage fluid on postoperative day 3 ≥ 375 IU/L ($P < 0.001$). Pancreatic configuration data including MPDd and parenchymal thickness were good indicators of clinically relevant POPF.

Keywords Postoperative pancreatic fistula · Pancreaticoduodenectomy · Pancreatic configuration · Main pancreatic duct diameter · Parenchymal thickness

Introduction

Postoperative pancreatic fistula (POPF) is still a devastating complication after pancreaticoduodenectomy (PD), because it is intractable, needs prolonged drain insertion, and can lead to further morbidity and mortality. It is generally reported that the incidence of clinically relevant POPF after PD is 7.6–36.4 %,[1–5] in accordance with the definition of the International Study Group of Pancreatic Fistula (ISGPF).[6] To reduce the incidence of POPF after PD, accurate preoperative assessment of POPF risk, as well as appropriate surgical techniques and perioperative management especially for high-risk cases, is required. Preoperative assessment of risk factors in a simple, objective way could be utilized in a widespread manner. For instance, a surgical trial with stratification of patients according to the definitive POPF risk may enhance the statistical power for a specific procedure.

Multidetector computed tomography (MDCT) to create a picture of the pancreas may express the POPF risk inherent in the pancreas. A small main pancreatic duct (MPD) is widely accepted as a significant risk factor for POPF after PD,[5,7–16] and so is a thick pancreas for POPF after distal pancreatectomy,[17,18] both of which can be demonstrated quite simply by MDCT. Schematic understanding of the pancreatic configuration by referring to preoperative MDCT findings, as established in our previous study of distal pancreatectomy,[18] may enable evaluation of preoperative risk factors for POPF after PD. The aims of this study were to assess simple and objective parameters using preoperative MDCT, compare their prognostic value for clinically relevant POPF with that of other preoperative, intraoperative, and postoperative parameters, and educe accurate risk factors available preoperatively.

M. Sugimoto · S. Takahashi (✉) · N. Gotohda · Y. Kato · T. Kinoshita · H. Shibasaki · M. Konishi
Department of Digestive Surgical Oncology, National Cancer Center Hospital East, 6-5-1, Kashiwa-no-ha, Kashiwa, Chiba Prefecture 277-8577, Japan
e-mail: shtakaha@east.ncc.go.jp

Materials and Methods

Patients and Clinical Data Collection

Three hundred and eighteen consecutive patients who underwent PD with curative intent at the National Cancer Center Hospital East between November 2006 and March 2013 were retrospectively investigated. Clinicopathological data were reviewed from the medical records. All patients underwent preoperative contrast-enhanced MDCT focusing on the pancreas and surrounding region as a part of the diagnostic workup, and PD was indicated for suspected malignancy. During this period, the reconstruction method for the remnant pancreas and postoperative management were standardized. The study was approved by the institutional review board of the National Cancer Center.

Operative Techniques

Subtotal stomach-preserving PD was performed in most of the cases, whereas conventional resection with antrectomy was performed particularly in cases with a gastric tumor. D2 lymphadenectomy was routinely performed with skeletonization of the arteries of the hepatoduodenal ligament, and removal of the retroportal pancreatic lamina on the right aspect of the mesenteric artery, paraaortic lymph node sampling, or extended resection including adjacent organs was performed based on the surgeon's decision to achieve curative resection. The pancreas was divided using a scalpel, ultrasonically activated device, or a combination of both. Segmental resection of the portal vein (PV) and/or superior mesenteric vein (SMV) was performed when a periampullary tumor was inseparable from the vein. For reconstruction, end-to-side pancreaticojejunostomy was performed using the modified technique first described by Kakita et al.[19] (Fig. 1). For the outer layer, two to four interrupted sutures penetrating the pancreatic parenchyma and picking up the seromuscular layer of the jejunum were placed using 3–0 nonabsorbable monofilament sutures with a straightened needle. Next, the pancreatic duct and full thickness jejunal wall were fixed as the inner layer with 8 to 14 interrupted stitches using 5–0 or 6–0 absorbable monofilament sutures, according to the size of the MPD. Then approximation of the jejunal wall and the pancreatic stump was accomplished with ligation of the outer layer stitches to cover fully the cut surface of the pancreas. A 6-Fr short internal drainage tube was placed through the pancreatic duct with an anchoring suture using one of the inner layer stitches, except in cases with an exceedingly dilated MPD. The number of stitches and the size of the suture material were at the surgeon's discretion for each case. No autologous grafts, artificial grafts, or sealing agents were applied in covering the anastomosis. Jackson–Pratt-type closed suction drains were placed near the pancreaticojejunal and choledochojejunal anastomoses, avoiding direct contact with vascular structures. Pancreatic consistency, especially at the pancreatic resection site, was evaluated subjectively as soft or hard by the surgeon during the operation.

Perioperative Management

D-Amy (in International units per liter) and drainage fluid culture were evaluated on POD 1, 3, and 5 and as necessary. Drains were removed when the drainage fluid did not show high D-Amy or signs of infection after POD 3–6. In cases showing signs of infection in the drainage fluid, drain replacement via the ordinary tract created at operation was performed under fluorography on POD 7–10, to prevent drain occlusion and achieve effective drainage. Postoperative CT was not planned routinely but was carried out if clinical symptoms suggested an intraabdominal inflammatory complication. In cases with drainage failure, percutaneous drainage was facilitated by CT or ultrasonographic guidance. An oral diet was restarted on POD 3 in general, and was not prohibited unless delayed gastric emptying or anastomotic failure in the digestive passage was diagnosed radiologically. Somatostatin and its analogs were never administered perioperatively in an attempt to prevent or treat POPF. Readmission for surgical complications within 30 days after discharge was evaluated. The POPF cases focused on in this study were “clinically relevant,” consistent with grades B and C of the ISGPF criteria.

Schematic Understanding of Pancreatic Configuration

The configuration of the pancreatic stump was evaluated in detail.[18] The pancreatic stump was recognized as an eclipse, the MPD as a circle, and the parenchyma as the difference between the whole stump and MPD, as shown in Fig. 2. Parameters including stump thickness, stump width, and MPD diameter (MPDd) were measured using axial and coronal 2-mm-slice high-resolution MDCT, at the pancreatic resection site, which was determined with reference to the positional relationship with the adjacent vessels (Fig. 3). Pancreatic thickness was considered to be the length of the pancreas in an approximately ventrodorsal direction and vertical to the MPD, whereas pancreatic width was considered to be the length of the pancreas in an approximately cephalocaudal direction and vertical to the pancreatic thickness. Parameters including parenchymal thickness, parenchymal width, MPD area, stump area, and parenchymal area were defined and calculated using each formula (Fig. 2). The resection site was determined mainly by preoperative MDCT, confirmed by intraoperative ultrasound, and occasionally changed to a distal site because of the finding of microscopic malignancy in a frozen biopsy of the stump, with consideration of obtaining a secure tumor margin and the remnant pancreatic volume.

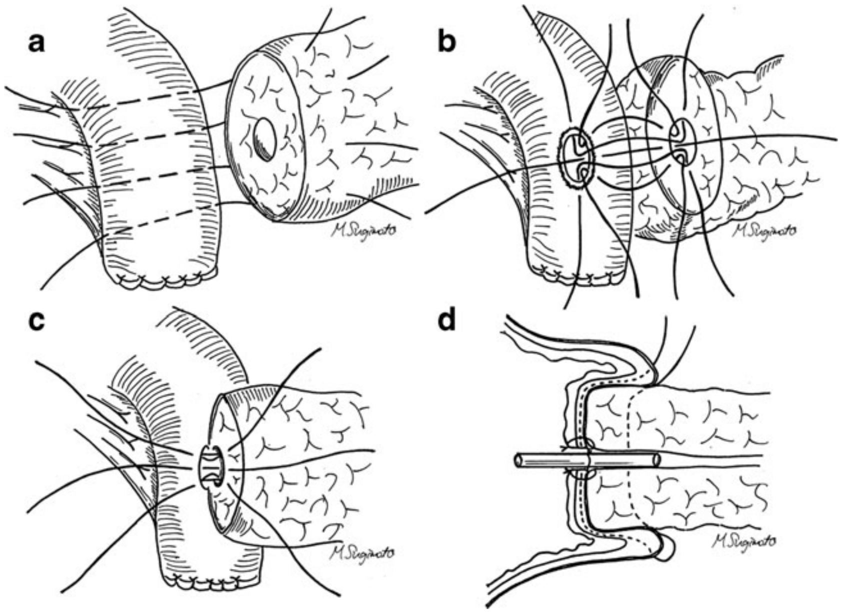

Fig. 1 Reconstructive procedure of end-to-side pancreaticoduodenectomy. **a** Four interrupted sutures penetrating the pancreatic parenchyma and picking up the seromuscular layer of the jejunum were placed for the outer layer, using 3–0 nonabsorbable monofilament sutures with a straightened needle. **b** The posterior wall of the pancreatic duct and full thickness jejunal wall were fixed as the inner layer with five interrupted stitches using 5–0 absorbable monofilament sutures. Outer layer stiches are omitted in figure. **c** The anterior wall of the inner layer of pancreatic duct and full thickness jejunal wall were fixed with three interrupted stitches using 5–0 absorbable monofilament sutures. Outer layer stiches are omitted in figure. **d** Approximation of the jejunal wall and the pancreatic stump was accomplished with ligation of the outer layer stitches to fully cover the cut surface of the pancreas. A 6-Fr short internal drainage tube was placed through the pancreatic duct with an anchoring suture using one of the inner layer stitches

Statistical Analysis

Preoperative patient characteristics, pancreatic configuration data, intraoperative factors, and D-Amy, representing postoperative data, were compared between patients who did and did not experience clinically relevant POPF in univariate logistic regression analysis. Covariates reported to be risk factors for POPF were included.[3–5,7–16,20–23] Categorical variables are summarized as numbers and percentages, and continuous variables are presented as median±standard deviation. Preoperative and intraoperative factors achieving statistical significance at a 0.1 level in univariate analysis were included in multivariate analysis. Receiver operating characteristic (ROC) curves were used and area under the curve (AUC) was analyzed, to determine the cut-off value with sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy, and to identify especially predictive variables in pancreatic configuration data. One postoperative parameter, among D-Amy on POD 1, 3, and 5, was also included in multivariate analysis, although it was not considered causative or predictive. Then multivariate logistic regression analysis was conducted to identify independent risk factors or associated parameters for POPF grade B/C during the perioperative period. Odds ratios (OR) with 95 % confidence intervals (95 % CI) were obtained. All P values were based on two-sided statistical tests, setting the significance level as 0.05. All statistical analyses were performed using SPSS Statistics version 19.0 software (SPSS, Chicago, IL, USA).

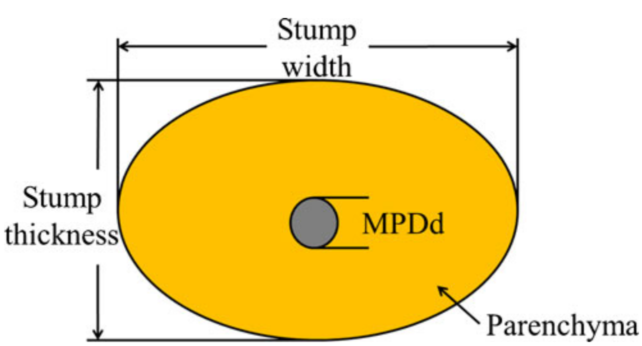

Fig. 2 Schematic configuration of pancreatic stump. *MPDd* main pancreatic duct diameter (in millimeters). *parenchymal thickness* stump thickness−MPDd (in millimeters), *parenchymal width* stump width−MPDd (in millimeters), *MPD area* 1/4×MPDd×MPDd×π (in square millimeters), *stump area* 1/4×stump width×stump thickness×π (in square millimeters), *parenchymal area* stump area−MPD area (in square millimeters)

Results

Postoperative Outcome

The postoperative course with respect to POPF in 318 patients is tabulated in Table 1. POPF grade A was observed in 52 cases (16.4 %), grade B in 84 cases (26.4 %), and grade C in 6

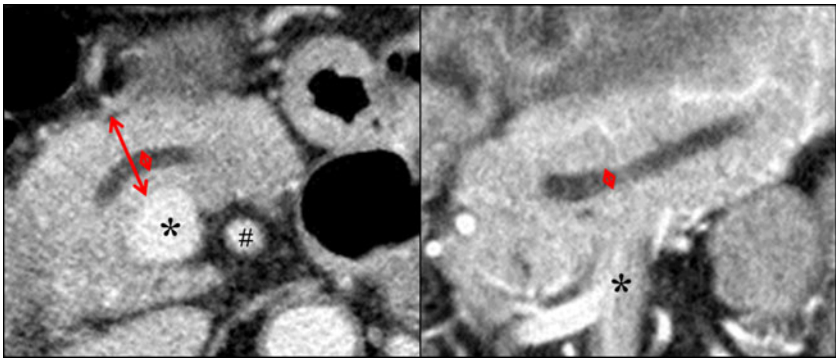

Fig. 3 Assessment of pancreatic thickness and main pancreatic duct by preoperative MDCT. Pancreatic thickness and main pancreatic duct diameter (*MPDd*) were measured at the resection site in axial (*left*) and coronal (*right*) views of preoperative MDCT. *Large arrow* pancreatic thickness; *small arrow* MPDd. *Asterisk* denotes superior mesenteric vein. *Number sign* denotes superior mesenteric artery

cases (1.9 %). Patients with POPF grade B/C experienced prolonged drain insertion (29±21 vs. 6±5 days), higher need for percutaneous drainage (22.2 vs. 2.3 %), prolonged postoperative hospital stay (33±20 vs. 13±12 days), and higher mortality (2.2 vs. 0.0 %), compared with patients who did not develop POPF (POPF grade A/none). Reoperation was never performed with an intention to manage POPF. The detailed reasons for 30-day readmission were mild transient anorexia in three patients, cholangitis in two, and delayed gastric emptying in two, with POPF grade A/none, whereas intraabdominal bleeding (POPF grade C) in one patient with POPF grade B/C. Both of the mortality cases underwent radiologic intervention for aneurysmal rupture induced by POPF and died of subsequent liver failure.

Evaluation of Risks for Clinically Relevant POPF

Factors reported or assumed to be associated with clinically relevant POPF after PD were compared between the patient groups with POPF grade A/none and POPF grade B/C by univariate analysis (Tables 2). Of the preoperative factors, patients with high BMI and pathological condition other than pancreatic cancer had a significantly higher incidence of POPF grade B/C ($P<0.001$ and $P<0.001$), whereas patients without diabetes showed a tendency for a higher incidence ($P=0.051$). Of the pancreatic configuration data, MPDd, stump width, parenchymal thickness, parenchymal width, and parenchymal area differed significantly between patients with POPF grade A/none and POPF grade B/C ($P<0.001$, $P=0.003$, $P<0.001$, $P<0.001$, and $P<0.001$, respectively). ROC curves for pancreatic configuration data are shown in Fig. 4. Values of AUC in these data were as follows; MPDd, 0.764; stump thickness, 0.523, stump width, 0.614; parenchymal thickness, 0.709; parenchymal width, 0.687; stump area, 0.589; and parenchymal area, 0.656. These results indicated that parameters with "fair accuracy" were MPDd and parenchymal thickness (AUC≥0.700). When a cut-off value of 2 mm was applied for MPDd, sensitivity was 42.2 %; specificity, 89.5 %; PPV, 61.3 %; NPV, 79.7 %; and accuracy 76.1 %, whereas sensitivity was 68.9 %; specificity, 71.9 %; PPV, 49.2 %; NPV, 85.4 %; and accuracy, 71.1 % when the cut-off value was 3 mm. When a cut-off value of 8 mm was applied for parenchymal thickness, sensitivity was 71.1 %; specificity, 64.5 %; PPV, 44.1 %; NPV, 85.0 %; and accuracy, 66.4 %. Of the intraoperative factors, soft pancreas and not performing PV/SMV resection were significantly associated with clinically relevant POPF ($P<0.001$ and $P=0.001$, respectively). Of the postoperative data, D-Amy on POD 1, 3, and 5 differed significantly between patients with POPF grade A/none and POPF grade B/C ($P=0.005$, $P<0.001$, and $P<0.001$, respectively). D-Amy on POD 3≥375 was considered to be most strongly associated with POPF grade B/C, because it is the criterion for POPF grade A. BMI≥25 kg/m^2, absence of diabetes, pathological condition other than pancreatic cancer, MPDd<2 mm, parenchymal thickness≥8 mm, soft pancreas, not performing PV/SMV resection, and POD 3 D-Amy≥375 IU/L were included in multivariate analysis of POPF grade B/C. Independent risk factors for clinically relevant POPF were MPDd<2 mm (OR, 3.589 (95 % CI, 1.665–7.737), $P=0.001$), parenchymal thickness≥8 mm

Table 1 Postoperative outcome after PD

	Overall ($n=318$)	POPF grade A/none ($n=228$)	POPF grade B/C (n=90)
Drain insertion (days)	7±17	6±5	29±21
Percutaneous drainage	25 (7.9 %)	5 (2.3 %)	20 (22.2 %)
Reoperation	3 (0.9 %)	2 (0.9 %)	1 (1.1 %)
Postoperative hospital stay (days)	15±18	13±12	33±20
30-day readmission	8 (2.5 %)	7 (3.1 %)	1 (1.1 %)
Mortality	2 (0.6 %)	0 (0.0 %)	2 (2.2 %)

PD pancreaticoduodenectomy, *POPF* postoperative pancreatic fistula

Table 2 Characteristics of patients and univariate analysis of risk factors for clinically relevant POPF after PD

Parameter	Overall (*n*=318)	POPF grade A/none (*n*=228)	POPF grade B/C (*n*=90)	*P*
Preoperative factors				
Age	69±11	69±11	70±10	0.489
Sex (male)	207 (65.1 %)	149 (68.3 %)	58 (64.4 %)	0.879
BMI (kg/m^2)	21.5±3.1	21.0±3.0	22.8±3.1	<0.001*
ASA score (1/2/3)	109/192/17	77/138/13	32/54/4	0.607
Diabetes	73 (23.0 %)	59 (27.1 %)	14 (15.6 %)	0.051
Coronary artery disease	18 (5.7 %)	12 (5.5 %)	6 (6.7 %)	0.626
Preoperative biliary drainage	161 (50.6 %)	121 (55.5 %)	40 (44.4 %)	0.167
Preoperative therapy	12 (3.8 %)	11 (5.0 %)	1 (1.1 %)	0.152
Albumin (g/dL)	3.8±0.4	3.8±0.4	3.9±0.5	0.958
Creatinine (mg/dL)	0.8±0.2	0.7±0.2	0.8±0.2	0.581
Pathological diagnosis (pancreatic cancer)	158 (49.7 %)	131 (60.1 %)	27 (30.0 %)	<0.001*
Pancreatic configuration data				
MPDd (mm)	3.8±3.4	4.7±3.6	2.2±1.7	<0.001*
Stump thickness (mm)	12.4±3.7	12.4±3.9	13.0±3.3	0.941
Stump width (mm)	24.0±6.3	24.0±6.4	27.0±5.7	0.003*
Parenchymal thickness (mm)	7.7±3.7	7.0±3.5	9.9±3.5	<0.001*
Parenchymal width (mm)	20.5±7.9	19.3±8.0	24.4±6.3	<0.001*
Stump area (mm^2)	235.2±99.5	230.8±104.3	255.9±84.5	0.086
Parenchymal area (mm^2)	211.9±91.1	199.6±90.5	247.3±84.9	<0.001*
Intraoperative factors				
Soft pancreas	172 (54.1 %)	99 (45.4 %)	73 (81.1 %)	<0.001*
Extended lymph node dissection	14 (4.4 %)	9 (4.1 %)	5 (5.6 %)	0.531
Pancreatic resection at PV-SMV level	272 (85.5 %)	194 (89.0 %)	78 (86.7 %)	0.676
PV/SMV resection	61 (19.2 %)	55 (25.2 %)	6 (6.7 %)	0.001*
Operation time (min)	363±76	361±79	366±70	0.774
Estimated blood loss (mL)	812±669	802±651	844±711	0.230
Transfusion	52 (16.4 %)	37 (17.0 %)	15 (16.7 %)	0.924
Postoperative data				
POD 1 D-Amy (IU/L)	2,029±48,783	462±36,399	13,530±68,325	0.005*
POD 3 D-Amy (IU/L)	134±5,666	51±2,183	1,964±9,696	0.001*
POD 5 D-Amy (IU/L)	107±12,385	46±2,439	1,267±21,583	0.001*

Differences between the two groups were evaluated using logistic regression analyses

POPF postoperative pancreatic fistula, *PD* pancreaticoduodenectomy, *BMI* body mass index, *ASA* American Society of Anesthesiologists, *MPDd* main pancreatic duct diameter, *PV/SMV* portal vein and/or superior mesenteric vein, *POD* postoperative day, *D-Amy* amylase level of drainage fluid

*$P<0.05$

(2.214 (1.146–4.278), $P=0.018$), not performing PV/SMV resection (5.564 (1.721–17.994), $P=0.004$), and POD 3 D-Amy ≥ 375 IU/L (13.044 (6.114–27.826), $P<0.001$) (Table 3).

Validation of Combination of Pancreatic Configuration Data as Risk Factor for Clinically Relevant POPF

There were 43 patients (13.5 %) with both MPDd<2 mm and parenchymal thickness≥8 mm. They were significantly associated with POPF grade B/C (9.458 (4.576–19.545), $P<0.001$), with sensitivity, 34.4 %; specificity, 94.7 %; PPV, 72.1 %; NPV, 78.5 %; and accuracy, 77.7 %.

Discussion

The present study investigated predictive factors for clinically relevant POPF after PD, and demonstrated the significance of schematic understanding of pancreatic configuration as a preoperative risk factor. Soft pancreatic texture has been widely recognized as an important risk factor, but is problematic as it

Table 3 Multivariate analysis of risk factors for clinically relevant POPF after PD (n=318)

Parameter	OR	95 % CI	*P*
BMI≥25 kg/m^2	2.137	0.897–5.095	0.087
Absence of diabetes	1.367	0.568–3.293	0.486
Pathological condition other than pancreatic cancer	0.467	0.183–1.187	0.110
MPDd<2 mm	3.589	1.665–7.737	0.001*
Parenchymal thickness≥8 mm	2.214	1.146–4.278	0.018*
Soft pancreas	1.317	0.497–3.492	0.580
Not performing PV/SMV resection	5.564	1.721–17.994	0.004*
POD 3 D-Amy≥375 IU/L	13.044	6.114–27.826	<0.001*

Independent risk factors for clinically relevant POPF were evaluated using logistic regression analysis

POPF postoperative pancreatic fistula, *PD* pancreaticoduodenectomy, *OR* odds ratio, *95 % CI* 95 % confidence interval, *BMI* body mass index, *MPDd* main pancreatic duct diameter, *PV/SMV* portal vein and/or superior mesenteric vein, *POD* postoperative day, *D-Amy* amylase level of drainage fluid

*$P<0.05$

is revealed intraoperatively in a subjective way, lacks quantitative analysis, and has imperfect predictive value. Recent Japanese multicenter data from 1,239 patients showed that clinically relevant POPF occurred in 142 (21.9 %) of 648 cases with soft pancreas and 36 (6.1 %) of 591 cases with hard pancreas.[3] Clinical parameters including D-Amy and blood test data in the postoperative period can be the basis

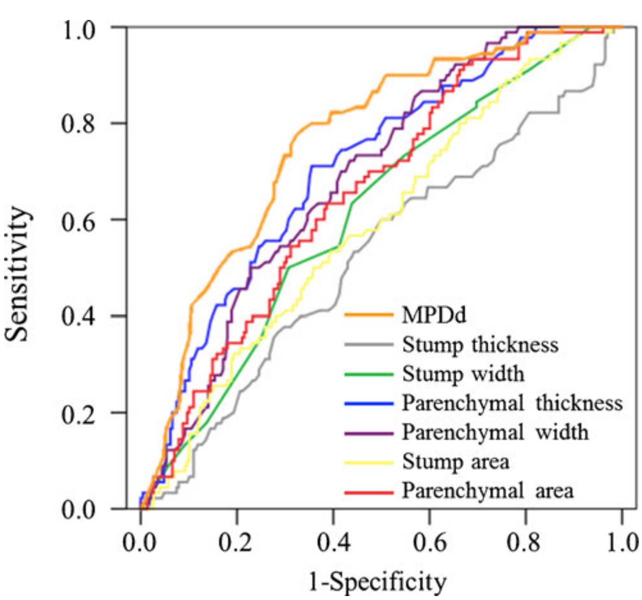

Fig. 4 ROC curves for risk of clinically relevant POPF grade B/C after PD in schematic pancreatic configuration data. Values of AUC: MPDd, 0.764; stump thickness, 0.523, stump width, 0.614; parenchymal thickness, 0.709; parenchymal width, 0.687; stump area, 0.589; parenchymal area, 0.656. *POPF* postoperative pancreatic fistula, *PD* pancreaticoduodenectomy, *MPDd* main pancreatic duct diameter

for early drain removal[24] or an early marker of latent fistula, and possibly reflect other ominous clinical conditions. D-Amy is of course a reliable postoperative factor associated with POPF,[3,20] because D-Amy on POD 3 is itself a definitive ISGPF criterion. Conversely, accurate and reliable risk factors for POPF that can be detected preoperatively will allow pancreatic surgeons to carry out preventive measures against postoperative complications. This study indicates the utility of schematic pancreatic configuration data as a prognostic marker for POPF after PD. MPDd, stump width, parenchymal thickness, parenchymal width, and parenchymal area were significantly correlated with POPF grade B/C in univariate analysis. AUC to determine the cut-off value showed that MPDd and parenchymal thickness were especially important among the pancreatic configuration data. A cut-off value of 2 mm for MPDs was more accurate than that of 3 mm, and it seemed to be a good clinical benchmark of difficult anastomosis in our operative setting. Thick pancreatic parenchyma with well-preserved exocrine function and small MPDd, which made the anastomotic technique physically difficult, might frequently result in leakage of pancreatic juice, injury of the anastomotic tissue, and infection, and lead to clinically relevant POPF. These two parameters were independent predictive factors, as were not performing PV/SMV resection and high D-Amy on POD 3, and surpassed soft pancreatic consistency in multivariate analysis. The combination of MPD< 2 mm and parenchymal thickness≥8 mm showed high specificity (94.7 %) and NPV (78.5 %). Preoperative MDCT is expected to allow earlier and more objective and precise measurement of pancreatic configuration data than were other methods of measurement, such as intraoperative ultrasound or direct measurement of the stump or resected specimen with a ruler.

Regarding other options using imaging modalities, Tajima et al.[25,26] reported that the time-signal intensity curve profile correlated with fibrosis of the pancreas in a dynamic MRI study, and a relationship between fibrosis and MPD dilation was suggested.[26] Atrophic pancreas caused by chronic inflammation revealed increased fibrosis, decreased exocrine function, and a low risk of POPF.[27,28] Conversely, Mathur et al. reported that patients with fatty pancreas had increased risk of POPF and showed decreased pancreatic fibrosis, blood vessel density, and MPDd.[29] MPDd and parenchymal thickness assessed by preoperative MDCT might be accurate indicators of the degree of fibrosis and fatty infiltration of the pancreas. Investigating the relationships among pancreatic configuration data, detailed histopathological findings, and operative outcome should be the next concern. Parameters such as the absence of diabetes, high BMI, pathological condition other than pancreatic cancer, soft pancreatic consistency, and not performing PV/SMV resection might be associated with histopathological alteration of the pancreatic parenchyma.

The incidence of clinically relevant POPF in the current study seemed to be relatively high.[1–5] Although evaluation of POPF using the definition of the ISGPF is convenient and important in the worldwide effort to reduce complications, there may still exist dilemmas and inter-institutional differences in its interpretation and application. In some cases, it is difficult to identify the origin of intraabdominal infection as POPF or another cause. We have a policy of drain management to perform an exchange procedure under fluorography on POD 7–10 in cases in which signs of infection are observed in the drainage fluid. Patients who underwent exchange procedure were considered to be grade B, even if the true origin was unclear. Our patient population had a relatively low rate of reoperation (1.0 %), 30-day readmission (2.5 %), and mortality (0.6 %).[1,30,31] Aggressive management to obtain effective drainage was given priority to reduce septic and lethal complications in our institution.

There are some limitations to our study. First, although we tried to standardize the surgical management in this single institution study and identify objective preoperative predictors of POPF, this study should be reproduced. Second, the shape of the actual surgical stump is not exactly elliptical, and that of the MPD is not a circle. The pancreatic parenchymal area at the resection site calculated on the basis that schematic configuration did not express POPF risk as accurately as did parenchymal thickness. The schematic pancreatic configuration was a good indicator of the risk of clinically relevant POPF; however, a volumetric imaging modality may have superiority in meticulous evaluation of the pancreatic configuration and volume.[32,33] Last, in cases in which the extent of tumor was beyond expectation, remeasurement by MDCT should be performed at the modified resection site intraoperatively, although these cases were rare. In fact, in most cases (85.5 %), the pancreas was divided at the PV/SMV level, which was consistent with the assessment by preoperative MDCT. Imaging modalities that facilitate more convenient and precise rendering ability and reflect the histopathological findings and function of the remnant pancreas are anticipated in the near future.

Appropriate surgical technique and perioperative management as well as understanding accurate risk factors are mandatory to reduce POPF. Efforts to reduce the incidence of POPF have encompassed various modifications of the anastomotic technique and pharmacological measures, pancreaticogastrostomy or pancreaticojejunostomy, duct-to-mucosa, invagination, the use of stents, internal or external drainage, application of topical agents to the anastomotic site, placement of an autologous graft such as omentum or falciform ligament on the anastomotic site, and prophylactic administration of somatostatin or its analog.[16,34–38] Preoperative patient stratification using accurate risk factors may lead to careful management in high-risk patients, and well-designed surgical trials can be exploited to improve the surgical technique and perioperative management. Pancreatic configuration data based on preoperative MDCT may be useful to evaluate the risk of POPF accurately, simply, and objectively. In the future, we believe that the reconstruction technique should be tailored to the individual patient according to the definitive risk of POPF.

Conclusions

MPDd and parenchymal thickness were identified as independent risk factors for clinically relevant POPF after PD, based on a schematic understanding of the pancreatic configuration. These parameters were assessed by preoperative MDCT in a simple and objective way, and the prognostic value was comparable to that of other preoperative, intraoperative, and even postoperative risk factors. The combination of MPDd$<$2 mm and parenchymal thickness$\geq$8 mm was significantly associated with clinically relevant POPF, with high accuracy.

Conflict of interest None

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