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HEPATOBILIARY-PANCREAS

Multidetector CT findings differ between surgical grades of pancreatic fistula after pancreaticoduodenectomy

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Abstract

Objectives To define and correlate multidetector CT (MDCT) findings of pancreatic fistula after pancreaticoduodenectomy with surgical grading based on the 2016 Revised International Study Group of Pancreatic Fistula (ISGPF) classification.

Methods Between May 2011 and December 2016, 235 patients with periampullary tumor underwent pancreaticoduodenectomy and postoperative MDCT. Patients were classified into three groups (clinically no pancreatic fistula (cNo-PF), grade B, and grade C) according to the ISGPF classification. MDCT images were retrospectively evaluated by two radiologists in consensus for the presence of pancreaticojejunostomy (PJ) dehiscence, PJ dehiscence diameter, PJ defect, acute necrotic collection (ANC), peripancreatic fluid collection, and imaging findings of complications. Categorical MDCT findings were compared among the three groups using Pearson's chi-square test, and PJ dehiscence diameter was compared using the Kruskal–Wallis test.

Results There was no significant difference in patient demographics among the groups (cNo-PF = 133, grade B = 68, and grade C = 34), but the MDCT findings were significantly different regarding the presence of PJ dehiscence ($p < 0.001$), PJ defect ($p < 0.001$), ANC ($p = 0.002$), and imaging findings of total complications ($p < 0.001$). The diameters of PJ dehiscence were significantly different among the groups (cNo-PF [0.42 ± 1.54 mm], grade B [1.47 ± 2.33 mm], and grade C [5.38 ± 6.45 mm]) ($p < 0.001$).

Conclusion With respect to the presence of PF, postoperative MDCT findings may differ between surgical grading based on the ISGPF classification.

Key Points

- *Regarding the presence of pancreatic fistula, the postoperative multidetector CT findings correlate well with surgical grading based on the International Study Group of Pancreatic Fistula classification.*
- *Multidetector CT may provide reliable information to suggest pancreatic fistula after pancreaticoduodenectomy.*

Keywords Pancreaticoduodenectomy · Pancreatic fistula · Pancreaticojejunostomy · Postoperative complications

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Abbreviations

ANC	Acute necrotic collection
AUC	Area under the receiver operating characteristic curve
CI	Confidence interval
cNo-PF	Clinically no pancreatic fistula
ISGPF	2016 Revised International Study Group of Pancreatic Fistula
MDCT	Multidetector CT
PF	Pancreatic fistula
PJ defect	Pancreaticojejunostomy defect
PJ dehiscence	Pancreaticojejunostomy dehiscence
POP	Postoperative pancreatitis
POPF	Postoperative pancreatic fistula
PPPD	Pylorus-preserving pancreaticoduodenectomy

Introduction

Pancreaticoduodenectomy, including Whipple's operation and pylorus-preserving pancreaticoduodenectomy (PPPD), is the most common surgical method for resecting periampullary tumors [1, 2]. Owing to the refinement in operative technique and advancement in postoperative management, the mortality rate has dropped to below 5% [3]. However, postoperative complications still occur with a frequency of 30–65% [3]. Among them, pancreatic fistula (PF) is a troublesome complication after pancreaticoduodenectomy [1]. PF is the single most important cause of morbidity and mortality after pancreaticoduodenectomy [4]. The development of an abscess or sepsis in conjunction with PF can result in a mortality rate of 20–40% [5]. Thus, grading system of postoperative pancreatic fistula (POPF; biochemical leak, grade B, and grade C) according to their clinical impact on the patient's hospital course has been defined by the International Study Group of Pancreatic Fistula (ISGPF) [6, 7]. The "grade A" PF is newly defined as "biochemical leak (BL)" by the 2016 Revised ISGPF classification because it is considered having no clinical importance and now considered no "true" fistula [7]. Among many attempts to reduce the incidence of POPF by prospectively identifying patients at risk and modifying the surgical technique, their recognition and prompt management are the most important factors that affect patient outcomes [5].

Callery et al [8] derived a clinical fistula risk score which can be simply learned and applied in pre- and intraoperative assessment. Radiological evaluation also has important roles in identifying erosion or migration of the drain into the bowel and in deciding whether to withdraw or maintain the drain [6]. However, radiological documentation is considered neither mandatory nor necessarily recommended for the diagnosis of PF despite the routine performance of postoperative CT [9]. Although the expeditious and accurate diagnosis of PF is important for prompt management, to our knowledge, imaging findings of PF are not well-described yet in the literature and most diagnoses of PF rely on clinical criteria such as laboratory tests and clinical symptoms. Thus, the aim of this study is to define and correlate the multidetector CT (MDCT) findings of PF after pancreaticoduodenectomy with surgical grading based on the 2016 Revised ISGPF classification scheme.

Materials and methods

Study design

Our institutional review board approved this retrospective study, and the need for informed consent was waived. To establish the diagnostic MDCT findings for PF, two radiologists used medical record database of 69 patients who underwent pancreaticoduodenectomy and postoperative MDCT between January 2010 and December 2010 at a single tertiary center. One experienced pancreatic surgeon retrospectively categorized those patients according to ISGPF classification. Two radiologists retrospectively analyzed the postoperative MDCT images and defined the MDCT findings of PF on the basis of structure of pancreatic surgery and pathophysiology of PF in consensus as follows: pancreaticojejunostomy (PJ) dehiscence, PJ defect, acute necrotic collection (ANC), and peripancreatic fluid collection around the PJ site (Fig. 1).

Then, diagnostic accuracy of the established MDCT findings was evaluated in comparison with surgical grading based on ISGPF classification.

Patient population

Between May 2011 and December 2016, a total of 235 patients who underwent pancreaticoduodenectomy and postoperative MDCT due to periampullary tumor were enrolled in this study. All patients were classified into three groups (clinically no pancreatic fistula [cNo-PF], grade B, and grade C) based on the detailed analyses of their medical data and clinical courses according to the ISGPF classification [7]. cNo-PF group included both patients showing drain output with amylase level < 3 times normal serum level and > 3 times normal serum level without clinical impact (which means "biochemical leak" in the 2016 revised ISGPF classification). The type of pathologic diagnosis of each periampullary tumor and clinical parameters associated with changes in POPF management were investigated.

Surgical technique

Two surgeons with 22 and 10 years of experience in pancreatic surgery performed PPPD or Whipple's operation in all patients, and they routinely used duct-to-mucosa PJ and ductal

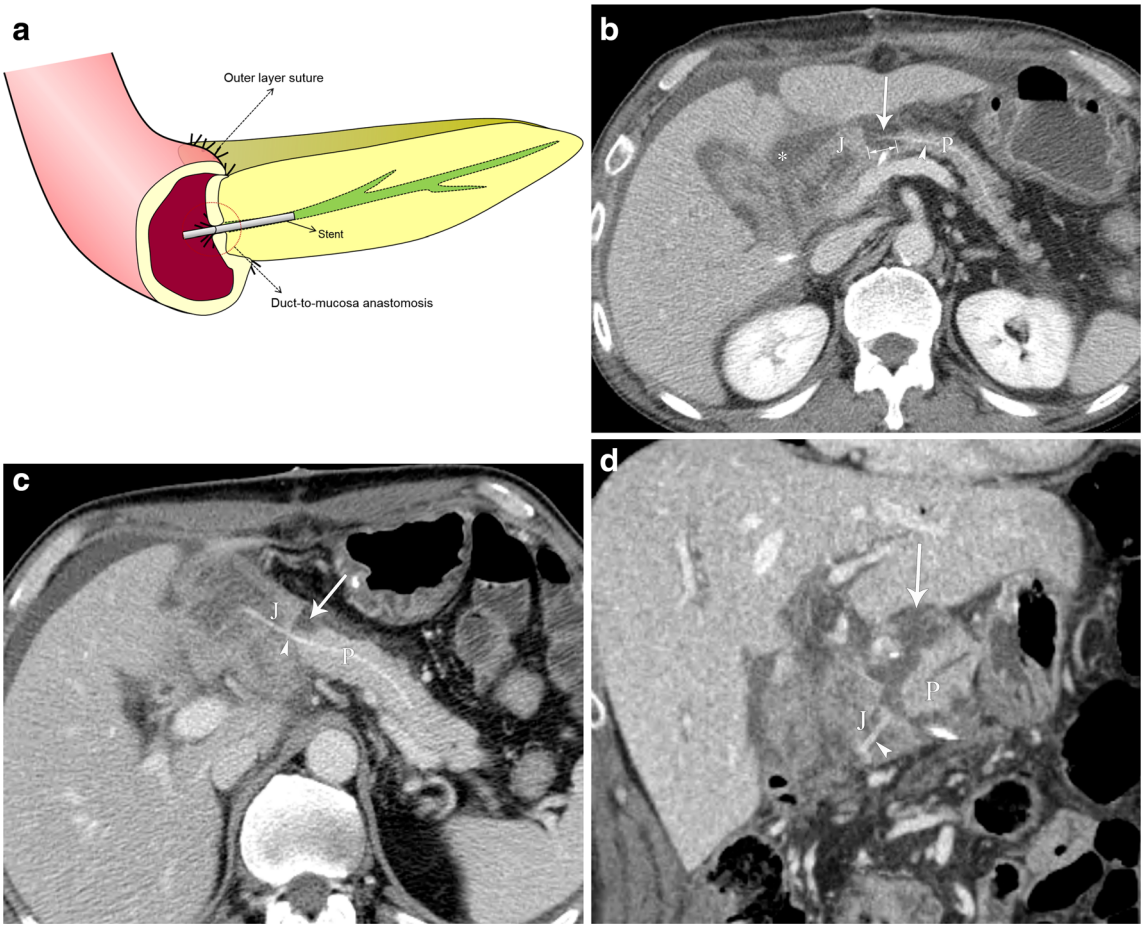

Fig. 1 Schematic drawing of the surgical suture (**a**) between the pancreas and jejunum and the representative multidetector CT (MDCT) findings of pancreatic fistula including pancreaticojejunostomy dehiscence (PJ dehiscence) (**b**), pancreaticojejunostomy defect (PJ defect) (**c**), and acute necrotic collection (ANC) (**d**). **a** This schematic drawing demonstrates that the surgical suture of pancreaticojejunostomy (PJ) consists of duct-to-mucosa anastomosis and outer layer suture between the seromuscular layer of the jejunum and pancreatic parenchyma after pancreaticoduodenectomy. The stent is usually inserted into the pancreatic duct to prevent the obstruction of the pancreatic duct at the PJ site and formation of pancreatic fistula. **b** Contrast-enhanced postoperative MDCT image shows a large PJ dehiscence (arrow) that indicates a definite pancreatic fistula of the PJ between the remnant pancreas (P) and the edematous jejunum (J). Dimension line indicates the diameter of PJ dehiscence. A large amount of acute peripancreatic fluid collection (asterisk) is contiguous with the PJ and is seen around the jejunum and in the perihepatic space. A hyperdense stent (arrowhead) is still located within the pancreatic duct and jejunal lumen is observed. **c** Contrast-enhanced postoperative MDCT image depicts wedge-shaped PJ defect (arrow) at the anterior suture line of the PJ between the pancreatic parenchyma (P) and jejunum (J). Note the intact duct-to-mucosa anastomosis (arrowhead) at the PJ site and the pancreatic stent along the pancreatic duct and jejunum. **d** Coronal contrast-enhanced postoperative MDCT image shows ANC (arrow) with internal heterogeneous collection in the left subhepatic space, and the ANC is contiguous with the PJ dehiscence between the remnant pancreas (P) and edematous jejunum (J). Note the displaced stent (arrowhead) extending into the jejunum from the pancreatic duct

stent insertion, because duct-to-mucosa PJ has been accepted as having lower prevalence of postoperative pancreatic fistula (POPF) than invagination PJ ("dunking" the remnant of pancreas into the jejunal lumen) [10] (Fig. 1a).

All patients received a standardized postoperative treatment after pancreaticoduodenectomy. Prophylactic octreotide (Novartis Pharma) was routinely administered subcutaneously (150 μg every 8 h) and continued postoperatively in all patients to prevent PF. A single drain was usually placed around PJ site. Multiple drains were placed in 17 patients considered to be at a high risk of PF. Outputs from all drains were recorded daily for at least 5 days. The serum and drain amylase levels were determined on postoperative days 1, 3, and 5. All drains were removed on day 6 according to the surgeon's discretion if the drain amylase level was at least three times below normal. A drain was maintained longer if the serum or drain amylase level did not decrease or if the drain fluid was turbid or bloody [3].

Postoperative pancreatic fistula classification

Traditionally, a fistula has been defined as an abnormal track between two epithelial surfaces. If pancreatic–enteric anastomosis failed to be sealed, or if there is parenchymal leakage from raw surface not directly related to an anastomosis, PF might be created. PF is defined as any measurable drain output from the drainage catheter in the operation bed on the first three

postoperative days, with drain amylase content greater than three times the upper limit of normal serum amylase level (> 300 IU/L) [3]. ISGPF grades for each patient could be determined only when complete postoperative follow-up check was accomplished without loss [3], and the pancreatic surgeon retrospectively graded the patients according to ISGPF classification.

Imaging technique

Postoperative contrast-enhanced MDCT was routinely performed on postoperative day 7 for assessing anastomoses and possible complications. If complications including PF were clinically suspected, the prearranged CT was performed earlier. Additional follow-up CT was performed if patients showed signs of clinical deterioration despite the proper management. In patients who underwent multiple CT examinations, the first contrast-enhanced MDCT indicating complication was used for a review.

CT was performed using a 64-slice MDCT scanner (Sensation Cardiac 64; Siemens Medical Solutions) after intravenous injection of iodinated contrast material (iobitridol, Xenetix®; Guerbet or iopromide, Ultravist 300®; Bayer Schering Pharma) (2 mL/kg at 3 mL/s).

The scanning parameters were as follows: section thickness, 3 mm; beam pitch, 0.8; gantry rotation time, 0.5 s; table speed, 30.72 mm per rotation; reconstruction interval, 3 mm; tube voltage, 120 kV; and tube current, 120–350 mA. Automated tube current modulation (CareDose; Siemens Medical Solutions) was used for all patients. The raw data were reformatted in the coronal and sagittal plane, by creating maximum intensity projection images for the patients suspected of having internal bleeding.

Imaging analysis

MDCT images of all 235 patients were carefully reviewed, and each imaging finding was recorded in consensus by two radiologists with 14 and 10 years of experience in abdominal imaging, who were blinded to the patients' ISGPF grades. Each imaging finding was recorded regarding the presence of PJ dehiscence, diameter of PJ dehiscence, PJ defect, ANC, peripancreatic fluid collection, and radiologically diagnosed postoperative complications (postoperative bleeding, intraabdominal abscess, delayed gastric emptying [DGE], postoperative pancreatitis [POP], biliary leak, biliary obstruction, paralytic ileus, incisional hernia, and venous thrombosis in the portal vein or superior mesenteric vein) on axial, coronal, sagittal, and maximum intensity projection images of unenhanced and dual-phase contrast-enhanced MDCT [2, 11–14]. PJ dehiscence was defined as a gap greater than 2 mm between the pancreatic duct and jejunal mucosa along the duct-to-mucosa suture line at the PJ site. The gap was measured using the submillimeter measurement and magnification tool on a picture archiving and communication system (PACS; Maroview) with maximum magnification on 1 × 1 image (Fig. 1b). In cases without PJ dehiscence on MDCT images, PJ dehiscence diameter was considered 0. PJ defect was defined as a wedge-shaped or rectangular separation at the anterior or posterior parenchymal suture line of the PJ site. In the usual acute perioperative setting, fluid collection, edema, and fat stranding in the surgical bed are normal changes and anastomotic leak cannot be reliably diagnosed with CT [15–18]. However, if the fluid collection is adjacent to the duct-to-mucosa anastomosis or parenchymal suture line, it strongly suggests the presence of PF [2, 19]. In this study, ANC containing variable amount of both fluid and necrosis as well as peripancreatic fluid collection without associated necrosis in contiguity with the duct-to-mucosa anastomosis or anastomotic suture line were respectively investigated.

Statistical analysis

Statistical analyses were conducted using MedCalc version 17.6 (MedCalc Software). Statistical significance was set at $p < 0.05$. Patient demographics, including age, sex, and surgery type, were compared using the Kruskal–Wallis test for age and Pearson's chi-square test for sex and surgery type. Clinical parameters for the 235 patients were analyzed using Pearson's chi-square test to validate the clinical classification. MDCT findings and postoperative complications were compared using Pearson's chi-square test, and the diameter of PJ dehiscence was analyzed using the Kruskal–Wallis test and pairwise Mann–Whitney *U* test with Bonferroni correction among the three groups. Receiver operating characteristic (ROC) analysis was performed for evaluating the diagnostic accuracy of MDCT findings for differentiating between the clinically relevant PF and cNo-PF groups. An optimal cutoff value was chosen to maximize the sum of sensitivity and specificity to optimize the diagnostic performance of PJ dehiscence diameter among the three groups.

Results

The flowchart illustrating the inclusion criteria for patients is shown in Fig. 2. A total of 235 patients (141 men and 94 women; mean age, 65.3 ± 10.7 years; range, 23–90 years) who underwent pancreaticoduodenectomy (PPPD, $n = 190$; Whipple's operation, $n = 45$) were included.

Final pathological analysis revealed that most patients had adenocarcinoma of the bile duct ($n = 86$), pancreatic ductal adenocarcinoma ($n = 58$), or adenocarcinoma of the ampulla of Vater ($n = 44$). Other pathologies encountered were intraductal papillary mucinous neoplasm ($n = 9$), intraductal papillary mucinous malignancy ($n = 8$), neuroendocrine tumor ($n = 5$), cystic neoplasms ($n = 3$), chronic pancreatitis ($n = 3$),

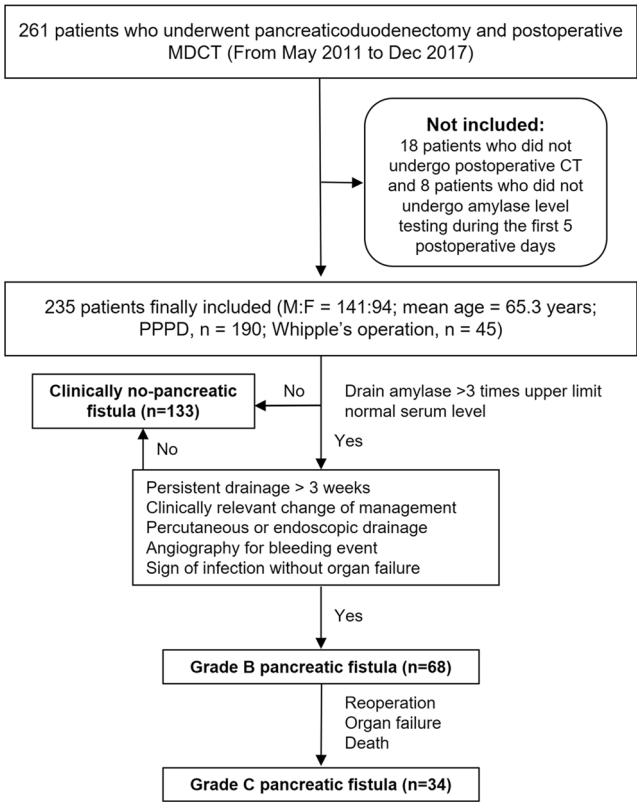

Fig. 2 Flow diagram for the study. In total, 235 patients who underwent pancreaticoduodenectomy and MDCT were included in the current study. Clinically no pancreatic fistula, grade B, and grade C based on the detailed analyses of their medical data and clinical courses, according to the ISGPF classification [7]. MDCT, multidetector CT; ISGPF, International Study Group of Pancreatic Fistula; PJ, pancreaticojejunostomy; PPPD, pylorus-preserving pancreaticoduodenectomy

paraganglioma ($n = 4$), pseudocyst ($n = 1$), and other conditions (biliary intraepithelial neoplasia and tubular adenoma of the ampulla of Vater; $n = 14$).

According to the ISGPF classification, 235 patients were classified into the cNo-PF ($n = 133$), grade B ($n = 68$), and grade C ($n = 34$) groups (Table 1). Age showed statistical difference among the three groups ($p = 0.023$), especially, cNo-PF and grade B showed significant difference in age by post hoc analysis. There was statistical difference of surgery type among the three groups ($p = 0.044$). The distribution of the clinical parameters adopted from the ISGPF classification among the three groups was in accord with the updated 2016 ISGPF classification ($p < 0.001$) (Table 2). The average interval between surgery and CT among the three groups was shorter in grade C compared to those of cNo-PF and grade B (cNo-PF, 6.86 ± 0.50 days; grade B, 6.85 ± 0.43 days; grade C, 6.00 ± 1.91 days; $p < 0.001$). The MDCT findings were significantly different among the groups regarding the presence of PJ dehiscence ($p < 0.001$), PJ defect ($p < 0.001$), and ANC ($p = 0.002$) (Table 3). Imaging findings of complications such as postoperative bleeding, intraabdominal abscess, DGE, and POP were significantly more frequent in grade C ($p < 0.05$). The diameter

Table 1 Patients' demographics among the three groups according to ISGPF classification scheme ($n = 235$)

	cNo-PF	Grade B	Grade C	*p*
Number	133 (56.6)	68 (28.9)	34 (14.5)	
Age (years, mean ± SD)	63.9 ± 10.6	66.9 ± 12.1	67.8 ± 7.6	0.023*
Gender				0.588†
Male	76 (57.1)	43 (63.2)	22 (64.7)	
Female	57 (42.9)	25 (36.8)	12 (35.3)	
Surgery type				0.044†
PPPD	108 (81.2)	50 (73.5)	32 (94.1)	
Whipple's operation	25 (18.8)	18 (26.5)	2 (5.9)	

Data in parentheses are percentages

SD standard deviation, *PPPD* pylorus-preserving pancreaticoduodenectomy, *cNo-PF* clinically no pancreatic fistula

*The Kruskal–Wallis test was used for comparison of age among the three groups

† Pearson's chi-square test was used for comparison of gender and surgery type among the three groups

of PJ dehiscence was significantly different among the three groups (cNo-PF [0.42 ± 1.54 mm], grade B [1.47 ± 2.33 mm], and grade C [5.38 ± 6.45 mm]) ($p < 0.001$) (Fig. 3).

The overall diagnostic performance of each MDCT finding for differentiating between the clinically relevant PF and cNo-PF groups according to the ISGPF classification was compared using their areas under the receiver operating characteristic curves (AUCs) (Table 4) [20]. Accordingly, the diameter of PJ dehiscence showed the best diagnostic performance (AUC = 0.792; sensitivity = 73.53; specificity = 78.61). In addition, PJ dehiscence, PJ defect, and ANC showed appropriate diagnostic performances for differentiating between the clinically relevant PF and cNo-PF groups (AUC = 0.790, 0.674, and 0.619, respectively). When PJ dehiscence diameter between the groups was greater than or equal to 2 mm, the clinically relevant PF group could be distinguished from the cNo-PF group with high specificity (sensitivity = 73.53% [95% CI 55.6–87.1]; specificity = 78.61% [95% CI 72.3–84.1]). Among the imaging findings of complications, postoperative bleeding, intraabdominal abscess, DGE, and POP showed significant diagnostic performances (AUC = 0.836, 0.837, 0.753, and 0.775, respectively).

Discussion

Although imaging findings of PF have not been well-described in the literature, among the postoperative MDCT findings, PJ dehiscence, diameter of PJ dehiscence, PJ defect, ANC, and imaging findings of complications such as intraabdominal abscess, postoperative bleeding, DGE, and POP were significantly different among the three groups of PF in this study.

Surgical suture of PJ consists of two stages: duct-to-mucosa anastomosis and outer layer suture between the seromuscular layer of the jejunum and pancreatic parenchyma. In particular,

Table 2 Clinical parameters among the three groups according to the ISGPF classification scheme

	cNo-PF ($n = 133$)	Grade B ($n = 68$)	Grade C ($n = 34$)	p*
Persisting peripancreatic drainage > 3 weeks	0 (0)	8 (11.8)	18 (52.9)	< 0.001
Clinically relevant change in the management of POPF	0 (0)	21 (30.9)	29 (85.3)	< 0.001
Percutaneous or endoscopic drainage	0 (0)	18 (26.5)	23 (67.6)	< 0.001
Angiographic procedures for bleeding	0 (0)	3 (4.4)	6 (17.6)	< 0.001
Signs of infection without organ failure	0 (0)	62 (91.2)	33 (97.1)	< 0.001
Reoperation	0 (0)	0 (0)	16 (47.1)	< 0.001
Organ failure	0 (0)	0 (0)	22 (64.7)	< 0.001
Death	0 (0)	0 (0)	9 (26.5)	< 0.001

A fistula is classified into each grade in the presence of at least one corresponding criterion. Data in parentheses are percentages

ISGPF International Study Group of Pancreatic Fistula, *POPF* postoperative pancreatic fistula, *cNo-PF* clinically no pancreatic fistula

* Pearson's chi-square test was used for comparison of each clinical parameter among the three groups

duct-to-mucosa anastomosis with stent insertion is commonly used to prevent the obstruction of the pancreatic duct at the PJ site and formation of PF [10]. Regarding the relationship between surgical structure and MDCT findings, the disruption of duct-to-mucosa anastomosis resulted in PJ dehiscence, and disruption of the outer layer suture resulted in PJ defect. In this study, postoperative MDCT findings correlate well with surgical grading based on the ISGPF classification. Among the MDCT findings of PF, the diameter of PJ dehiscence was the most accurate finding with high specificity according to ROC analysis. In cases of disruption of the duct-to-mucosa anastomosis, pancreatic juice can leak through the disrupted site, usually resulting in PF formation. Therefore, the presence of PJ dehiscence is generally considered to be directly related to PF, and in the same vein, more anastomotic leak will occur if the PJ dehiscence diameter is larger. In this study, statistically significant difference in PJ dehiscence diameter was observed between the clinically relevant PF and cNo-PF groups. Some patients with relatively small PJ dehiscence diameters were included in grade C, probably because of significant pancreatic juice leak from the raw surface rather than the duct-to-mucosa anastomosis. Meanwhile, several patients with PJ dehiscence

Table 3 MDCT findings among the three groups according to the ISGPF classification scheme

	cNo-PF ($n = 133$)	Grade B ($n = 68$)	Grade C ($n = 34$)	$p^{\dagger}$
PJ dehiscence	13 (9.8)	28 (41.2)	25 (73.5)	< 0.001
PJ defect	65 (48.9)	48 (70.6)	32 (94.1)	< 0.001
Acute necrotic collection	40 (30.1)	30 (44.1)	21 (61.8)	0.002
Peripancreatic fluid collection	41 (30.8)	26 (38.2)	12 (35.3)	0.561
PJ dehiscence diameter (mm, mean ± SD)	0.42 ± 1.54	1.47 ± 2.33	5.38 ± 6.45	< 0.001
Imaging findings of complications	27 (20.3)	46 (67.6)	32 (94.1)	< 0.001
Postoperative bleeding	2 (1.5)	8 (11.8)	14 (41.2)	< 0.001
Intraabdominal abscess	0 (0)	9 (13.2)	8 (23.5)	0.021
Delayed gastric emptying	8 (6.0)	25 (36.8)	14 (41.2)	< 0.001
Pancreatitis	10 (7.5)	19 (27.9)	21 (61.8)	< 0.001
Other complications*	8 (6.0)	3 (4.4)	3 (8.8)	0.674

Data in parentheses are percentages

MDCT multidetector CT, *ISGPF* International Study Group of Pancreatic Fistula, *PJ dehiscence* pancreaticojejunostomy dehiscence, *PJ defect* pancreaticojejunostomy defect, *SD* standard deviation, *cNo-PF* clinically no pancreatic fistula

*Other complications include biliary leak, biliary obstruction, paralytic ileus, incisional hernia, and venous thrombosis in the portal vein or superior mesenteric vein which could be diagnosed on MDCT

† Pearson's chi-square test was used for comparison of each variable except PJ dehiscence diameter among the three groups. The Kruskal–Wallis test was used for comparison of PJ dehiscence diameter among the three groups

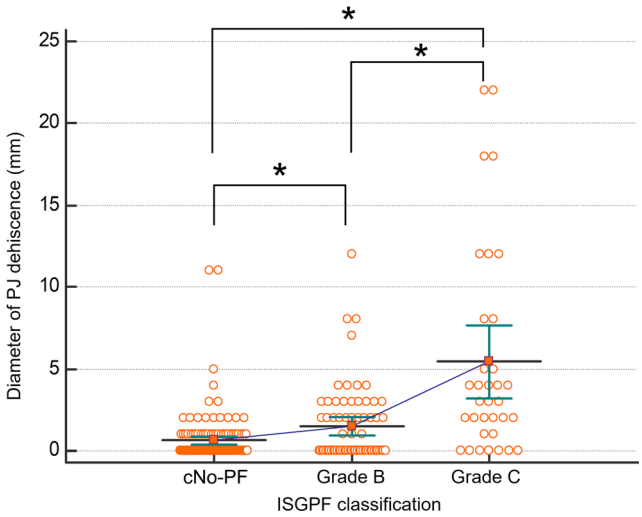

Fig. 3 Scatter dot plot of pancreaticojejunostomy (PJ) dehiscence diameter in three groups (clinically no pancreatic fistula [cNo-PF], grade B, and grade C) according to the International Study Group of Pancreatic Fistula (ISGPF) classification ($p < 0.001$). The groups were compared using the Kruskal–Wallis test. Post hoc analysis was performed using the pairwise Mann–Whitney *U* test with Bonferroni correction. Red open circles, black horizontal bars, and green error bars represent the measured PJ dehiscence diameters, the mean PJ dehiscence diameter, and 95% confidence intervals for mean, respectively, in each group. *$p < 0.001$

diameter greater than 2 mm were categorized into cNo-PF or grade B, and this could be explained by the effective treatment of multiple drain tubes or prolonged deployment of drain tube to prevent PF deterioration.

ANC around the PJ site can occur because of PF, especially when pancreatic juice containing rich proteolytic enzyme leaks from PF and causes necrosis of the pancreatic parenchyma and peripancreatic tissue. However, it could be simply by postoperative necrotizing pancreatitis or even by usual operative manipulation, and this distinction might be difficult to make. Nevertheless, CT can be helpful in making a distinction with the presence of this fluid collection in contiguity with duct-to-mucosa anastomosis or anastomotic suture line, which strongly suggests the disruption of duct-to-mucosa anastomosis and parenchymal loss by PF [2, 15].

Intraabdominal abscesses also can arise secondary to PF or superinfection of postoperative fluid collection with forming thickened and enhanced wall, with incidence of up to 6% [2, 21].

Postoperative bleeding from the PJ site has been considered a relatively less common complication after pancreaticoduodenectomy; however, its morbidity and mortality rates markedly increase upon PF manifestation [1, 2, 22]. Among postoperative bleeding events, pseudoaneurysm formation and active bleeding are easily caused by leakage of pancreatic juice with consequent erosion of the vessel wall and may be associated with anastomotic breakdown [22–24].

POP is difficult to be differentiated from normal postoperative inflammatory change, especially if inflammation is minimal and stent migration or obstruction is absent. Nevertheless, severe pancreatic swelling and inflammatory change surrounding the remnant parenchyma based on the CT severity index in association with increased serum amylase

Table 4 Receiver operating characteristic analysis of MDCT findings for differentiating between the clinically relevant PF and cNo-PF groups according to the ISGPF classification scheme

	AUC	Standard error	95% confidence interval	Significance level *p* (area = 0.5)	Sensitivity* (95% CI)	Specificity* (95% CI)
PJ dehiscence	0.790	0.032	0.732–0.840	< 0.001	80.30 (68.7–89.1)	71.01 (63.5–77.7)
PJ defect	0.674	0.030	0.611–0.734	< 0.001	55.17 (46.7–63.4)	75.56 (65.4–84.0)
Acute necrotic collection	0.619	0.034	0.553–0.681	< 0.001	56.04 (45.2–66.4)	64.58 (56.2–72.4)
Peripancreatic fluid collection	0.533	0.036	0.467–0.598	0.361	48.10 (36.7–59.6)	58.97 (50.8–66.8)
PJ dehiscence diameter (≥ 2 mm)	0.792	0.044	0.734–0.842	< 0.001	73.53 (55.6–87.1)	78.61 (72.3–84.1)
Imaging findings of complications	0.802	0.027	0.745–0.851	< 0.001	74.29 (64.8–82.3)	81.54 (73.8–87.8)
Postoperative bleeding	0.836	0.040	0.782–0.881	< 0.001	91.67 (73.0–99.0)	62.09 (55.2–68.7)
Intraabdominal abscess	0.837	0.030	0.784–0.882	< 0.001	100.00 (80.5–100)	61.01 (54.2–67.5)
Delayed gastric emptying	0.753	0.035	0.693–0.807	< 0.001	82.98 (69.2–92.4)	66.49 (59.3–73.2)
Pancreatitis	0.775	0.037	0.716–0.826	< 0.001	80.00 (66.3–90.0)	66.49 (59.2–73.2)
Other complications†	0.514	0.078	0.448–0.579	0.862	21.43 (4.7–50.8)	85.97 (80.7–90.3)

Receiver operating characteristic analysis was performed for evaluating the diagnostic accuracy of MDCT findings for differentiating between two groups

PF pancreatic fistula, *cNo-PF* clinically no pancreatic fistula, *ISGPF* International Study Group of Pancreatic Fistula, *AUC* area under the receiver operating characteristic curve, *CI* confidence interval, *PJ* pancreaticojejunostomy

*Diagnosis of PF between the clinically relevant PF and cNo-PF groups

† Other complications include biliary leak, biliary obstruction, paralytic ileus, incisional hernia, and venous thrombosis in the portal vein or superior mesenteric vein which could be diagnosed on MDCT

level strongly suggest POP [25]. PF can occur because of POP [4], and in this study, POP incidence was significantly higher in the severe PF group (grade C).

This study had several limitations. First, because of its retrospective nature, the suspicion for selection bias might be inevitable and the incidence of POPF and clinically relevant PF (grade B and C) in this study was revealed higher than that in previous study [26]. McMillan et al [26] reported that patients with clinically relevant PF had significantly higher fistula risk score and POPF incidence varied by not only endogenous factors but also each surgeon's experience or institution. We did not investigate the influencing factors of PF formation for high incidence of PF in this study, because the influencing factors of PF formation is not an aim of this study and the way to analyze the MDCT findings is equivalent irrespective of the incidence of PF. Second, this study included small numbers of patients at a single tertiary center. Thus, there is a statistical difference of patient demographics between Whipple's operation and PPPD in this study. However, Tran et al [27] reported that there was no difference in the incidence of PF between both operation techniques. Third, this study included patients who underwent duct-to-mucosa anastomosis only. Therefore, further study might be needed to define proper MDCT findings in cases of invagination PJ. Finally, external validation of this study in a larger cohort to evaluate its clinical relevance of these MDCT imaging criteria will be necessary.

In conclusion, regarding the presence of PF, postoperative MDCT findings may differ between surgical grading based on the ISGPF classification and emphasizing these findings in the report of a postoperative scan after pancreaticoduodenectomy could be useful.

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Compliance with ethical standards

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Ethical approval Institutional Review Board approval was obtained (No.: CNUHH-2017-140).

Methodology
- retrospective
- diagnostic or prognostic study
- performed at one institution

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