RESEARCH

Retrograde installation of percutaneous transhepatic negative-pressure biliary drainage stabilizes pancreaticojejunostomy after pancreaticoduodenectomy: a retrospective cohort study

Chang Min Lee, Yong Joon Suh and Sam-Youl Yoon

Abstract

Background: Leakage from the pancreatoenteric anastomosis has been one of the major complications of pancreaticoduodenectomy (PD). The aim of this study was to investigate the feasibility of retrograde installation of percutaneous transhepatic negative-pressure biliary drainage (RPTNBD), as part of which the drainage tube is intraoperatively inserted into the bile duct and afferent loop by surgical guidance to reduce pancreaticoenteric leakage after PD.

Methods: We retrospectively reviewed the medical records of the patients who underwent pylorus-preserving PD or Whipple’s operation for a malignant disease between June 2012 and August 2016. We performed intraoperative RPTNBD to decompress the biliopancreatic limb in all patients and compared their clinical outcomes with those of internal controls.

Results: Twenty-one patients were enrolled in this study. The operation time was 412.0 ± 92.8 min (range, 240–600 min). The duration of postoperative hospital stay was 39.4 ± 26.4 days (range, 13–105 days). Ten patients (47.6%) experienced morbidities of Clavien-Dindo grade > II, and 2 patients (9.5%) experienced pancreaticojejunostomy-related complications. The internal controls showed a higher incidence rate of pancreaticojejunostomy-related complications than the study participants (P = 0.020). Mortality occurred only in the internal controls.

Conclusion: For stabilizing the pancreaticoenteric anastomosis after PD for a malignant disease, RPTNBD is a feasible and effective procedure. When PD is combined with technically demanding procedures, including hepatectomy or vascular reconstruction, RPTNBD could prevent fulminant anastomotic failure.

Keywords: Pancreaticoduodenectomy, Pancreaticojejunostomy, Leakage, Fistula, Drainage

Background

Pancreaticoduodenectomy (PD) is a standard procedure for treating malignancy in the pancreatic head and periampullary area. Because PD includes anastomoses, which requires an advanced surgical technique, the mortality rates associated with this procedure in the past few decades have been reported to be approximately 25–30% [1]. Although the mortality rate of patients undergoing PD has recently decreased owing to improvements in surgical techniques and perioperative management strategies, the postoperative morbidity rate is still as high as 40–50% [2]. One of the major complications of PD has been leakage from pancreaticoenteric anastomosis.

This morbidity frequently leads to a fatal course, because the leaked pancreatic juice may affect the surrounding structures. Digestive enzymes in the leaked fluid can also disrupt the other anastomoses (i.e., gastroenterostomy, • Correspondence: cdgx287@gmail.com
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enteroenterostomy, or choledochoenterostomy) and sometimes cause massive hemorrhage by eroding the vessels. These conditions delay the initiation of adjuvant chemotherapy, and eventually yielding poor long-term results, even though recent technologies provide effective interventions for controlling diverse complications. Thus, several procedures associated with PD have been investigated, with a focus on leakage prevention.

Strategies for preventing the incidence of pancreatic fistulas are divided into two categories. The first category includes procedures that reinforce the consistency of anastomosis. These are related to the methodology of anastomosis or pathway of pancreatic juice. There is no consensus regarding the clinical effectiveness of this category of strategies. For example, whether the dunking technique is superior or inferior to duct-to-mucosa anastomosis during pancreaticojejunostomy (PJ) cannot be concluded [3]. In addition, although recent studies showed the advantage of pancreaticogastrostomy (PG) over PJ in reducing the incidence of pancreatic fistula, no consensus has been reached regarding the issues of morbidity and mortality [4, 5].

Meanwhile, the second category includes several procedures that reduce the burden of pancreaticoenteric anastomosis. Some of these procedures are associated with the preoperative or intraoperative conditioning of the biliary tree, and others with stabilizing the anastomoses by special reconstruction methods. Still, others involve pancreatic or biliary decompression using the external drainage. In this regard, in June 2012, we introduced retrograde installation of percutaneous transhepatic negative-pressure biliary drainage (RPTNBD) for biliopancreatic decompression in patients who had undergone PD for malignant disease (i.e., duodenal cancer, pancreatic cancer, bile duct cancer, and other malignant conditions requiring PD for R0 resection). Preoperatively, endoscopic nasobiliary drainage (ENBD) was applied for biliary decompression. This novel procedure could minimize the leakage rates of pancreaticoenterostomy and decompress both PJ and choledochojejunostomy (CJ) simultaneously.

The aim of this study was to investigate the feasibility of RPTNBD by comparing clinical outcomes before and after the introduction of this technique.

Methods

Study design and participants

This was a retrospective cohort study performed in a single institute. We reviewed the medical charts of patients who underwent pylorus-preserving PD (PPPD) or Whipple’s operation for malignant disease between June 2012 and August 2016. Clinical outcomes of the patients were compared to those of internal controls. Internal controls included the patients who underwent PPPD or Whipple’s operation due to malignant disease before June 2012. Percutaneous transhepatic biliary drainage (PTBD) was not inserted in these patients postoperatively. PTBD insertion was not technically feasible because the biliary system was compressed in these patients. Only percutaneous abscess drainage (PAD) was inserted to remove the digestive juice that leaked from anastomoses. Approval to perform research on human subjects in this study was provided by the Institutional Review Board of Korea University Medical Center Ansan Hospital (registration number: 2018AS0029). This study adhered to the tenets of the Declaration of Helsinki.

Procedures

The lymph nodes of the hepatoduodenal ligament, the celiac trunk, and the right side of the superior mesenteric artery were excised. We performed pancreaticoenteric resection, which included resection of the pancreatic head, duodenum, proximal jejunum (the first 15 cm from the ligament of Treitz), common bile duct, and gall bladder. The pancreas was divided with electrocauterity, and the pancreatic duct was cut with Metzenbaum scissors. Bleeding of the cut surface was controlled by electrosurgicalization or suture ligation.

For pancreaticoenteric anastomosis, the divided jejunum was lifted through the mesocolon of the transverse colon (retrocolic approach). A duct-to-mucosa anastomosis was made between the pancreatic duct and the jejunal mucosa. A polyvinyl chloride (PVC) stent was inserted in the jejunal opening and pancreatic duct to stabilize the inner strength of the pancreaticoenteric anastomosis. Before starting CJ, we inserted a blunt-pointed probe into the cut bile duct. This probe was passed through the peripheral duct and pulled through the liver parenchyma. A PVC drain tube was docked to the blunt point of the probe and retracted through the cut bile duct (Fig. 1). An end-to-side anastomosis was made between the bile duct and the jejunum (distal from PJ). The retracted end of the PVC drain was inserted into the jejunal opening during CJ. The opposite end of the PVC drain was pierced through the abdominal wall and was connected to a low-vacuum silicone reservoir. The final scheme of RPTNBD is shown in Fig. 2. To restore the gastrointestinal continuity, Billroth II or Roux-en-Y reconstruction was performed. For Billroth II reconstruction, a Braun anastomosis was added.

Assessments

Demographic, clinical, pathological, and therapeutic information was obtained from the medical records of the study participants. Outcomes, including the operation time, vascular reconstruction method, duration of postoperative hospital stay, time to the first semi-blend diet, and postoperative complications, were investigated. Postoperative complications were graded according to the Clavien-Dindo classification of surgical complications.
Fig. 1 Surgical retrograde installation of percutaneous transhepatic negative-pressure biliary drainage. 

- **a** The opening of the cut bile duct was identified for the insertion of a blunt-pointed probe.
- **b** The metal probe penetrated through the liver parenchyma.
- **c** A drainage tube was docked to the metal probe.
- **d** The drainage tube was retracted through the cut bile duct.

**Fig. 2** Final scheme of retrograde installation of percutaneous transhepatic negative-pressure biliary drainage. CJ choledochojejunostomy, PJ pancreaticojejunostomy.
Analysis
Internal controls were defined as patients, who underwent PPPD or Whipple’s operation for malignant disease without RPTNBD. Clinical, pathological, and therapeutic outcomes, including the incidence of PJ leakage, were compared between the study participants and the internal controls. In the present study, PJ leakage was defined as a drain output of any volume occurring on or after postoperative day 3 with an amylase level of at least three times the serum amylase levels [6].

Statistical analyses
Patients with and without RPTNBD were compared using the chi-squared test or Fisher’s exact test for categorical data and the Student’s t test or Mann-Whitney U test for continuous data with abnormal distribution. In two-tailed tests, a P value < 0.05 was considered statistically significant. Statistical analysis was performed using SPSS 24.0 (SPSS Inc., Chicago, IL, USA).

Results
Twenty-one patients underwent RPTNBD during PD for a malignant disease of the duodenum, common bile duct, or pancreas. The patients’ demographics are presented in Table 1. The mean age and BMI of the enrolled patients were 65.5 ± 11.2 years (range, 36–82 years) and 22.6 ± 4.1 kg/m² (range, 15.3–33.3 kg/m²), respectively. Among the 21 enrolled patients, 13 (61.9%) underwent PPPD. The operation time was 412.0 ± 92.8 min (range, 240–600 min), and the duration of hospital stay was 39.4 ± 26.4 days (range, 13–105 days). The time to the first semi-blend diet was 8.4 ± 5.6 days (range, 3–31 days). The tumor size was 3.1 ± 1.2 cm (range, 1.1–5.4 cm). The numbers of retrieved and metastatic lymph nodes were 18.0 ± 8.1 (range, 2–36) and 1.6 ± 2.8 (range, 0–8), respectively. Thirteen patients showed postoperative morbidities. Among the 13 cases, 10 (47.6%) corresponded to a morbidity of Clavien-Dindo grade III or higher (Table 2). Four patients underwent radiological interventions for fluid collection around the PJ or CJ sites (cases 7, 11, 14, and 16); however, tubographic images acquired via the RPTNBD pathway showed no association between PJ and the fluid collection. All the patients recovered with conservative treatment.

Table 1
Demographic data of the RPTNBD group in the present study

| Number | Age | Sex | BMI  | ASA score | Preoperative ENBD | Diagnosis                |
|--------|-----|-----|------|-----------|-------------------|-------------------------|
| 1      | 78  | Male| 23.4 | III       | No                | Pancreatic head cancer  |
| 2      | 56  | Male| 21.3 | II        | No                | Pancreatic head cancer  |
| 3      | 82  | Male| 24.7 | III       | No                | Pancreatic head cancer  |
| 4      | 66  | Male| 23.3 | II        | Yes               | CBD cancer              |
| 5      | 36  | Male| 17.9 | II        | No                | Pancreatic head cancer  |
| 6      | 77  | Female| 20.7 | II        | Yes               | CBD cancer              |
| 7      | 53  | Male| 21.2 | II        | No                | Klatskin tumor          |
| 8      | 75  | Male| 19.7 | III       | Yes               | Pancreatic head cancer  |
| 9      | 60  | Male| 18.4 | III       | Yes               | Pancreatic head cancer  |
| 10     | 78  | Female| 27.8 | II        | No                | Pancreatic head cancer  |
| 11     | 68  | Male| 23.4 | II        | No                | Pancreatic head cancer  |
| 12     | 72  | Female| 15.3 | II        | Yes               | Pancreatic head cancer  |
| 13     | 60  | Male| 20.7 | II        | No                | Pancreatic head cancer  |
| 14     | 71  | Male| 27.0 | II        | Yes               | AOV cancer              |
| 15     | 72  | Male| 24.3 | II        | No                | CBD cancer              |
| 16     | 57  | Female| 33.3 | III       | No                | Klatskin tumor          |
| 17     | 68  | Male| 25.0 | III       | No                | CBD cancer              |
| 18     | 76  | Female| 26.2 | II        | No                | AOV cancer              |
| 19     | 58  | Male| 19.3 | II        | Yes               | Pancreatic head cancer  |
| 20     | 54  | Female| 17.7 | III       | No                | Pancreatic head cancer  |
| 21     | 59  | Male| 24.2 | II        | No                | CBD cancer              |

BMI: body mass index, ASA: American Society of Anesthesiologists, ENBD: endoscopic nasobiliary drainage, CBD: common bile duct, AOV: ampulla of Vater
time was 420.2 ± 170.4 min (range, 267–1,015 min) and the duration of hospital stay was 30.3 ± 22.5 days (range, 9–118 days). The time to the first semi-blend diet was 12.0 ± 12.4 days (range, 4–61 days). The tumor size was 3.2 ± 1.4 cm (range, 0.8–5.8 cm). The numbers of retrieved and metastatic lymph nodes were 19.7 ± 6.7 (range, 4–36) and 1.5 ± 2.4 (range, 0–8), respectively.

Twenty-two patients had postoperative morbidities. Among the 22 cases, 10 (52.4%) corresponded to a morbidity of Clavien-Dindo grade III or higher (Table 4).

As shown in Table 5, the incidence of postoperative complications did not differ between the study participants and the internal controls (P = 0.494). However, the internal controls showed a higher incidence of PJ complications than the study participants (P = 0.020). Mortality occurred in the internal controls, although 12 (38.7%) patients with PJ complication underwent radiological interventions of PAD to remove the digestive juice leaked from the anastomoses. The internal control group showed higher morbidity and mortality rates than the RPTNBD group (Additional file 1).

**Discussion**

Considering the results, we believe that RPTNBD might contribute to the salvage treatment of a morbidity after PD. Because the present study included far advanced cases that required some challenging procedures (i.e., major vessel reconstruction or simultaneous hepatectomy) to accomplish R0 resection, several cases carried a high risk of morbidity or mortality. However, most postoperative complications were managed with intravenous antibiotics and additional PAD. One patient who underwent portal vein and right hepatic artery reconstructions did not show any postoperative morbidity. It was remarkable that no mortality occurred even in the advanced cases that required technically demanding procedures.

Because the corrosive property of pancreatic juice might cause secondary catastrophes in the surgical field, several strategies have been designed to prevent pancreaticoenteric leakage after the introduction of PD. Although many strategies have been established for the postoperative safety of PD, biliary tract decompression is one of the most traditional methods that reduces the
In 1935, Whipple et al. first proposed preoperative biliary drainage (PBD), by which obstructive jaundice could be corrected in patients with periampullary lesions [7]. Preoperative correction of jaundice could be related to the clinical outcomes of patients undergoing PD, because hyperbilirubinemia is associated with impaired liver function, coagulation disorder, compromised immunity, accumulation of circulating endotoxin, and wound problems [8–11]. Currently, PBD has been facilitated by the technical advancement of radiological interventions (i.e., PTBD) and endoscopic procedures. With regard to the clinical outcomes of patients undergoing PD, some studies showed the benefits of PBD, including improved resection rate, morbidity, and mortality rates [12, 13]. However, other reports indicated drawbacks of this procedure. Several researchers reported the possibility of hyperamylasemia after radiological or endoscopic procedures [14, 15]. In addition, some comparative studies revealed that PBD caused certain morbidities rather than advantages in patients who underwent PD [16, 17]. Therefore, the benefit of performing PBD before PD is not yet established.

Biliary drainage can be performed intraoperatively. Doi et al. reported an intraoperative biliary decompression technique in which a newly developed curved drainage clamp (Mizuho Co., Tokyo, Japan) was used for the

**Table 3** Demographic data of the internal controls in the present study

| Number | Age | Sex  | BMI  | ASA score | Preoperative ENBD | Diagnosis                  |
|--------|-----|------|------|-----------|-------------------|---------------------------|
| 1      | 63  | Male | 23.3 | II        | No                | Pancreatic head cancer    |
| 2      | 52  | Male | 18.8 | II        | No                | CBD cancer                |
| 3      | 59  | Female | 32.4 | II        | Yes               | Pancreatic head cancer    |
| 4      | 57  | Female | 24.1 | II        | No                | CBD cancer                |
| 5      | 51  | Male | 21.0 | II        | No                | Pancreatic head cancer    |
| 6      | 52  | Male | 24.0 | II        | Yes               | Pancreatic head cancer    |
| 7      | 45  | Male | 23.6 | I         | No                | Duodenal cancer           |
| 8      | 50  | Male | 18.8 | II        | Yes               | Duodenal cancer           |
| 9      | 76  | Male | 24.1 | II        | No                | CBD cancer                |
| 10     | 69  | Male | 21.9 | II        | No                | CBD cancer                |
| 11     | 76  | Female | 18.1 | II        | No                | CBD cancer                |
| 12     | 73  | Female | 22.9 | III       | Yes               | Pancreatic head cancer    |
| 13     | 57  | Female | 23.4 | I         | No                | Pancreatic head cancer    |
| 14     | 75  | Male | 21.3 | II        | Yes               | AOV cancer                |
| 15     | 73  | Female | 29.1 | II        | Yes               | CBD cancer                |
| 16     | 53  | Male | 26.6 | II        | No                | Pancreatic head IPMN      |
| 17     | 70  | Female | 17.2 | I         | No                | Pancreatic head cancer    |
| 18     | 74  | Male | 25.7 | II        | No                | Pancreatic head cancer    |
| 19     | 62  | Male | 24.1 | III       | Yes               | Pancreatic head IPMN      |
| 20     | 72  | Female | 23.1 | III       | No                | Pancreatic head cancer    |
| 21     | 58  | Female | 23.8 | II        | No                | CBD cancer                |
| 22     | 77  | Male | 23.1 | II        | No                | CBD cancer                |
| 23     | 71  | Male | 18.5 | II        | Yes               | Pancreatic head cancer    |
| 24     | 58  | Male | 24.8 | II        | No                | Pancreatic head cancer    |
| 25     | 66  | Male | 18.7 | II        | Yes               | Pancreatic head cancer    |
| 26     | 50  | Male | 18.2 | II        | No                | AGC                       |
| 27     | 60  | Female | 20.0 | II        | No                | Duodenal GIST             |
| 28     | 59  | Male | 18.8 | II        | No                | Pancreatic head cancer    |
| 29     | 65  | Male | 25.3 | III       | No                | AOV cancer                |
| 30     | 72  | Male | 27.4 | II        | Yes               | CBD cancer                |
| 31     | 78  | Female | 19.8 | II        | Yes               | CBD cancer                |

BMI: body mass index, ASA: American Society of Anesthesiologists, ENBD: endoscopic nasobiliary drainage, CBD: common bile duct, AOV: ampulla of Vater, IPMN: intraductal papillary mucinous neoplasm, AGC: advanced gastric cancer, GIST: gastrointestinal stromal tumor
drainage of the common hepatic duct stump [18]. However, it was difficult to determine the effect of this technique on anastomosis, despite the possibility that this technique reduces the risk of hepatic complications. As part of another biliary decompression technique, the special structures are added after PD. Two strategies were used for adding these special structures over the last few decades. Braun anastomosis is one of these two strategies; it reduces the pressure in the biliopancreatic limb to avoid the afferent loop syndrome. The result of a randomized clinical trial showed that Braun anastomosis might decrease the pressure in the biliopancreatic limb after standard Whipple’s operation [19]. Separating anastomoses is the other strategy. Isolated Roux loop PJ was performed to lower the incidence rate of pancreatic fistula [20]. Double Roux-en-Y reconstruction was proposed to isolate pancreaticoenteric, choledochoenteric, or gastroenteric anastomosis [21]. However, all these modified structures rendered no significant protection against pancreaticoenteric leakage [19–21].

When PJ failures are diagnosed postoperatively, several radiological interventions can be helpful in maintaining the conservative treatment. PTBD and PAD are the representative procedures that have been widely accepted in

| Number | Operation | Vascular reconstruction | Operation time (min) | Hospital stay (day) | Time to SBD (day) | C-D classification | Pathology | RLN | MLN |
|--------|-----------|------------------------|----------------------|---------------------|------------------|-------------------|-----------|-----|-----|
| 1      | Whipple   | 345                    | 42                   | 6                   | IIIa             | AC                | 22        | 0   |     |
| 2      | PPPD      | 275                    | 15                   | 6                   | 0                | AC                | 14        | 1   |     |
| 3      | PPPD      | 267                    | 14                   | 9                   | 0                | AC                | 19        | 0   |     |
| 4      | PPPD      | 330                    | 70                   | 39                  | IIIb             | AC                | 26        | 0   |     |
| 5      | PPPD      | 400                    | 14                   | 6                   | 0                | NEC               | 16        | 0   |     |
| 6      | PPPD      | 480                    | 66                   | 8                   | IIIa             | AC                | 22        | 4   |     |
| 7      | Whipple   | 365                    | 12                   | 7                   | 0                | AC                | 13        | 0   |     |
| 8      | Whipple   | 765                    | 31                   | 6                   | IIIa             | AC                | 19        | 8   |     |
| 9      | PPPD      | 370                    | 9                    | 7                   | 0                | AC                | 11        | 0   |     |
| 10     | PPPD      | 330                    | 15                   | 7                   | 0                | AC                | 24        | 8   |     |
| 11     | PPPD      | 370                    | 17                   | 12                  | II               | AC                | 10        | 0   |     |
| 12     | PPPD      | 350                    | 15                   | 7                   | 0                | AC                | 20        | 0   |     |
| 13     | PPPD      | 340                    | 44                   | 33                  | IVa              | NEC               | 4         | 1   |     |
| 14     | PPPD      | 505                    | 41                   | 7                   | IIIa             | AC                | 18        | 0   |     |
| 15     | PPPD      | 310                    | 24                   | 22                  | II               | AC                | 36        | 3   |     |
| 16     | PPPD      | 1015                   | 30                   | .                   | V                | AC                | 25        | 1   |     |
| 17     | PPPD      | 570                    | 118                  | 61                  | IIIb             | AC                | 32        | 0   |     |
| 18     | PPPD      | 490                    | 23                   | 13                  | II               | AC                | 20        | 0   |     |
| 19     | PPPD      | 290                    | 23                   | 15                  | II               | AC                | 13        | 0   |     |
| 20     | Whipple   | 355                    | 41                   | 4                   | II               | AC                | 21        | 4   |     |
| 21     | PPPD      | 327                    | 31                   | 6                   | IIIa             | AC                | 15        | 0   |     |
| 22     | Whipple   | 362                    | 53                   | 8                   | V                | AC                | 17        | 0   |     |
| 23     | Whipple   | PV                     | 467                  | 31                  | 9                | V                 | 21        | 6   |     |
| 24     | PPPD      | 313                    | 23                   | 8                   | IIIa             | AC                | 24        | 0   |     |
| 25     | Whipple   | PV                     | 755                  | 10                  | .                | V                 | AC        | 28   | 4   |
| 26     | Whipple   | 650                    | 34                   | 9                   | II               | AC                | 18        | 0   |     |
| 27     | Whipple   | 285                    | 19                   | 5                   | II               | AC                | 13        | 0   |     |
| 28     | Whipple   | 365                    | 19                   | 6                   | 0                | NEC               | 21        | 0   |     |
| 29     | Whipple   | 365                    | 23                   | 7                   | IIIa             | AC                | 19        | 4   |     |
| 30     | PPPD      | 318                    | 19                   | 7                   | 0                | AC                | 21        | 1   |     |
| 31     | PPPD      | 297                    | 14                   | 7                   | II               | AC                | 29        | 0   |     |

SBD semi-blend diet, C-D Clavien-Dindo, RLN retrieved lymph nodes, MLN metastatic lymph nodes, PPPD pylorus-preserving pancreatoduodenectomy, NEC neuroendocrine carcinoma, AC adenocarcinoma, PV portal vein
the clinical field. These interventions can minimize anastomotic soling. PTBD reduces biliary flow into the afferent loop, which effectively decreases pressure in the disrupted anastomosis. PAD, on the contrary, may remove the digestive juice that has already leaked from the PJ or CJ site. Currently, the conservative strategy for the management of PJ or CJ failure is usually composed of PTBD or PAD, when radiological interventions can be performed under the guidance of real-time imaging techniques. Although PTBD heals the failed anastomosis by reducing the leakage, this intervention depends on biliary imaging. If the biliary ducts are not dilated, postoperative PTBD is technically demanding. Therefore, we performed RPTNBD intraoperatively. Our novel method was designed by incorporating the advantages of the previous procedures. The biliary decompression effect of RPTNBD may be equal to that of PTBD; however, the former does not require radiological guidance. As RPTNBD is intraoperatively performed during PD, surgeons can insert the drainage tube into the biliary duct.

RPTNBD has a protective effect against anastomotic leakage in both PJ and CJ sites. Similar to PTBD, RPTNBD decreases the high pressure of the afferent loop resulting from the accumulation of bile or pancreatic juice, which inevitably occurs during the paralytic ileus period after PD. When a minor leakage occurs in the PJ or CJ site, RPTNBD can reduce the risk of anastomotic failure. Although PAD had to be applied for fluid collection around the PJ or CJ site in several cases (cases 7, 11, 14, and 16) in the present study, these morbidities did not lead to the fulminant failure of PJ or CJ. Their drain amylase levels did not exceed three times the serum amylase levels. Tubography is also possible via the RPTNBD route, which can facilitate making a critical decision in the postoperative course (Additional file 2). For example, although computed tomography implied complicated fluid collection around the pancreas in two cases (cases 7 and 11), in our study, we could confirm no connection between the fluid collection and PJ using tubography via RPTNBD. In such cases, tubography via RPTNBD could provide an important clue to avoid unnecessary delay of the clinical decision.

One limitation of RPTNBD is that the surgeon should have reliable knowledge regarding the hepato-biliary anatomy. This is also an important precondition for performing RPTNBD. Although we did not encounter any accidental hemorrhage, introducing a probe into the intrahepatic bile duct may harbor a risk of injury to the hepatic structures.

**Conclusion**

In conclusion, if a skilled surgeon performs RPTNBD, pancreaticoenteric anastomosis may be stabilized after PD. RPTNBD is expected to be effective in minimizing PJ or CJ anastomotic failure, which can arise in compromised patients.

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Table 5 Comparison of outcomes between the RPTNBD group and internal control group

|                         | RPTNBD group (n = 21) | Internal control group (n = 31) | P    |
|-------------------------|-----------------------|-------------------------------|------|
| Age (years), means ± SD | 65.5 ± 11.2           | 62.6 ± 11.4                   | 0.330|
| Female (%)              | 28.6                  | 35.5                          | 0.765|
| BMI (kg/m²), means ± SD | 22.6 ± 4.1            | 22.6 ± 3.5                    | 0.980|
| PPPD (%)                | 61.9                  | 64.5                          | 1.000|
| Preoperative ENBD (%)   | 33.3                  | 35.5                          | 1.000|
| Operation time (min), means ± SD | 412.0 ± 92.8        | 420.2 ± 170.4                | 0.843|
| Hospital stay (days), means ± SD | 39.4 ± 26.4          | 30.3 ± 22.5                   | 0.190|
| Time to SBD (day), means ± SD | 8.4 ± 5.6            | 11.3 ± 11.7                   | 0.307|
| Vascular reconstruction (%) | 33.3                 | 6.5                           | 0.012|
| Hepatectomy (%)         | 9.5                   | 3.2                           | 0.339|
| Postoperative PAD (%)   | 19.0                  | 45.2                          | 0.076|
| Fluid collection (%)    | 19.0                  | 6.5                           | 0.207|
| Anastomotic leakage (%) | 0                     | 38.7                          | 0.001|
| Morbidity (%)           | 61.9                  | 71.0                          | 0.494|
| C-D grade > II (%)      | 47.6                  | 45.2                          | 1.000|
| PJ complication (%)     | 9.5*                  | 38.7                          | 0.020|
| Mortality (%)           | 0.0                   | 12.9                          | 0.087|

*These patients had only fluid collection around PJ sites with no evidence of leakage in tubography

**SD** standard deviation, **BMI** body mass index, **PPPD** pylorus-preserving pancreatodudodenectomy, **ENBD** endoscopic nasobiliary drainage, **SBD** semi-blend diet, **PAD** percutaneous abscess drainage, **C-D** Clavien-Dindo, **PJ** pancreaticojejunostomy
Additional files

**Additional file 1:** Table S1. Comparison of outcomes between RPTNBD group and internal controls with PAD related to anastomotic leakage. SD standard deviation. BMI body mass index, PPPD pylorus-preserving pancreaticoduodenectomy, ENBD endoscopic nasobiliary drainage, SBD semi–blend diet, PAD percutaneous abscess drainage, C–D Clavien–Dindo, PJ pancreaticojejunostomy. (DOCX 26 kb)

**Additional file 2:** Figure S1. Tubography showing each anastomosis via the route of retrograde installation of percutaneous transhepatic negative-pressure biliary drainage. Cj choledochojejunostomy, PJ pancreaticojejunostomy, Gj gastrojejunostomy. (PPTX 1740 kb)

Abbreviations

BMI: Body mass index; Cj: Choledochojejunostomy; PAD: Percutaneous abscess drainage; PBD: Preoperative biliary drainage; PD: Pancreatectoduodenectomy; PG: Pancreaticogastrostomy; PJ: Pancreaticojjunostomy; PPPD: Pylorus-preserving pancreaticoduodenectomy; PTBD: Percutaneous transhepatic biliary drainage; PVC: Polyvinyl chloride; RPTNBD: Retrograde installation of percutaneous transhepatic negative-pressure biliary drainage

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Authors’ contributions

CML and SYY designed the study. CML and YJS collected the data. CML and SYY drafted the manuscript. YJS revised the manuscript critically. All authors read and approved the final manuscript.

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Availability of data and materials

The authors presented all the necessary information about the study in the manuscript and its supplementary material.

Ethics approval and consent to participate

This study adhered to the tenets of the Helsinki Declaration. Approval to perform research on human subjects in this study was provided by Institutional Review Board of Korea University Medical Center Ansan Hospital (registration number: 2018AS0029). Due to the retrospective nature of this study, the usual requirement for signed written informed consent forms was waived.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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