Original Research

INTERNATIONAL JOURNAL OF SURGERY

OPEN

Textbook outcome as a composite outcome measure in laparoscopic pancreaticoduodenectomy: a multicenter retrospective cohort study

Yi Wu, MD[a], Bing Peng, MD[i], Jianhua Liu, MD[c], Xinmin Yin, MD[d], Zhijian Tan, MD[e], Rong Liu, MD[f], Defei Hong, MD[g], Wenxing Zhao, MD[o], Heshui Wu, MD[b], Rufu Chen, MD[j], Dewei Li, MD[k], Heguang Huang, MD[l], Yi Miao, MD[m,n], Yahui Liu, MD[p], Tingbo Liang, MD[h], Wei Wang, MD[q], Jingxiong Yuan, MD[a], Shizhen Li, MD[a], Hang Zhang, MD[a,*], Min Wang, MD[a,*], Renyi Qin, MD, PhD[a,*]; on behalf of the Minimally Invasive Treatment Group in the Pancreatic Disease Branch of China's International Exchange and Promotion Association for Medicine and Healthcare (MITG-P-CPAM)

Background: Textbook outcome (TO) is a composite outcome measure for surgical quality assessment. The aim of this study was to assess TO following laparoscopic pancreaticoduodenectomy (LPD), identify factors independently associated with achieving TO, and analyze hospital variations regarding the TO after case-mix adjustment.

Methods: This multicenter cohort study retrospectively analyzed 1029 consecutive patients undergoing LPD at 16 high-volume pancreatic centers in China from January 2010 to August 2016. The percentage of patients achieving TO was calculated. Preoperative and intraoperative variables were compared between the TO and non-TO groups. Multivariate logistic regression was performed to identify factors independently associated with achieving TO. Hospital variations regarding the TO were analyzed by the observed/expected TO ratio after case-mix adjustment. Differences in expected TO rates between different types of hospitals were analyzed using the one-way analysis of variance test.

Results: TO was achieved in 68.9% ($n=709$) of 1029 patients undergoing LPD, ranging from 46.4 to 85.0% between different hospitals. Dilated pancreatic duct (>3 mm) was associated with the increased probability of achieving TO [odds ratio (OR): 1.564; $P=0.001$], whereas advanced age (≥75 years) and concomitant cardiovascular disease were associated with a lower likelihood of achieving TO (OR: 0.545; $P=0.037$ and OR: 0.614; $P=0.006$, respectively). The observed/expected TO ratio varied from 0.62 to 1.22 after case-mix adjustment between different hospitals, but no significant hospital variations were observed. Hospital volume, the surgeon's experience with open pancreaticoduodenectomy and minimally invasive surgery, and surpassing the LPD learning curve were significantly correlated with expected TO rates.

Conclusion: TO was achieved by less than 70% of patients following LPD. Dilated pancreatic ducts, advanced age, and concomitant cardiovascular disease were independently associated with achieving TO. No significant hospital variations were observed after case-mix adjustment.

Keywords: composite outcome measure, hospital variation, laparoscopic pancreaticoduodenectomy, textbook outcome

[a]Department of Biliary-Pancreatic Surgery, Affiliated Tongji Hospital, [b]Department of Pancreatic Surgery, Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, Hubei, [c]Department of Hepato-Pancreato-Biliary Surgery, The Second Hospital of Hebei Medical University, Shijiazhuang, Hebei, [d]Department of Hepatobiliary Surgery, Hunan Provincial People's Hospital, The First Affiliated Hospital of Hunan Normal University, Changsha, Hunan, [e]Department of Hepatobiliary and Pancreatic Surgery, Guangdong Provincial Hospital of Chinese Medicine, Guangzhou, Guangdong, [f]The Second Department of Hepato-Pancreato-Biliary Surgery, Chinese PLA General Hospital, Beijing, [g]Division of General Surgery, Sir Run Run Shaw Hospital (SRRSH), Affiliated with the Zhejiang University School of Medicine, [h]Department of Hepatobiliary and Pancreatic Surgery, The First Affiliated Hospital, Zhejiang University School of Medicine, Hangzhou, Zhejiang, [i]Department of Pancreatic Surgery, West China Hospital, Sichuan University, Chengdu, Sichuan, [j]Department of Pancreaticobiliary Surgery, Sun Yat-sen Memorial Hospital, Sun Yat-sen University, Guangzhou, [k]Department of Hepatobiliary Surgery, The First Affiliated Hospital of Chongqing Medical University, Chongqing, [l]Department of General Surgery, Fujian Medical University Union Hospital, Fuzhou, Fujian, [m]Pancreas Center, The First Affiliated Hospital of Nanjing Medical University, Nanjing, [n]Pancreas Center, Nanjing Medical University, Nanjing, [o]Department of General Surgery, The Affiliated Hospital of Xuzhou Medical University, Xuzhou, Jiangsu, [p]Department of Hepatobiliary and Pancreatic Surgery, The First Hospital of Jilin University, Changchun, Jilin and [q]Department of Biliopancreatic Surgery, Huadong Hospital, Fudan University, Shanghai, China

Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

R.Q., M.W. and H.Z. are equally contributed.

**Corresponding author. Address: Department of Biliary-Pancreatic Surgery, Affiliated Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, No. 1095 Jiefang Avenue, Wuhan 430030, Hubei Province, China. Tel: +86 278 366 5294, fax: +86 278 366 5294. E-mails address: ryqin@tjh.tjmu.edu.cn (R. Qin); wangmin0013128@aliyun.com (M. Wang) and zhanghang@hust.edu.cn (H. Zhang).*

International Journal of Surgery (2023) 109:374–382

Received 21 November 2022; Accepted 26 January 2023

Supplemental Digital Content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's website, www.journal-surgery.net.

Published online 24 March 2023

http://dx.doi.org/10.1097/JS9.0000000000000303

Introduction

Laparoscopic pancreaticoduodenectomy (LPD) remains one of the most complex and technically challenging procedures in pancreatic surgery, although LPD has developed rapidly worldwide in recent years[1–5]. Traditionally, quality assessment of LPD has mainly focused on individual outcome measures such as morbidity, mortality, operative time, operative blood transfusion, readmission rates, and length of hospital stay (LOS)[6–10].

However, individual outcome parameters do not reflect the multiple facets of the whole surgical procedure and do not measure actual variations among different hospitals[10–15]. In this context, several outcome experts have suggested that composite measures of surgical quality may be better than individual outcome parameters to compare hospital performance[7,16–21]. Textbook outcome (TO) is a composite outcome measure of multiple desirable outcome metrics that was first proposed in 2013 by Dutch colorectal surgeons in order to give a comprehensive summary of hospital performance[22]. TO is realized when all of the desired outcome parameters are achieved following surgery and represents the optimal ('textbook') hospitalization.

Different surgical specialties adopted different TO definitions. In 2020, van Roessel *et al.*[23] proposed a TO definition in pancreatic surgery based on an international expert consensus. Although several studies on TO in pancreatic surgery have been reported, relevant data on LPD are lacking[10,23–29]. The objective of this study was to assess TO among patients undergoing LPD, identify factors independently associated with achieving TO, and analyze hospital variations regarding the TO after case-mix adjustment.

HIGHLIGHTS

- Textbook outcome (TO) was achieved in 68.9% ($n = 709$) of 1029 patients undergoing laparoscopic pancreaticoduodenectomy (LPD), ranging from 46.4 to 85.0% between different hospitals.
- Dilated pancreatic duct (> 3 mm), advanced age (≥ 75 years) and concomitant cardiovascular disease were independently associated with achieving TO following LPD.
- The observed/expected TO ratio varied from 0.62 to 1.22 after case-mix adjustment between different hospitals, but no significant hospital variations were observed.
- Hospital volume, surgeon's experience with open pancreaticoduodenectomy and minimally invasive surgery, and surpassing the LPD learning curve were significantly correlated with expected TO rates.

Methods

Study design

This cohort study was a secondary analysis of the multicenter retrospective analysis study, which included 1029 consecutive patients from 16 high-volume pancreatic centers (> 60 pancreaticoduodenectomies per year) in China[30]. All patients undergoing LPD for malignant or benign lesions from January 2010 to August 2016 were enrolled in this study. The inclusion and exclusion criteria were as previously described[30]. Given the retrospective nature of this study, the need for informed consent was waived according to Chinese legislation. This study was registered at ClinicalTrials (NCT05616403). This work has been reported in accordance with the STROCSS criteria[31], Supplemental Digital Content 1, http://links.lww.com/JS9/A91.

Surgical procedure

Patients were placed in the supine position with the legs separated. Under general anesthesia, five trocars were placed in a V shape. After the initial exploration of the abdominal cavity to rule out any metastasis, the gallbladder was resected and set aside. The Kocher maneuver was performed, and then the distal stomach was transected with an endostapler. Lymph node station 8 was dissected after the common hepatic arteries were identified and suspended. The gastroduodenal artery and the right gastric artery were ligated and transected. Lymph nodes in the hepatoduodenal ligament were dissected, and then the common hepatic duct was transected for anastomosis. A tunnel was dissected posterior to the pancreatic neck and anterior to the superior mesenteric vein and portal vein. The pancreas was transected with ultrasonic shears, and the pancreatic duct was carefully transected with scissors. The jejunum was transected ~15 cm from the ligament of Treitz with an endostapler. The uncinate process was dissected by handling the branches of the superior mesenteric vessels after retracting the jejunum and duodenum to the right side of the mesenteric root.

The pancreatic stump remnant was dissected to ~0.5 cm (no more than 1.0 cm) in length, and careful hemostasis was performed with the absorbable sutures or ultrasonic shears. The jejunal limb was brought up to the right of the middle colic vessels in a retrocolic manner, and the blind end was placed near the pancreatic remnant. A pancreaticojejunostomy was performed with different pancreatic anastomosis techniques according to the surgeon's preference, including duct-to-mucosa pancreaticojejunostomy, end-to-end invagination pancreaticojejunostomy, and imbedding end-to-side pancreaticojejunostomy[30]. Subsequently, an end-to-side hepaticojejunostomy was performed with either continuous or interrupted sutures ~10 cm distal to the pancreatic anastomosis. An antecolic side-to-side gastroenterostomy was performed with the staple technique ~40 cm distal to the biliary anastomosis, and two layers of continuous sutures were used to close the gastric stump. Two drainage catheters were routinely positioned near the pancreatojejunostomy and the hepaticojejunostomy. The resected specimen was extracted through an upper-middle incision, which was subsequently closed in layers with the closure of the trocars.

Variables and definitions of TO

Case-mix factors were patient and tumor characteristics. The surgeon-level and hospital-level factors included hospital volume (beds), center volume (cases/year), surgeon's experience with open pancreaticoduodenectomy (OPD) (cumulative cases), the surgeon's experience with minimally invasive surgery (MIS) (cumulative cases), and the LPD learning curve (cases), defined as previously reported[30]. The MIS concerned laparoscopic hepatectomy, splenectomy, gastrointestinal surgery, and distal pancreatectomy. The postoperative complications were graded into mild complications (I–II) and severe complications ($\geq$ III) according to the Clavien–Dindo classification of surgical

complications[32]. Specific complications related to pancreatic surgery, such as postoperative pancreatic fistula (POPF), postpancreatectomy hemorrhage (PPH), and bile leakage, were defined by the International Study Group on Pancreatic Surgery (ISGPS) or International Study Group of Liver Surgery (ISGLS) definition[33–35]. TO was defined as the absence of POPF, PPH, bile leakage (all ISGPS or ISGLS grades B/C), severe complications (Clavien–Dindo grade ≥ III), in-hospital or 30-day mortality, and readmission within 30 days after discharge, as previously reported by van Roessel *et al.*[23]. A TO was realized when all six parameters were achieved. A subanalysis was conducted using an extended definition (TO +) by adding no prolonged LOS, defined as LOS <75th percentile [10,23,36].

Statistical analysis

The percentage of patients achieving TO was calculated. Preoperative and intraoperative variables were compared between the non-TO group and the TO group. Continuous data following normal distribution are presented as mean with SD and analyzed using independent samples *t*-test. Non-normally distributed continuous variables are expressed as medians with interquartile ranges and were compared using the Mann–Whitney *U* or Kruskal–Wallis test, as appropriate. Categorical variables are presented as numbers and percentages and are evaluated using Pearson's χ^2 or Fisher's exact test, as appropriate. The factors associated with achieving TO were evaluated by univariate and multivariate logistic regression with odds ratios (OR) and 95% CI. Variables with a *P* value less than 0.1 on univariate analysis were entered into multivariate analysis.

Patient and tumor characteristics may largely affect hospital TO rates. Therefore, a case-mix adjustment should be performed before assessing the hospital's performance on TO rates. Case-mix adjustment was performed with multivariable logistic regression model using all available case-mix factors in order to analyze hospital variations in TO[22,23,37]. All available case-mix factors were variables with a *P* value less than 0.1 on univariate logistic analysis and were included in multivariable logistic regression model. Patients' predicted probability of achieving TO was estimated from the multivariable logistic regression model mentioned above. The observed TO rate was the proportion of patients who achieved TO in a hospital, and the expected TO rate was the mean of all patients' predicted probabilities for achieving TO in a hospital. Hospital performances were analyzed by calculating the observed/expected (O/E) TO ratio per hospital and showing it in funnel plots with 95% CIs. Hospitals with an O/E TO ratio higher than 1 have better performance than average. Hospitals with an O/E TO ratio lower than 1 represent worse performance than the average. Differences in expected TO rates between different types of hospitals were analyzed using the one-way analysis of variance test. All statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS) version 25 and R Foundation Statistical software (version 4.2.1). The *P* value less than 0.05 was considered statistically significant.

Results

Baseline characteristics

Among the 1029 consecutive patients who underwent LPD, TO was achieved in 709 patients (68.9%). Results for the six individual outcome metrics were displayed in Figure 1. The outcome metric least frequently realized was 'no Clavien–Dindo grade ≥ III complications' (82.4%), followed by 'no PPH' realized in 87.6%, while the most frequently realized was 'no mortality' (97.6%). Baseline characteristics of patients with or without achieving TO were presented in Table 1 and Supplementary Table, Supplemental Digital Content 2, http://links.lww.com/JS9/A92. Significant differences in concomitant cardiovascular disease, concomitant chronic pancreatitis, kind of pancreatic anastomosis, pylorus-preserving, removal of the nasogastric tube during operation, and dilated pancreatic duct (> 3 mm) were observed between the non-TO group and TO group (all $P < 0.05$). There were no significant differences in sex, age, BMI, symptom, total bilirubin after preoperative biliary drainage, kind of preoperative biliary drainage, neoadjuvant chemotherapy, American Society of Anesthesiologists score, estimated blood loss, texture of the pancreas, tumor size, number of lymph nodes, and pathological outcomes between the two groups (all $P > 0.05$). The patients in non-TO group had a longer time of pancreatic anastomosis, a longer time of biliary anastomosis, and a longer length of postoperative hospital stays compared with the TO group (all $P < 0.05$).

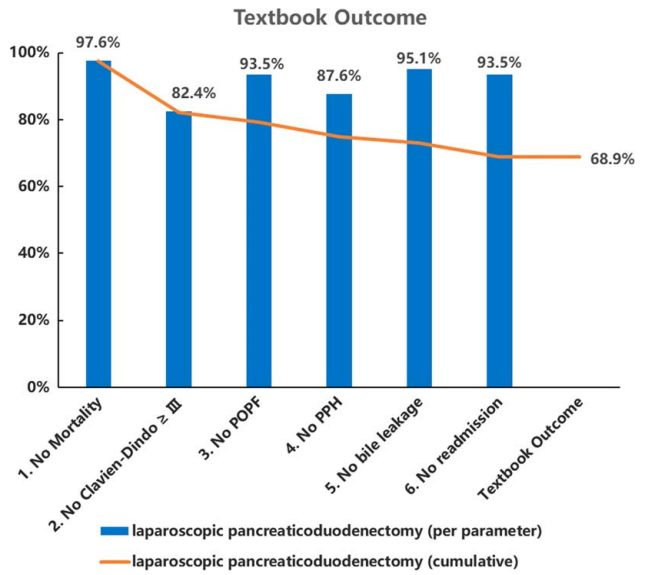

Figure 1. Textbook outcome: a composite measure of outcome parameters after laparoscopic pancreaticoduodenectomy in entire cohort. POPF, postoperative pancreatic fistula; PPH, postpancreatectomy hemorrhage.

TO

The unadjusted TO percentages varied from 46.4 to 85.0% between different hospitals performing LPD. The unadjusted TO percentages were significantly lower with decreasing center volume (cases/year), from 74.7% in centers performing more than 50 cases/year to 69.9% in centers performing 20–50 cases/year and 63.0% in centers performing fewer than 20 cases/year ($P = 0.020$). When six individual metrics of TO were stratified by center volume, percentages of 'no mortality' were significantly lower in centers performing fewer than 20 cases/year compared with 20–50 cases/year and more than 50 cases/year ($P = 0.019$). In addition, percentages of 'no POPF' were significantly lower in

Table 1

Baseline characteristics of patients with or without achieving textbook outcomes after laparoscopic pancreaticoduodenectomy

Variables	Textbook Outcome Group ($n=709$) [n (%)]	Nontextbook Outcome Group ($n=320$) [n (%)]	P value
Sex (male/female)	402 (56.7%)/307 (43.3%)	169 (52.8%)/151 (47.2%)	0.245
Age (years)	59 [50, 65]	59 [50, 67]	0.448
BMI (kg/m^2)	21.7 [19.7, 23.8]	22.0 [19.8, 24.2]	0.307
ASA score			0.384
I–II	606 (85.5)	280 (86.1)	
III–IV	103 (14.5)	40 (13.9)	
TBIL (μmol/l)	55.0 [13.3, 163.7]	71.1 [14.6, 267.8]	0.417
Comorbidity			
Cardiovascular disease	110 (15.5)	78 (24.4)	0.001
Diabetes mellitus	81 (11.4)	40 (12.5)	0.620
Chronic pancreatitis	41 (5.8)	8 (2.5)	0.022
Hepatitis	23 (3.2)	18 (5.6)	0.071
Pylorus-preserving LPD	154 (21.7)	46 (14.4)	0.006
Operative time (minutes)	445 [385, 540]	480 [384.5, 557]	0.052
Resection	334 [280, 414]	350.5 [271, 438.5]	0.180
Reconstruction	109 [91, 126]	114 [91.5, 134]	0.052
Pancreatic anastomosis	45 [38, 54]	46 [40, 55]	0.003
Biliary anastomosis	29 [23, 37]	31 [25, 40]	0.003
Gastrointestinal anastomosis	32 [25, 41]	30 [24, 40]	0.702
Pancreatic anastomosis			0.029
Duct-to-mucosa	518 (73.1)	211 (65.9)	
End-to-end (invaginated)	31 (4.4)	12 (3.8)	
Modified end-to-side (imbedding)	160 (22.6)	97 (30.3)	
Removal of NGT during operation	252 (35.5)	149 (46.6)	0.001
Estimated blood loss (ml)	200 [100, 300]	200 [100, 400]	0.581
Number of transfusion	148 (20.9)	70 (21.9)	0.724
Transfusion (ml)	450 [400, 800]	650 [400, 900]	0.063
Dilated pancreatic duct (> 3 mm)	387 (54.6)	139 (43.4)	0.001
Texture of pancreas			0.112
Hard	310 (43.7)	123 (38.4)	
Soft	399 (56.3)	197 (61.6)	
Pathological outcomes			0.977
Benign	149 (21.0)	67 (20.9)	
Malignant	560 (79.0)	253 (79.1)	
Tumor size (cm)	2.1 [1.5, 3.0]	2.4 [1.5, 3.0]	0.611
Number of lymph nodes	11 [6, 15]	11 [6, 14]	0.358
Postoperative hospital stays (days)	17 [12, 22]	19 [14, 30]	< 0.001

ASA, American Society of Anesthesiologists; LPD, laparoscopic pancreaticoduodenectomy; NGT, nasogastric tube; TBIL, total bilirubin.

centers performing fewer than 20 cases/year compared with 20–50 cases/year and more than 50 cases/year ($P=0.002$), but no significant differences between 20 and 50 cases/year and more than 50 cases/year. No significant differences were observed in the other four individual metrics (no PPH, no bile leakage, no readmission, and no Clavien–Dindo ≥ III) of TO stratified by center volume (Fig. 2).

When using the extended definition (TO+) by adding 'no prolonged LOS', the unadjusted TO+ percentages decreased from 68.9 to 56.0%, varying from 25.0 to 84.2% between different hospitals. The outcome parameter that was least frequently realized was 'no prolonged LOS' (76.6%) instead of 'no Clavien–Dindo grade ≥ III complications' (82.4%) by using the TO+ definition.

Factors associated with TO

On univariate and multivariate analysis, a dilated pancreatic duct (> 3 mm) was independently associated with achieving TO among patients undergoing LPD, whereas factors independently associated with not achieving TO were advanced age (≥ 75 years) and concomitant cardiovascular disease (Table 2). Specifically, patients with cardiovascular disease had a lower likelihood of achieving TO (OR: 0.614, 95% CI: 0.434–0.867; $P=0.006$). In addition, patients with age 75 years and older had decreased odds of achieving TO (OR: 0.545, 95% CI: 0.307–0.965; $P=0.037$). Notably, a dilated pancreatic duct (> 3 mm) was associated with an increased probability of achieving TO (OR: 1.564, 95% CI: 1.189–2.058; $P=0.001$).

Hospital variations

As shown in Table 2, all available case-mix factors were included in the multivariable logistic regression model, including age, total bilirubin after preoperative biliary drainage, concomitant cardiovascular disease, concomitant chronic pancreatitis, concomitant hepatitis, kind of pancreatic anastomosis, pylorus-preserving, removal of a nasogastric tube during the operation, estimated blood loss, pancreatic duct diameter, and number of lymph nodes. The mean expected TO rate was 69.4% (95% CI: 66.5–72.2%), ranging from 59.4 to 80.4% and the mean O/E TO ratio was 0.96 (95% CI: 0.88–1.04), varying from 0.62 to 1.22 after case-mix adjustment between different hospitals. As shown in Figure 3, there were no hospitals with a significantly higher or lower O/E TO ratio compared with the mean (all hospitals within 95% CI). Hospitals with higher center volume might be more likely to have better performance (O/E TO ratio > 1), but no significant variations were observed between the hospitals for achieving TO following LPD.

The differences in expected TO rates between different types of hospitals were further explored, as presented in Table 3. The mean expected TO rates in the high-hospital volume group (> 4000 beds) and medium-hospital volume group (2800–4000 beds) were significantly higher than those in the low-hospital volume group (< 2800 beds), although there were no differences in the observed TO rates (mean expected TO rate of 71.3 vs. 67.8%, $P=0.018$ and 69.7 vs. 67.8%, $P=0.047$, respectively). The mean expected TO rates in high-OPD volume group (> 1000 cases) were significantly higher than medium-OPD volume group (200–1000 cases) and low-OPD volume group (< 200 cases), and significant differences were also found in mean observed TO rates between high-OPD volume group and low-OPD volume group (mean expected TO rate, 76.1 vs. 67.9%, $P<0.001$ and 76.1 vs. 66.2%, $P<0.001$, respectively; mean observed TO rate, 75.4 vs. 64.5%, $P=0.008$). The mean expected TO rates in high-MIS volume group (> 500 cases) and medium-MIS volume group (100–500 cases) were significantly higher than low-MIS volume group (< 100 cases), although there were no differences in observed TO rates (mean expected TO rate, 70.5 vs. 61.4%, $P<0.001$ and 68.7 vs. 61.4%, $P<0.001$, respectively). The mean expected TO rates in LPD learning curve phase 3 group (> 104 cases) and LPD learning curve phase 2 group (41–104 cases) were significantly higher than LPD learning curve phase 1 group (< 41

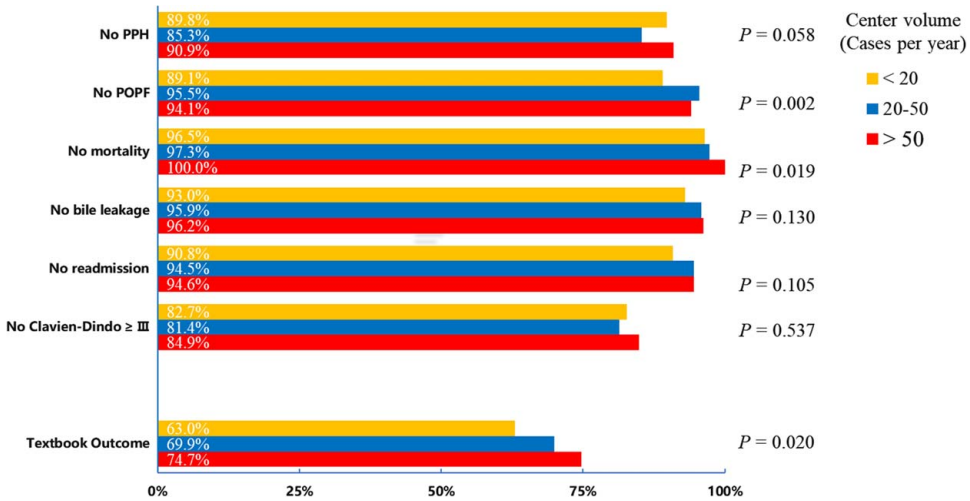

Figure 2. Textbook outcome: a composite measure of outcome parameters after laparoscopic pancreaticoduodenectomy stratified by center volume. POPF, postoperative pancreatic fistula; PPH, postpancreatectomy hemorrhage.

cases), and significant differences were also found in mean observed TO rates between phase 3 and phase 1 groups (mean expected TO rate, 70.3 vs. 67.4%, $P = 0.009$ and 69.8 vs. 67.4%, $P = 0.022$, respectively; mean observed TO rate, 72.4 vs. 61.7%, $P = 0.006$). No differences were observed in mean expected TO rates between different center volume (cases/year) groups, despite significant differences being found in mean observed TO rates (mean expected TO rate, $P = 0.384$; mean observed TO rate, $P = 0.020$).

Discussion

This study was the first to assess TO among patients undergoing LPD. The TO definition in this study adopted an international expert consensus-based definition for pancreatic surgery previously reported in 2020 by van Roessel *et al.*[23]. Adopting this TO definition, TO was achieved in 68.9% of patients undergoing LPD. Of note, the outcome metric of 'no Clavien–Dindo grade ≥ III complications' was the major obstacle to achieving TO for

Table 2

Univariate and multivariable logistic regression analysis of factors associated with textbook outcomes after laparoscopic pancreaticoduodenectomy.

	Univariate analysis		Multivariate analysis	
Patient variables	**OR (95% CI)**	***P* value**	**OR (95% CI)**	***P* value**
Age (≤65 years)	Ref		Ref	
66–74	0.816 (0.586–1.139)	0.232	0.891 (0.627–1.265)	0.518
≥75	0.535 (0.310–0.922)	0.024	0.545 (0.307–0.965)	0.037
Sex (female)	0.855 (0.656–1.114)	0.246		
BMI (18.5–24 kg/m^2)	Ref			
<18.5	0.994 (0.670–1.477)	0.978		
>24	0.805 (0.589–1.100)	0.174		
ASA score (III–IV)	1.190 (0.804–1.760)	0.385		
TBIL (>51.3 μmol/l)	0.792 (0.607–1.033)	0.086	0.793 (0.601–1.046)	0.100
Comorbidity				
Cardiovascular disease	0.570 (0.411–0.790)	0.001	0.614 (0.434–0.867)	0.006
Chronic pancreatitis	2.394 (1.109–5.167)	0.026	2.049 (0.929–4.519)	0.075
Hepatitis	0.563 (0.299–1.058)	0.074	0.613 (0.314–1.195)	0.151
Pancreatic anastomosis (invagination)	0.714 (0.537–0.949)	0.020	0.737 (0.510–1.064)	0.103
Pylorus-preserving LPD	1.653 (1.153–2.368)	0.006	1.117 (0.744–1.679)	0.593
Time of pancreatic anastomosis (≥40 min)	0.579 (0.420–0.798)	0.001	0.712 (0.495–1.025)	0.068
Time of biliary anastomosis (>30 min)	0.655 (0.502–0.854)	0.002	0.764 (0.571–1.022)	0.070
Removal of NGT during operation	0.633 (0.484–0.827)	0.001	0.826 (0.582–1.174)	0.288
Estimated blood loss (≥400 ml)	0.748 (0.550–1.017)	0.064	0.855 (0.616–1.188)	0.351
Dilated pancreatic duct (>3 mm)	1.565 (1.200–2.042)	0.001	1.564 (1.189–2.058)	0.001
Texture of pancreas (soft)	0.804 (0.614–1.052)	0.112		
Pathological outcomes (malignant)	1.045 (0.772–1.413)	0.777		
Number of lymph nodes (>14)	1.306 (0.961–1.776)	0.088	1.301 (0.942–1.796)	0.110

ASA, American Society of Anesthesiologists; LPD, laparoscopic pancreaticoduodenectomy; NGT, nasogastric tube; OR, odds ratio; TBIL, total bilirubin.

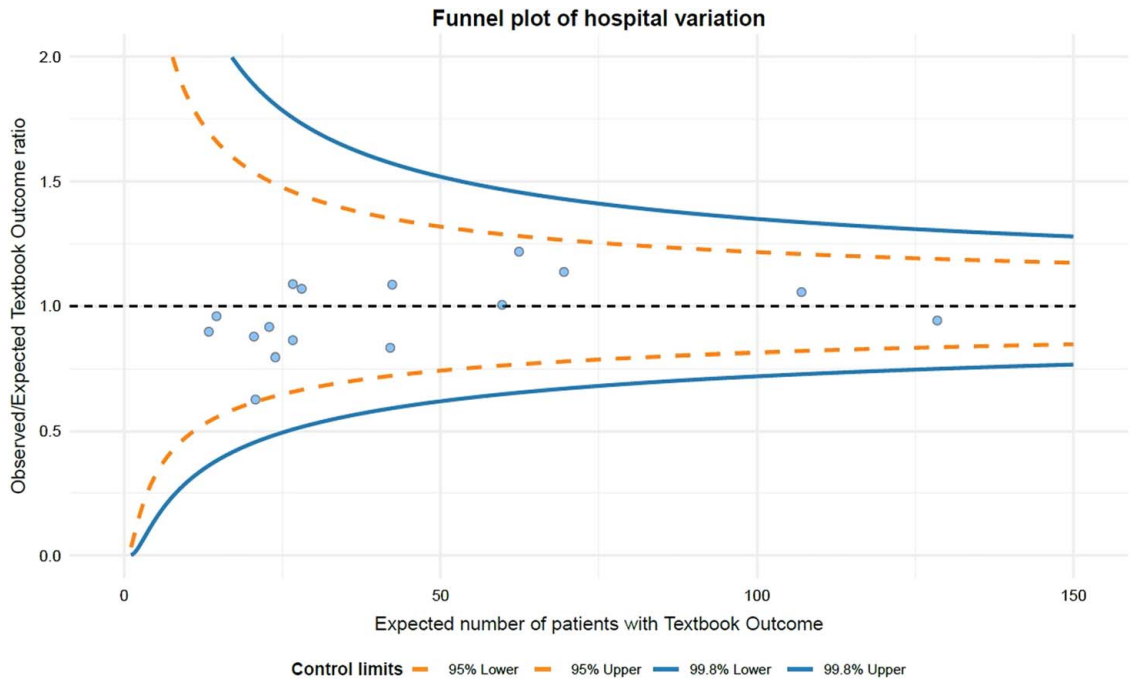

Figure 3. Funnel plot of hospital variations in observed/expected textbook outcome ratio.

patients following LPD compared with other outcome metrics. Patients without achieving TO had longer LOS compared with achieving TO. However, this TO definition in pancreatic surgery did not include the parameter: 'no prolonged LOS', which was included in other surgical procedures[11,13,22,38–41]. LOS is an important metric in the quality assessment of surgical procedures and closely related to postoperative complications[1,36,40]. When using the TO + definition by adding 'no prolonged LOS', the TO rates decreased significantly, and the main limiting outcome metric shifted from 'no Clavien–Dindo grade ≥ III complications' to 'no prolonged LOS'. These results indicated that the quality assessment of LPD was multidimensional, and the individual outcome parameter did not reflect the multiple facets of the whole surgical procedure. A composite outcome measure containing

Table 3

Hospital variations in expected textbook outcome rate after laparoscopic pancreaticoduodenectomy.

Variables	Mean Expected TO Rate (%)	*P* Value	Mean Observed TO Rate (%)	*P* Value	Observed/Expected TO Ratio	95% CI
Hospital volume (beds)		0.005		0.139		
< 2800 A, C	67.8	A: 0.047	61.8		0.91	0.79–1.03
2800–4000 A, B	69.7	B: 0.710	68.0		0.98	0.92–1.03
> 4000 B, C	71.3	C: 0.018	71.2		1.00	0.97–1.03
OPD volume (cases)		< 0.001		0.028		
< 200 D, F	66.2	D: 0.076	64.5	D: 0.120	0.97	0.91–1.03
200–1000 D, E	67.9	E: <0.001	69.4	E: 0.132	1.02	0.98–1.07
> 1000 E, F	76.1	F: <0.001	75.4	F: 0.008*	0.99	0.93–1.05
Minimally invasive surgery (cases)		< 0.001		0.142		
< 100 G, I	61.4	G: <0.001	69.6		1.13	1.06–1.20
100–500 G, H	68.7	H: 0.094	67.0		0.98	0.94–1.01
> 500 H, I	70.5	I: <0.001	74.0		1.05	0.98–1.12
Center volume (cases/year)		0.384		0.020		
< 20 J, L	69.1		63.0	J: 0.042	0.91	0.83–0.98
20–50 J, K	68.4		69.9	K: 0.212	1.02	0.99–1.06
> 50 K, L	69.5		74.7	L: 0.008*	1.08	1.01–1.15
Learning curve (cases)		0.003		0.017		
< 40 M, O	67.4	M: 0.022	61.7	M: 0.025	0.92	0.84–0.99
40–104 M, N	69.8	N: > 0.999	70.1	N: 0.490	1.00	0.96–1.05
> 104 N, O	70.3	O: 0.009	72.4	O: 0.006*	1.03	0.99–1.07

OPD, open pancreaticoduodenectomy; TO, Textbook outcome.

*Multiple comparison: $P < 0.0167$ was considered statistically significant.

multiple individual outcome metrics should be used to assess surgical quality.

Several factors were identified to be independently associated with achieving TO among patients undergoing LPD. On multivariate analysis, dilated pancreatic duct (> 3 mm) was predictive for achieving a better TO rate. Previous studies had demonstrated that small pancreatic duct diameter (< 3 mm) was strongly associated with POPF, which was the outcome parameter of TO in LPD[23,42–45]. Our result was consistent with finding in previous studies. This study showed that advanced age (≥ 75 years) and concomitant cardiovascular disease would decrease the probability of achieving TO after LPD. That was because elderly patients suffered more frequently from postoperative complications and mortality after pancreaticoduodenectomy compared with young patients[3,46–48]. Patients with cardiovascular disease had an increased risk of heart failure and major surgical complications following pancreaticoduodenectomy[49–53]. Elderly patients were more likely to suffer from cardiovascular disease, which was also found in this study. When selecting suitable patients for LPD, the identified factors may be taken into consideration to plan surgical strategies and adjust the interventions.

After case-mix adjustment, no significant hospital variations were observed, despite the O/E TO ratio varying from 0.62 to 1.22. The expected TO rates were higher in high-volume hospitals and medium-volume hospitals than low-volume hospitals. The expected TO rates increased with the accumulation of the surgeon's experience with MIS and the surgeon's experience with OPD. The expected TO rates were higher when surpassing the LPD learning curve. Previous studies had demonstrated that outcomes and complications after LPD strongly correlated to surgeon experience and hospital volume[54–60]. In order to achieve a better TO rate after LPD, the surgeon's experience with OPD and MIS is of vital importance. A step-by-step LPD training program will be conducive to helping surgeons surpass the learning curve while reducing postoperative complications and mortality[30,61–63].

The surgical outcomes of complex surgical procedures could vary widely among surgeons and hospitals[40]. As a composite measure of surgical quality, the TO can be used to analyze individual hospital performance and hospital variations. Through comparing the included parameters with hospitals with better performance, the individual hospital's quality of care may be improved. It is also convenient for patients to choose an appropriate hospital for treatment, as this composite measure (TO) is easy to interpret. It is required to improve the quality of LPD. Implementing the TO measure may facilitate such improvements in the short-term outcomes of LPD.

There are several limitations to this study. First, data are collected retrospectively, which could be subject to selection bias. Second, the long-term follow-up data are lacking. But TO is a composite outcome measure of multiple short-term outcome metrics and may be associated with long-term survival[39]. Third, there may be some differences in perioperative management strategies and patient selection for LPD.

Ethical approval

This research was waived by the Ethics Committee of Tongji Hospital and registered at ClinicalTrials.gov (Identifier: NCT05616403).

Sources of funding

This study was supported by grants from the National Natural Science Foundation of China (82273442, 82073249 and 81874205 to RQ; 81773160 to MW), Tongji Hospital Clinical Research Flagship Program (2019CR203 to RQ), Hubei Natural Science Foundation (WJ2017Z010 to RQ; 2017CFB467 to MW), National Key Research and Development Program of China (2019TFC1315905 to RQ), and Tongji Hospital Science Fund for Distinguished Young Scholars (2017).

Author contribution

Y.W., B.P., J.L., X.Y., Z.T., R.L., D.H., W.Z., H.W., R.C., D.L., H.H., Y.M., Y.L., T.L., and W.W. participated in data collection, analysis, interpretation, and drafting of the manuscript. Y.W., B.P., J.L., X.Y., Z.T., R.L., D.H., W.Z., H.W., R.C., D.L., H.H., Y.M., Y.L., T.L., H.Z, M.W., and R.Q. contributed equally. J.Y. and S.L. participated in data collection and the statistical analysis. H.Z., M.W., and R.Q. were involved in the conception, design, critical revision of the manuscript, and supervision and obtained funding. All authors approved the submitted version of the manuscript.

Acknowledgements

The authors wish to thank Prof Miao Yi for his help to this study.

Conflicts of interest disclosure

The authors have no conflicts of interest to declare.

Research registration unique identifying number (UIN)

1. Name of the registry: ClinicalTrials.
2. Unique Identifying number or registration ID: NCT05616403.
3. Hyperlink to your specific registration (must be publicly accessible and will be checked): https://clinicaltrials.gov/ct2/show/NCT05616403

Guarantor

Renyi Qin.

Data availability statement

The data underlying this article will be shared on reasonable request to the corresponding author (Renyi Qin). E-mail: ryqin@tjh.tjmu.edu.cn

Provenance and peer review

Not commissioned, externally peer-reviewed.

References

[1] Wang M, Li D, Chen R, *et al*. Laparoscopic versus open pancreatoduodenectomy for pancreatic or periampullary tumours: a multicentre, open-

label, randomised controlled trial. Lancet Gastroenterol Hepatol 2021;6:438–47.
[2] Klompmaker S, van Hilst J, Wellner UF, *et al*. Outcomes after minimally-invasive versus open pancreatoduodenectomy: a pan-European propensity score matched study. Ann Surg 2020;271:356–63.
[3] Lof S, Vissers FL, Klompmaker S, *et al*. Risk of conversion to open surgery during robotic and laparoscopic pancreatoduodenectomy and effect on outcomes: international propensity score-matched comparison study. Br J Surg 2021;108:80–7.
[4] van Hilst J, de Graaf N, Festen S, *et al*. Laparoscopic versus open pancreatoduodenectomy for pancreatic or peri-ampullary tumours. Lancet Gastroenterol Hepatol 2021;6:688–9.
[5] Torphy RJ, Friedman C, Halpern A, *et al*. Comparing short-term and oncologic outcomes of minimally invasive versus open pancreaticoduodenectomy across low and high volume centers. Ann Surg 2019;270:1147–55.
[6] Vollmer CM Jr, Lewis RS, Hall BL, *et al*. Establishing a quantitative benchmark for morbidity in pancreatoduodenectomy using ACS-NSQIP, the Accordion Severity Grading System, and the Postoperative Morbidity Index. Ann Surg 2015;261:527–36.
[7] Pitt HA. Benchmark, textbook or optimal pancreatic surgery? Ann Surg 2019;270:219–20.
[8] Tsai TC, Joynt KE, Orav EJ, *et al*. Variation in surgical-readmission rates and quality of hospital care. N Engl J Med 2013;369:1134–42.
[9] Lassen K, Nymo LS, Olsen F, *et al*. Benchmarking of aggregated length of stay after open and laparoscopic surgery for cancers of the digestive system. BJS Open 2018;2:246–53.
[10] Merath K, Chen Q, Bagante F, *et al*. Textbook outcomes among medicare patients undergoing hepatopancreatic surgery. Ann Surg 2020;271:1116–23.
[11] Oesophago-Gastric Anastomotic Audit (OGAA) Collaborative. Textbook outcome following oesophagectomy for cancer: international cohort study. Br J Surg 2022;109:439–49.
[12] Elfrink AKE, van Zwet EW, Swijnenburg RJ, *et al*. Case-mix adjustment to compare nationwide hospital performances after resection of colorectal liver metastases. Eur J Surg Oncol 2021;47(pt B):649–59.
[13] Karthaus EG, Lijftogt N, Busweiler LAD, *et al*. Textbook outcome: a composite measure for quality of elective aneurysm surgery. Ann Surg 2017;266:898–904.
[14] de Graaff MR, Elfrink AKE, Buis CI, *et al*. Defining textbook outcome in liver surgery and assessment of hospital variation: a nationwide population-based study. Eur J Surg Oncol 2022;48:2414–23.
[15] Koh CY, Inaba CS, Sujatha-Bhaskar S, *et al*. Association of Centers for Medicare & Medicaid Services Overall Hospital Quality Star Rating With Outcomes in Advanced Laparoscopic Abdominal Surgery. JAMA Surg 2017;152:1113–7.
[16] Dimick JB, Birkmeyer NJ, Finks JF, *et al*. Composite measures for profiling hospitals on bariatric surgery performance. JAMA Surg 2014;149:10–6.
[17] Dimick JB, Staiger DO, Baser O, *et al*. Composite measures for predicting surgical mortality in the hospital. Health Aff (Millwood) 2009;28:1189–98.
[18] Dimick JB, Staiger DO, Osborne NH, *et al*. Composite measures for rating hospital quality with major surgery. Health Serv Res 2012;47:1861–79.
[19] O'Brien SM, Shahian DM, DeLong ER, *et al*. Quality measurement in adult cardiac surgery: part 2—Statistical considerations in composite measure scoring and provider rating. Ann Thorac Surg 2007;83(suppl):S13–26.
[20] Merkow RP, Hall BL, Cohen ME, *et al*. Validity and feasibility of the american college of surgeons colectomy composite outcome quality measure. Ann Surg 2013;257:483–9.
[21] Shwartz M, Restuccia JD, Rosen AK. Composite measures of health care provider performance: a description of approaches. Milbank Q 2015;93:788–825.
[22] Kolfschoten NE, Kievit J, Gooiker GA, *et al*. Focusing on desired outcomes of care after colon cancer resections; hospital variations in 'textbook outcome'. Eur J Surg Oncol 2013;39:156–63.
[23] van Roessel S, Mackay TM, van Dieren S, *et al*. Textbook outcome: nationwide analysis of a novel quality measure in pancreatic surgery. Ann Surg 2020;271:155–62.
[24] Sweigert PJ, Wang X, Eguia E, *et al*. Does minimally invasive pancreaticoduodenectomy increase the chance of a textbook oncologic outcome? Surgery 2021;170:880–8.
[25] Lof S, Benedetti Cacciaguerra A, Aljarrah R, *et al*. Implementation of enhanced recovery after surgery for pancreatoduodenectomy increases the proportion of patients achieving textbook outcome: a retrospective cohort study. Pancreatology 2020;20:976–83.
[26] Kulshrestha S, Sweigert PJ, Tonelli C, *et al*. Textbook oncologic outcome in pancreaticoduodenectomy: do regionalization efforts make sense? J Surg Oncol 2022;125:414–24.
[27] Nicholas E, van Roessel S, de Burlet K, *et al*. Using textbook outcomes to benchmark practice in pancreatic surgery. ANZ J Surg 2021;91:361–6.
[28] Sweigert PJ, Eguia E, Baker MS, *et al*. Assessment of textbook oncologic outcomes following pancreaticoduodenectomy for pancreatic adenocarcinoma. J Surg Oncol 2020;121:936–44.
[29] Heidsma CM, Hyer M, Tsilimigras DI, *et al*. Incidence and impact of textbook outcome among patients undergoing resection of pancreatic neuroendocrine tumors: results of the US Neuroendocrine Tumor Study Group. J Surg Oncol 2020;121:1201–8.
[30] Wang M, Peng B, Liu J, *et al*. Practice patterns and perioperative outcomes of laparoscopic pancreaticoduodenectomy in China: a retrospective multicenter analysis of 1029 patients. Ann Surg 2021;273:145–53.
[31] Agha R, Abdall-Razak A, Crossley E, *et al*. STROCSS 2019 Guideline: strengthening the reporting of cohort studies in surgery. Int J Surg 2019;72:156–65.
[32] Clavien PA, Barkun J, de Oliveira ML, *et al*. The Clavien-Dindo classification of surgical complications: five-year experience. Ann Surg 2009;250:187–96.
[33] Bassi C, Marchegiani G, Dervenis C, *et al*. The 2016 update of the International Study Group (ISGPS) definition and grading of postoperative pancreatic fistula: 11 years after. Surgery 2017;161:584–91.
[34] Wente MN, Veit JA, Bassi C, *et al*. Postpancreatectomy hemorrhage (PPH): an International Study Group of Pancreatic Surgery (ISGPS) definition. Surgery 2007;142:20–5.
[35] Koch M, Garden OJ, Padbury R, *et al*. Bile leakage after hepatobiliary and pancreatic surgery: a definition and grading of severity by the International Study Group of Liver Surgery. Surgery 2011;149:680–8.
[36] Görgec B, Benedetti Cacciaguerra A, Lanari J, *et al*. Assessment of textbook outcome in laparoscopic and open liver surgery. JAMA Surg 2021;156:e212064.
[37] Kolfschoten NE, Marang van de Mheen PJ, Gooiker GA, *et al*. Variation in case-mix between hospitals treating colorectal cancer patients in the Netherlands. Eur J Surg Oncol 2011;37:956–63.
[38] Busweiler LA, Schouwenburg MG, van Berge Henegouwen MI, *et al*. Textbook outcome as a composite measure in oesophagogastric cancer surgery. Br J Surg 2017;104:742–50.
[39] van der Kaaij RT, de Rooij MV, van Coevorden F, *et al*. Using textbook outcome as a measure of quality of care in oesophagogastric cancer surgery. Br J Surg 2018;105:561–9.
[40] Merath K, Chen Q, Bagante F, *et al*. A Multi-institutional international analysis of textbook outcomes among patients undergoing curative-intent resection of intrahepatic cholangiocarcinoma. JAMA Surg 2019;154:e190571.
[41] Halpern SE, Moris D, Gloria JN, *et al*. Textbook outcome: definition and analysis of a novel quality measure in lung transplantation. Ann Surg 2023;277:350–7.
[42] Mungroop TH, van Rijssen LB, van Klaveren D, *et al*. Alternative fistula risk score for pancreatoduodenectomy (a-FRS): design and international external validation. Ann Surg 2019;269:937–43.
[43] Endo Y, Kitago M, Shinoda M, *et al*. Clinical impact of portal vein distance on computed tomography for postoperative pancreatic fistula after pancreatoduodenectomy. World J Surg 2021;45:2200–9.
[44] Sugimoto M, Takahashi S, Kojima M, *et al*. In patients with a soft pancreas, a thick parenchyma, a small duct, and fatty infiltration are significant risks for pancreatic fistula after pancreaticoduodenectomy. J Gastrointest Surg 2017;21:846–54.
[45] Shi Y, Gao F, Qi Y, *et al*. Computed tomography-adjusted fistula risk score for predicting clinically relevant postoperative pancreatic fistula after pancreatoduodenectomy: training and external validation of model upgrade. EBioMedicine 2020;62:103096.
[46] Sukharamwala P, Thoens J, Szuchmacher M, *et al*. Advanced age is a risk factor for post-operative complications and mortality after a pancreaticoduodenectomy: a meta-analysis and systematic review. HPB (Oxford) 2012;14:649–57.

[47] Gleeson EM, Pitt HA, Mackay TM, *et al*. Failure to rescue after pancreatoduodenectomy: a transatlantic analysis. Ann Surg 2021;274:459–66.
[48] Al Abbas AI, Borrebach JD, Pitt HA, *et al*. Development of a novel pancreatoduodenectomy-specific risk calculator: an analysis of 10,000 patients. J Gastrointest Surg 2021;25:1503–11.
[49] Wiltberger G, Muhl B, Benzing C, *et al*. Pancreaticoduodenectomy in the elderly patient: age-adapted risk assessment. Dig Surg 2017;34:43–51.
[50] Khatkov IE, Izrailov RE, Khisamov AA, *et al*. Superior mesenteric-portal vein resection during laparoscopic pancreatoduodenectomy. Surg Endosc 2017;31:1488–95.
[51] Liu R, Cai Y, Cai H, *et al*. Dynamic prediction for clinically relevant pancreatic fistula: a novel prediction model for laparoscopic pancreaticoduodenectomy. BMC Surg 2021;21:7.
[52] Wang Q, Chen C, Li H. Laparoscopic pancreaticoduodenectomy in elderly patients: systematic review and meta-analysis. Front Surg 2022;9::807940.
[53] Jeon HJ, Kwon HJ, Hwang YJ, *et al*. Unfavorable effect of high postoperative fluid balance on outcome of pancreaticoduodenectomy. Ann Surg Treat Res 2022;102:139–46.
[54] Tran TB, Dua MM, Worhunsky DJ, *et al*. The first decade of laparoscopic pancreaticoduodenectomy in the United States: costs and outcomes using the nationwide inpatient sample. Surg Endosc 2016;30:1778–83.
[55] Katsuki R, Jo T, Yasunaga H, *et al*. Outcomes of laparoscopic versus open pancreatoduodenectomy: a nationwide retrospective cohort study. Surgery 2021;169:1427–33.
[56] van Hilst J, de Graaf N, Abu Hilal M, *et al*. The landmark series: minimally invasive pancreatic resection. Ann Surg Oncol 2021;28:1447–56.
[57] Tyutyunnik P, Klompmaker S, Lombardo C, *et al*. Learning curve of three European centers in laparoscopic, hybrid laparoscopic, and robotic pancreatoduodenectomy. Surg Endosc 2022;36:1515–26.
[58] Moekotte AL, Rawashdeh A, Asbun HJ, *et al*. Safe implementation of minimally invasive pancreas resection: a systematic review. HPB (Oxford) 2020;22:637–48.
[59] de Rooij T, van Hilst J, Topal B, *et al*. Outcomes of a Multicenter Training Program in Laparoscopic Pancreatoduodenectomy (LAELAPS-2). Ann Surg 2019;269:344–50.
[60] Adam MA, Thomas S, Youngwirth L, *et al*. Defining a hospital volume threshold for minimally invasive pancreaticoduodenectomy in the United States. JAMA Surg 2017;152:336–42.
[61] Morató O, Poves I, Burdío F, *et al*. Evaluation of the learning curve for laparoscopic pancreatoduodenectomy by CUSUM analyses. Cohort study. Int J Surg 2020;80:61–7.
[62] Asbun HJ, Moekotte AL, Vissers FL, *et al*. The Miami international evidence-based guidelines on minimally invasive pancreas resection. Ann Surg 2020;271:1–14.
[63] Dokmak S, Aussilhou B, Ftériche FS, *et al*. The outcome of laparoscopic pancreatoduodenectomy is improved with patient selection and the learning curve. Surg Endosc 2022;36:2070–80.