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RESEARCH

Achievement of benchmark outcomes by a young surgical attendant performing pancreatoduodenectomies

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Abstract

Purpose Pancreatoduodenectomy is a challenging procedure for young general surgeons, and no benchmark outcomes are currently available for young surgeons who have independently performed pancreatoduodenectomies after completing resident training. This study aimed to identify the competency of a young surgeon in performing pancreatoduodenectomies, while ensuring patient safety, from the first case following certification by a General Surgical Board.

Methods A retrospective review of data from the university hospital was performed to assess quality outcomes of a young surgical attendant who performed 150 open pancreatoduodenectomies between July 13, 2006, and July 13, 2020. Primary benchmark outcomes were hospital morbidity, mortality, postoperative pancreatic fistula, postoperative hospital stay, and disease-free survival.

Results All benchmark outcomes were achieved by the young surgeon. The 90-day mortality rate was 2.7%, and one patient expired in the hospital (0.7% in-hospital mortality). The overall morbidity rate was 34.7%. Postoperative pancreatic fistula grades B and C were observed in 5.3% and 0% of patients, respectively. The median postoperative hospital stay was 14 days. The 1- and 3-year disease-free survival were 71.3% and 51.4%, respectively.

Conclusion Pancreatoduodenectomy requires good standards of care as it is associated with high morbidity and mortality. As only one surgeon could be included in this study, our benchmark outcomes must be compared with those of other institutions.

Clinical trial registration The study was registered at Thai Clinical Trials Registry and approved by the United Nations (registration identification TCTR20220714002).

Keywords Benchmark outcomes · Young surgeon · Pancreatoduodenectomy · Competency

Introduction

Pancreatoduodenectomy (PD) was first reported in 1898 by an Italian surgeon [1]. The classic PD was popularized and named the Whipple operation, for the American surgeon [2]. Initial outcomes were limited due to high mortality rates. After the technique was modified to be pylorus-preserving, the overall morbidity and mortality outcomes were improved over time by experienced surgeons at high-volume centers [3–7]. The mortality rate has been decreasing and is accepted at 5%, whereas the morbidity rate ranges between 41 and 52% [8, 9]. Surgeon and patient factors affect the surgical outcomes [10–13].

Patient safety and individual competency of the surgeon are significant concerns for global health care and are continuously investigated [14]. Surgical experience is a critical factor for improving surgical outcomes [15]. A number of factors contribute to surgical experience, such as training programs, technical skills, leaning curve, hospital facility, supporting system, and health care policy. The main objectives of residency training are to improve doctors' ability to provide quality patient care, conduct research, and improve global health care. Inadequate expertise in hospitals involving patient care and coaching of young surgical attendants is a global health care problem. In the past, young surgical attendants were required to practice independently and without mentoring. These conditions created work-related stress, which affected decision-making and patient safety. We hypothesized that the competency of a young surgical

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attendant in performing complex abdominal surgery would be comparable with standard outcomes. We observed that no benchmark outcomes, for independently performed PDs, were available for young surgical attendants who become members of the general surgical staff after completing resident training.

Thus, this study aimed to develop and validate a novel benchmark to qualitatively assess the outcomes of PDs performed by a young surgical attendant.

Materials and methods

Database and surgeon selection

A retrospective study was performed to review data of 150 patients who underwent successful open PDs between July 13, 2006, and July 13, 2020, by a young surgical attendant at the academic university hospital.

Morbidity and mortality were reviewed 90 days after surgery. The final date for following up the data for statistical analysis was August 31, 2022. This study evaluated the work of a young surgical attendant, who was defined as a member of the general surgical staff following certification by the General Surgical Board, who performed their first PD within 3 months of certification and subsequently performed consecutive PDs for over 10 years. During the study period, our institution had 11 new young general surgical attendants. Four of them were interested in performing hepatobiliary and pancreatic surgeries; of these young surgical attendants, one had an experience of more than 10 years performing PDs and the remaining three had < 10 years' experience. The young surgeons' experience was divided into three phases: the initial 5 years, between 5 and 10 years, and after 10 years. A year of experience comprised all 365 working days, and the first year of experience was considered as the period from July 13, 2006, to July 12, 2007. Patient survival and cause of death were confirmed by the Bureau of Registration Administration, Thailand.

This study was approved by the Faculty of Medicine medical ethical committees (REC.63–338-10–1). The study was registered at Thai Clinical Trials Registry (registration identification TCTR20220714002). The requirement for informed consent was waived owing to the retrospective nature of the study.

Variables and definition

Heart disease included ischemic heart disease (history of or currently on treatment). Coagulopathy was defined as a prothrombin time value greater than the normal upper limit (4 s), an activated partial thromboplastin time value greater than the normal upper limit (10 s), conditions associated with bleeding disorders due to underlying disease, and current medication use (continuous use of antiplatelets or anticoagulants). Surgical waiting time was the duration from the first patient visit to the operation date. Blood loss (mL) was estimated through visualization by the anesthesiologist. The operative time (min) was recorded from the first incision until the patient was transported to the recovery room. Postoperative complications included postoperative pancreatic fistula (POPF) [16, 17], delayed gastric emptying (DGE) [18], chyle leak [19], and surgical site infections (SSI) [20]. The primary tumor was identified, and its size was recorded by a pathologist. Complex PD was defined as radical en bloc PD with adjacent organ resection or PD plus other intra-abdominal procedures. A high-risk patient was assessed as an American Society of Anesthesiologists (ASA) class ≥ III.

Benchmark outcomes

We identified and used 20 benchmark outcomes (15 metrics from previous publications and five new metrics from the literature review) to evaluate the quality of a young surgical attendant who performed PDs. Due to heterogeneity, metrics were developed from previous publications [21–26]; we selected and merged metric cut-off points based on the outcomes of our own metrics. The aim of the adjusted metrics was to reduce variations in their development and enable easy use for high- and low-volume centers. Metrics developed from previous publications were time from surgeon visit to surgery < 21 days, operation duration ≤ 450 min, hospital morbidity (patient had at least one complication, graded as per the Clavien–Dindo Classification) ≤ 73% [27], POPF grade B ≤ 15% and grade C ≤ 5%, biliary fistula < 14%, severe postoperative bleeding < 7%, reoperation < 20%, postoperative hospital stay (POHS) ≤ 15 days, readmission rate ≤ 21%, positive margin resection < 10%, in-hospital mortality ≤ 1.6%, 90-day mortality ≤ 5%, and 1- and 3-year disease-free survival (DFS) ≥ 53% and ≥ 9%, respectively. The five new metrics we used included blood loss ≤ 500 mL, SSI ≤ 25%, DGE ≤ 30%, chyle leakage ≤ 15%, and 5-year overall survival ≥ 14%.

Statistical analysis

Continuous variables with a normal distribution are expressed as mean ± standard deviation (SD) and were analyzed using the ANOVA F-test (or Student's t-test). Data with a non-normal distribution are expressed as median and interquartile range (IQR) and were analyzed using the Kruskal–Wallis test. Categorical variables are described using frequency distributions (%) and were compared using a Chi-squared test (or Fisher's exact test). Logistic regression analyses were performed to determine the association of the potential risk factors with the primary outcome variables and to estimate adjusted odds ratios and their 95% confidence intervals. *P*-values of < 0.05 were considered statistically significant. The learning curve was calculated based on the cumulative sum (CUSUM) analysis. The CUSUM chart plots the cumulative sums of deviations in each direction (positive and negative) of the sample values from a target value. The upper and lower CUSUMs called the reference values (normally indicated by K). K is often set to half the shift to be detected, in sigma units. All statistical analyses were performed using R software version 4.1.1 (R Foundation for Statistical Computing, Vienna, Austria).

Results

General database

A total of 150 PDs were performed by the young surgical attendant. Most patients were classified as ASA class II (68.7%; 103/150) or class III (30%; 45/150); the sex ratio was 1:1. The proportion of patients with at least one comorbidity was 53.3% (80/150). The median body mass index (BMI) was 21.5 (IQR, 19.1–24.6; range, 14.2–41.7) kg/m^2. Among the patients, 19.3% (29/150), 19.3% (29/150), and 4% (6/150) were underweight, overweight, and obese, respectively. High-risk patients were significantly older and had more comorbidities than low-risk patients (Table 1).

Preoperative management

Endoscopic retrograde cholangiopancreatography was performed in 55.3% (83/150) of patients, and its use has decreased over the last 10 years from 68.3% to 39.5% (*P* = 0.002) (Table 2). The rate of preoperative biliary drainage with internal stent placement was 41.3% (62/150), and its use has decreased over the last 10 years from 53.7% to 26.6% (*P* = 0.003). Preoperative percutaneous transhepatic biliary drainage was performed in only 2% of patients (3/150). The median surgical waiting time was 19 (IQR, 10–32) days.

Operative data

Pylorus-preserving PD (PPPD) was the routine operation for PD. Conventional PD (CPD) was performed in 10% of patients (15/150). Complex PD, which has significantly

Table 1 Pre- and postoperative data comparing high- and low-risk patients

Variables	Total (*n* = 150)	Low risk (*n* = 105)	High risk (*n* = 45)	*P* value
Age, mean (SD)	59.9 (13.3)	57.3 (13.3)	65.9 (11.2)	< 0.001
Heart disease, n (%)	21 (14.0)	8 (7.6)	13 (28.9)	0.001
Coagulopathy, n (%)	26 (17.3)	8 (7.6)	18 (40.0)	< 0.001
Prolonged PT, n (%)	8 (5.3)	3 (2.9)	5 (11.1)	0.053
PPPD, n (%)	135 (90.0)	93 (88.6)	42 (93.3)	0.554
CPD, n (%)	15 (10.0)	12 (11.4)	3 (6.7)	0.554
Complex PD, n (%)	23 (15.3)	17 (16.2)	6 (13.3)	0.675
Vein resection, n (%)	7 (4.7)	6 (5.7)	1 (2.2)	0.675
ICU monitoring, n (%)	65 (43.3)	40 (38.1)	25 (55.6)	0.072

PT prothrombin time, *PPPD* pylorus-preserving pancreatoduodenectomy, *CPD* classic pancreatoduodenectomy, *PD* pancreatoduodenectomy, *ICU* intensive care unit

Table 2 Pre- and post-operative data comparing the level of experience

Variables	Total (*n* = 150)	Initial 5 years (*n* = 82)	5–10 years (*n* = 43)	After 10^{th} year (*n* = 25)	*P* value
ERCP, n (%)	83 (55.3)	56 (68.3)	17 (39.5)	10 (40.0)	0.002
Biliary stent, n (%)	62 (41.3)	44 (53.7)	11 (25.6)	7 (28.0)	0.003
PPPD, n (%)	135 (90.0)	75 (91.5)	40 (93.0)	20 (80.0)	0.230
CPD, n (%)	15 (10.0)	7 (8.5)	3 (7.0)	5 (20.0)	0.230
Complex PD, n (%)	23 (15.3)	7 (8.5)	10 (23.3)	6 (24.0)	0.040
Vein resection, n (%)	7 (4.7)	2 (2.4)	5 (11.6)	0 (0)	0.055
Operative time, median (IQR)	302.5 (265, 370)	345 (295, 427.5)	270 (245, 305)	280 (260, 315)	< 0.001
Blood loss, median (IQR)	425 (300, 700)	450 (300, 800)	500 (225, 650)	350 (250, 600)	0.320

ERCP endoscopic retrograde cholangiopancreatography, *PPPD* pylorus-preserving pancreaticoduodenectomy, *CPD* classic pancreaticoduodenectomy, *PD* pancreaticoduodenectomy, *IQR* interquartile range increased in the last 10 years ($P = 0.040$) (Table 2), was performed in 15.3% of patients (23/150). Additional surgical procedures included wedge liver resections (10/150), colectomies (6/150), abdominal wall resections (3/150), wedge resection gastric tumors (2/150), gynecologic procedures (2/150), and jejunal resection with extended lymph node dissection (1/150). Complex PD was performed with PPPD in 76% (19/25) of patients. Major venous resection was performed in 4.7% (7/150) of patients.

The median operative time was 302.5 (IQR, 265–370) min. The mean PPPD operative time was 324.5 ± 90.5 min, which significantly differed ($P = 0.007$) from that of CPD (397.7 ± 156 min). The prolonged operative time was significant when associated with BMI ≥ 30 kg/m^2 ($P = 0.018$), CPD ($P = 0.007$), and blood loss ($P < 0.001$). The median blood loss was 425 (IQR, 300–700) mL.

Pathological reports

The pathology of PD specimens included adenocarcinoma of the ampulla (44.0%; 66/150), pancreas (16.0%; 24/150), bile duct (6.0%; 9/150), and duodenum (4.7%; 7/150); other malignancies (13.3%; 20/150); benign tumors (11.3%; 17/150); pancreatic neuroendocrine tumors (6.0%; 9/150); and chronic pancreatitis (2.0%; 3/150). There were 9.3% (14/150) specimens with positive resection margins.

Hospital course and morbidity

Postoperative intensive care unit (ICU) admission was requested in 43.3% (65/150) of cases and significantly reduced after the beginner stage ($P < 0.001$). Morbidity occurred in 34.7% (52/150) of cases; the overall morbidity rate did not differ significantly among the three levels of experience (Table 3). Common morbidities included SSI (18%; 27/150), DGE (10%; 15/150), POPF grade B (5.35%; 8/150), chyle leakage (4.0%; 6/150), bleeding (2.7%; 4/150), reoperation (2.7%; 4/150), bile leakage (2.0%; 3/150), and POPF grade C (0%; 0/150). The causes of reoperation included complicated SSI in two patients, bleeding, and bile leakage. The median postoperative hospital stay was 14 (IQR, 10–20.8) days and has significantly decreased over the 10 years of experience ($P = 0.041$). The readmission rate was 2.7% (4/150).

The 90-day mortality and survival

The 90-day mortality was 2.7% (4/150), and one patient (0.7%) expired in the hospital from acute myocardial infarction. The 1- and 3-year DFS were 71.3% (107/150) and 51.4% (73/150), respectively. The overall 5-year overall survival rate was 47.1% (65/138). Pancreatic cancer was the worst prognostic outcome (Table 4).

Benchmark outcomes

Overall benchmark outcomes of 150 PDs were achieved by a young surgical attendant (Table 5). No significant differences were observed in the metrics between high- and low-risk patients. In 46% of the cases, the waiting time for surgery was > 21 days; most of the patients had a waiting time of < 60 days. Operative time more than 450 min was encountered in 14.7% cases, and blood loss more than 500 mL was encountered in 38.7% cases. The morbidity rate was consistently stable at less than 30% after 60 cases of PD (Fig. 1). The operative time and blood loss decreased after the second year of experience. The CUSUM charts showing the waiting time for surgery, operative time, blood loss, and POHS

Table 3 Surgical outcomes of pancreatoduodenectomies by the number of years of experience of a young surgeon

Variables	Total (*n* = 150)	Initial 5 years (*n* = 82)	5–10 years (*n* = 43)	After 10th year (*n* = 25)	P value
Postoperative ICU, n (%)	65 (43.3)	50 (61.0)	13 (30.2)	2 (8.0)	< 0.001
Morbidity, n (%)	52 (34.7)	29 (35.4)	12 (27.9)	11 (44.0)	0.397
Surgical site infection, n (%)	27 (18.0)	20 (24.4)	3 (7.0)	4 (16.0)	0.053
Delay gastric emptying, n (%)	15 (10.0)	6 (7.3)	5 (11.6)	4 (16.0)	0.340
Percutaneous drainage, n (%)	11(7.3)	8 (9.8)	1 (2.3)	2 (8.0)	0.327
Pancreatic fistula grade B, n (%)	8 (5.3)	6 (7.3)	1 (2.3)	1 (4)	0.690
Chyle leakage, n (%)	6 (4.0)	1 (1.2)	2 (4.7)	3 (12.0)	0.031
Reoperation, n (%)	4 (2.7)	3 (3.7)	0 (0)	1 (4.0)	0.488
Readmission, n (%)	4 (2.7)	2 (2.4)	2 (4.7)	0 (0)	0.636
Bleeding, n (%)	4 (2.7)	2 (2.4)	1 (2.3)	1 (4.0)	0.812
Bile leakage, n (%)	3 (2.0)	3 (3.7)	0 (0)	0 (0)	0.741
POHS, median (IQR)	14 (10.0, 20.8)	13 (10, 19)	16 (12.5, 23.5)	11 (9, 20)	0.041

ICU intensive care unit, *POHS* postoperative hospital stays, *IQR* interquartile range

Table 4 Distribution survival by pathology report

Disease	Total (*n* = 138)	Survival < 5 years (*n* = 73)	Survival > 5 years (*n* = 65)	*P* value
Ampulla cancer, n (%)	62 (44.93)	33 (45.21)	29 (44.62)	1
Bile duct cancer, n (%)	8 (5.8)	7 (9.59)	1 (1.54)	0.066
Duodenal cancer, n (%)	6 (4.35)	1 (1.37)	5 (7.69)	0.099
Pancreatic cancer, n (%)	21 (15.22)	19 (26.03)	2 (3.08)	< 0.001
Neuroendocrine tumor, n (%)	7 (5.07)	2 (2.74)	5 (7.69)	0.253
Other cancer, n (%)	20 (14.49)	9 (12.33)	11 (16.29)	0.600
Chronic pancreatitis, n (%)	3 (2.17)	1 (1.37)	2 (3.08)	0.601
Benign conditions, n (%)	18 (13.04)	4 (5.48)	14 (21.54)	0.011

Table 5 Pancreatoduodenectomy benchmark outcomes of a young surgical attendant

Metrics and cut-off points	Outcomes (*n* = 150)
Time from surgeon visit to surgery < 21 days	19 days
Operative duration ≤ 450 min	302.5 min
Blood loss ≤ 500 mL	425 mL
Hospital morbidity ≤ 73%	34.7%
POPF grade B ≤ 15%	5.3%
POPF grade C ≤ 5%,	0%
Biliary fistula < 14%	2%
Delayed gastric emptying ≤ 30%	10%
Severe postoperative bleeding < 7%	2.7%
Chyle leakage ≤ 15%	4%
Surgical site infection ≤ 25%	18%
Reoperation < 20%	2.7%
POHS ≤ 15 days	14 days
Readmission rate < 21%	2.7%
Positive margin resection < 10%	9.3%
In-hospital mortality ≤ 1.6%	0.7%
90-day mortality ≤ 5%	2.7%
DFS at 1-year ≥ 53%	71.3%
DFS at 3-year ≥ 9%	51.4%
5-year overall survival ≥ 14%	47.1%

POPF postoperative pancreatic fistula, *POHS* postoperative hospital stays, *DFS* disease-free survival

are illustrated in Fig. 2. Only the operative time showed a decreasing trend over the study period. A total of 47 PDs were required to overcome the lower limit of the learning curve in terms of operative time. The POHS and blood loss exhibited an initial increasing trend and resumed the target values after 34 and 53 procedures, respectively.

Discussion

Our study showed that all benchmark outcomes for PD were achieved by a young surgical attendant. No significant differences were observed between high- and low-risk patient groups for all included metrics. The pancreatic cancer group had the worst prognostic outcome. Therefore, this group had a significantly poor 5-year survival. The overall morbidity and mortality were not significantly different among the year of experience of the surgeon. The operative time was directly related to the blood loss; both decreased over time as the surgeon's competency, experience, and familiarity with surgical anatomy increased. Additionally, overnight postoperative observation in ICU was not necessary after 5th year of experience, and postoperative care was no longer routinely requested. The overall morbidity rate stabilized and remained unchanged, even after the surgeon had attained adequate skills in performing PD. Contrastingly, POHS decreased over time to less than 7 days due to minor morbidity in PD. Although 90% of the cases were PPPD, the most common morbidity was SSI due to low incidence of POPF and intra-abdominal collection.

PD is one of the most challenging abdominal procedures for a general surgeon. For over 50 years, the PD mortality rate has decreased to < 5%; however, the morbidity rate has remained stable at 40–45% [13, 28]. Benchmark outcome is an effective tool for assessing quality of treatment and can improve practices. To our knowledge, there are no benchmark outcomes for evaluating the competency of a young surgeon to perform PD. We identified and used 20 metrics to assess the quality outcomes of our young surgical attendant in performing PD. The first 15 were selected from previous publications, and we added five new metrics from the literature review. Previous publication benchmarks for pancreatic surgery were developed using observational methods such as a survey of the experts, Delphi consensus process, and best in class analysis [21–26]. There is no international consensus for previous metrics, which require further validation [29]. Based on the literature review, we used the term "time from surgeon visit to surgery" instead of "time from

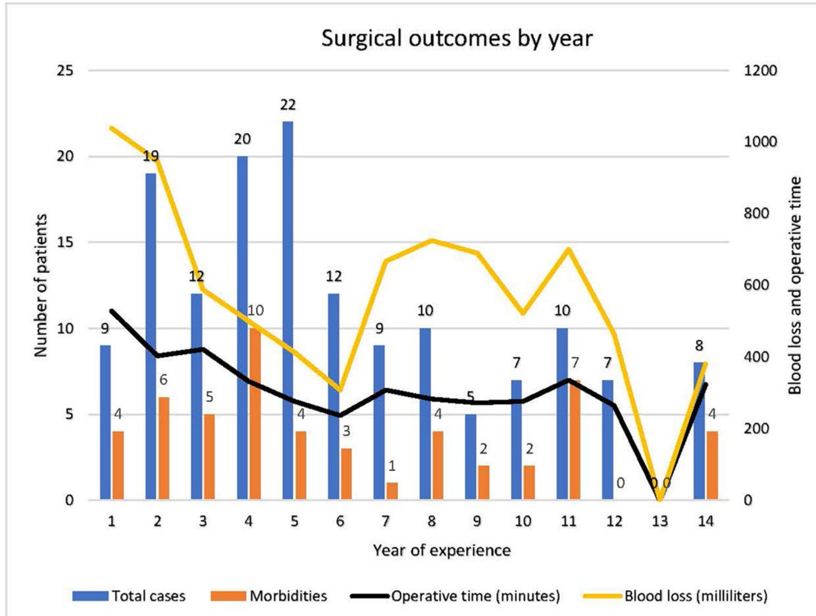

Fig. 1 Surgical outcomes of pancreatoduodenectomies according to the number of years of experience of the surgeon. Operative time and blood loss illustrate a decreasing trend after the 2nd year of experience. Morbidity rate revealed a decreasing trend that stabilized after the 4th year of experience

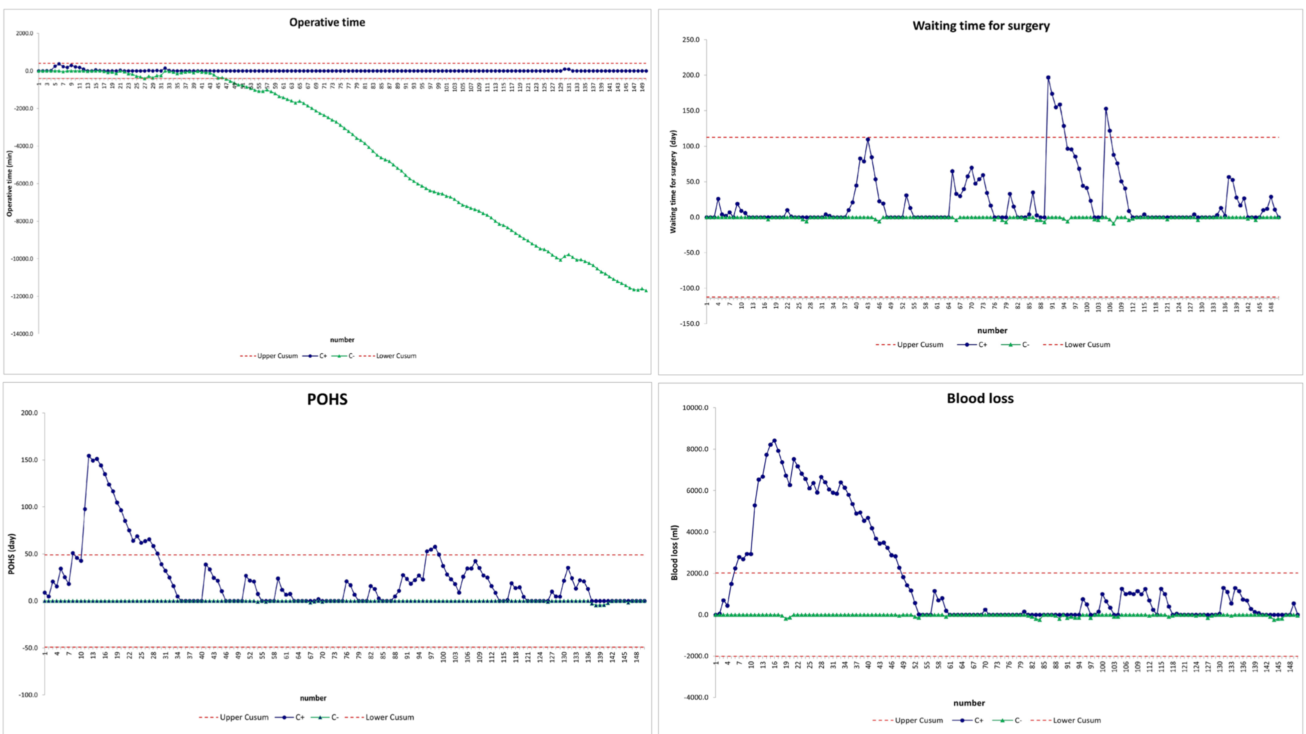

Fig. 2 CUSUM (cumulative sum) analysis of pancreatoduodenectomy outcomes. Only the operative time depicted a decreasing trend after 47 procedures. The waiting time for surgery was longer than the upper limit in seven cases. The postoperative hospital stay (POHS) and blood loss exhibited an initial increasing trend followed by a normal trend (at the target line) after 34 and 53 procedures, respectively

diagnosis to surgery" [30, 31]. This was because some centers had limitations for multidisciplinary team meetings and could not schedule regular weekly meetings. Our outcomes were not focused on hospital or surgeon volumes (pancreatic resections/year). We used CUSUM control charts to analyze the operative time for the learning curve of young surgeons because this method shows cumulative deviations over time and flags significant deviations from the respective group means. This method of analysis exhibits greater sensitivity for detecting shifts or trends as compared with the traditional control charts (Xbar charts) as a continuous process and improves the ability to detect small shifts. Similar to our result, a recent systematic review reported that the number of procedures to overcome the learning curve for open PDs is 30 [32]. Our CUSUM for blood loss did not show a decreasing trend over time. This result may be due to many factors such as the complexity of the PDs and inaccurate visual estimation of blood loss. The limitation of this study was that only one surgeon met the inclusion criteria for evaluation. This individual outcome cannot represent all young surgical attendants in achieving the benchmark. Further studies from multiple centers or large number of young surgeons' population are required to validate the metrics. Our metrics did not include patient report outcomes such as quality of life and postoperative satisfaction. We did not emphasize metrics for hospital structure, process, and supporting team quality. However, hospital outcomes were based on surgeon outcomes. Further investigation is required to assess hospital quality. Benchmark parameters and cut-off values should be revised regularly based on the new evidence, treatment trends (laparoscopic or robotic surgery), and world international consensus.

In conclusion, PD is associated with a high morbidity and mortality, and requires good standard of care. Young surgeons overcome the learning curve in terms of operative time after 47 procedures. This benchmark outcome is based on only one surgeon's learning curve; therefore, it must be compared with the benchmark outcomes of other institutions.

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Author contributions Sakchai Ruangsin, Somkiat Sunpaweravong, Supparerk Laohawiriyakamol participated in the study conception and design, drafting of the manuscript. All authors reviewed the manuscript.

Declarations

This study was approved by the Faculty of Medicine medical ethical committees (REC.63–338-10–1).

Statement of informed consent The requirement for informed consent was waived due to the retrospective nature of the study.

Statement of human and animal rights This study was approved by the Faculty of Medicine medical ethical committees (REC.63–338-10–1).

Consensus statement on submission and publication of manuscripts The study was not a duplicate of fraudulent submission, and this manuscript has not been submitted elsewhere/is not under consideration by another journal.

Competing interests The authors declare no competing interests.

References

1. Schnelldorfer T, Sarr MG (2009) Alessandro codivilla and the first pancreatoduodenectomy. Arch Surg 144:1179–1184. https://doi.org/10.1001/archsurg.2009.219
2. Whipple AO (1942) Present-day surgery of the pancreas. N Engl J Med 226:515–526. https://doi.org/10.1056/NEJM194203262261303
3. Traverso LW, Longmire WP Jr (1980) Preservation of the pylorus in pancreaticoduodenectomy a follow-up evaluation. Ann Surg 192:306–310. https://doi.org/10.1097/00000658-198009000-00005
4. Braasch JW, Rossi RL (1985) Pyloric preservation with the whipple procedure. Surg Clin North Am 65:263–271. https://doi.org/10.1016/s0039-6109(16)43581-4
5. Grace PA, Pitt HA, Tompkins RK, DenBesten L, Longmire WP Jr (1986) Decreased morbidity and mortality after pancreatoduodenectomy. Am J Surg 151:141–149. https://doi.org/10.1016/0002-9610(86)90024-3
6. Birkmeyer JD, Siewers AE, Finlayson EV et al (2002) Hospital volume and surgical mortality in the United States. N Engl J Med 346:1128–1137. https://doi.org/10.1056/NEJMsa012337
7. Birkmeyer JD, Stukel TA, Siewers AE, Goodney PP, Wennberg DE, Lucas FL (2003) Surgeon volume and operative mortality in the United States. N Engl J Med 349:2117–2127. https://doi.org/10.1056/NEJMsa035205
8. Cameron JL, Riall TS, Coleman J, Belcher KA (2006) One thousand consecutive pancreaticoduodenectomies. Ann Surg 244:10–15. https://doi.org/10.1097/01.sla.0000217673.04165.ea
9. He J, Ahuja N, Makary MA et al (2014) 2564 resected periampullary adenocarcinomas at a single institution: trends over three decades. HPB (Oxford) 16:83–90. https://doi.org/10.1111/hpb.12078
10. Greenblatt DY, Kelly KJ, Rajamanickam V et al (2011) Preoperative factors predict perioperative morbidity and mortality after pancreaticoduodenectomy. Ann Surg Oncol 18:2126–2135. https://doi.org/10.1245/s10434-011-1594-6
11. Eeson G, Chang N, McGahan CE et al (2012) Determination of factors predictive of outcome for patients undergoing a pancreaticoduodenectomy of pancreatic head ductal adenocarcinomas. HPB (Oxford) 14:310–316. https://doi.org/10.1111/j.1477-2574.2012.00448.x
12. Faraj W, Alameddine R, Mukherji D et al (2013) Postoperative outcomes following pancreaticoduodenectomy: how should age affect clinical practice? World J Surg Oncol 11:131. https://doi.org/10.1186/1477-7819-11-131
13. Kimura W, Miyata H, Gotoh M et al (2014) A pancreaticoduodenectomy risk model derived from 8575 cases from a national single-race population (japanese) using a web-based data entry system: the 30-day and in-hospital mortality rates for pancreaticoduodenectomy (japanese). Ann Surg 259:773–780. https://doi.org/10.1097/SLA.0000000000000263
14. Maruthappu M, El-Harasis MA, Nagendran M, Orgill DP, McCulloch P, Duclos A, Carty MJ (2014) Systematic review of methodological quality of individual performance measurement in surgery. Br J Surg 101:1491–8; discussion 1498. https://doi.org/10.1002/bjs.9642
15. Sheetz KH, Nuliyalu U, Nathan H, Sonnenday CJ (2020) Association of surgeon case numbers of pancreaticoduodenectomies vs related procedures with patient outcomes to inform volume-based credentialing. JAMA Netw Open 3:e203850. https://doi.org/10.1001/jamanetworkopen.2020.3850
16 Bassi C, Dervenis C, Butturini G et al (2005) Postoperative pancreatic fistula: an international study group (ISGPF) definition. Surgery 138:8–13. https://doi.org/10.1016/j.surg.2005.05.001.10.1016/j.surg.2005.05.001

17. Bassi C, Marchegiani G, Dervenis C et al (2017) The 2016 update of the international study group (ISGPS) definition and grading of postoperative pancreatic fistula: 11 years after. Surgery 161:584–591. https://doi.org/10.1016/j.surg.2016.11.014
18. Wente MN, Bassi C, Dervenis C et al (2007) Delayed gastric emptying (DGE) after pancreatic surgery: a suggested definition by the international study Group of Pancreatic Surgery (ISGPS). Surgery 142:761–768. https://doi.org/10.1016/j.surg.2007.05.005
19. Besselink MG, van Rijssen LB, Bassi C et al (2017) Definition and classification of chyle leak after pancreatic operation: a consensus statement by the international study group on pancreatic surgery. Surgery 161:365–372. https://doi.org/10.1016/j.surg.2016.06.058
20. National Healthcare Safety Network, Centers for Disease Control and Prevention (2017) Surgical site infection (SSI). http://www.cdc.gov/nhsn/pdfs/pscmanual/9pscssicurrent.pdf. Accessed 25 January 2017
21. Bilimoria KY, Bentrem DJ, Lillemoe KD, Talamonti MS, Ko CY, Pancreatic Cancer Quality Indicator Development Expert Panel, American College of Surgeons (2009) Assessment of pancreatic cancer care in the United States based on formally developed quality indicators. J Natl Cancer Inst 101:848-859. https://doi.org/10.1093/jnci/djp107
22. Sabater L, García-Granero A, Escrig-Sos J, Gómez-Mateo Mdel C, Sastre J, Ferrández A, Ortega J (2014) Outcome quality standards in pancreatic oncologic surgery. Ann Surg Oncol 21:1138–1146. https://doi.org/10.1245/s10434-013-3451-2
23. Abbott DE, Martin G, Kooby DA et al (2016) Perception is reality: quality metrics in pancreas surgery - a central pancreas consortium (CPC) analysis of 1399 patients. HPB (Oxford) 18:462–469. https://doi.org/10.1016/j.hpb.2015.11.006
24. Bassi C, Balzano G, Zerbi A, Ramera M (2016) Pancreatic surgery in Italy. criteria to identify the hospital units and the tertiary referral centers entitled to perform it. Update Surg 68:117–122. https://doi.org/10.1007/s13304-016-0371-2
25. Maharaj AD, Ioannou L, Croagh D et al (2019) Monitoring quality of care for patients with pancreatic cancer: a modified Delphi consensus. HPB (Oxford) 21:444–455. https://doi.org/10.1016/j.hpb.2018.08.016
26. Sánchez-Velázquez P, Muller X, Malleo G et al (2019) Benchmarks in pancreatic surgery: a novel tool for unbiased outcome comparisons. Ann Surg 270:211–218. https://doi.org/10.1097/SLA.0000000000003223
27. Clavien PA, Barkun J, de Oliveira ML et al (2009) The clavien-dindo classification of surgical complications: five-year experience. Ann Surg 250:187–196. https://doi.org/10.1097/SLA.0b013e3181b13ca2
28. Cameron JL, He J (2015) Two thousand consecutive pancreaticoduodenectomies. J Am Coll Surg 220:530–536. https://doi.org/10.1016/j.jamcollsurg.2014.12.031
29. Ou C, Rektorysova M, Othman B, Windsor JA, Pandanaboyana S, Loveday BPT (2021) Benchmarking performance in pancreatic surgery: a systematic review of published quality metrics. J Gastrointest Surg 25:834–842. https://doi.org/10.1007/s11605-020-04827-9
30. Fitzgerald TL, Seymore NM, Kachare SD, Zervos EE, Wong JH (2013) Measuring the impact of multidisciplinary care on quality for pancreatic surgery: transition to a focused, very high-volume program. Am Surg 79:775–780. https://doi.org/10.1177/000313481307900817
31. van Rijssen LB, van der Geest LGM, Bollen TL et al (2016) National compliance to an evidence-based multidisciplinary guideline on pancreatic and periampullary carcinoma. Pancreatology 16:133–137. https://doi.org/10.1016/j.pan.2015.10.002
32. Müller PC, Kuemmerli C, Cizmic A et al (2022) Learning curves in open, laparoscopic, and robotic pancreatic surgery: a systematic review and proposal of a standardization. Ann Surg Open 3:e111. https://doi.org/10.1097/AS9.0000000000000111