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# The required experience of open pancreaticoduodenectomy before becoming a specialist in hepatobiliary and pancreatic surgeons: a multicenter, cohort study of 334 open pancreaticoduodenectomies

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## Abstract

**Background** Open pancreaticoduodenectomy (OPD) is an essential surgical procedure for expert hepato-biliary-pancreatic (HBP) surgeons. However, there is no standard for how many surgeries must be performed by a surgeon in training before they are considered to have enough experience to ensure surgical safety.

**Methods** Cumulative Sum (CUSUM) analysis was performed using the surgical data of OPDs performed during the training period of board-certified expert surgeons of the Japanese Society of Hepato-Biliary-Pancreatic Surgery.

**Results** Fourteen HBP surgeons participated in this study and performed 334 OPDs during their training period. The median (interquartile range) values for operative time, blood loss, and length of hospital stay were 455 (397–519) minutes, 450 (234–716) ml, and 28 (21–38) days, respectively. CUSUM analysis showed inflection points at 20 surgeries performed for operative time. After 20 procedures, operative time was significantly shorter (461 min vs. 425 min,  $p=0.021$ ) and blood loss was significantly lower (470 ml vs. 340 ml,  $p=0.038$ ). No significant differences between within 20 and after 21 procedures were found in the complication rate (53% vs. 48%,  $p=0.424$ ) and rate of in-hospital deaths (1.5% vs. 1.4%,  $p=0.945$ ). Up to 20 surgeries, PDAC and another malignant tumor had longer operative time than benign/low malignant diseases (486 min vs. 472 min vs. 429 min,  $p<0.001$ ), and higher blood loss (500 ml vs. 502 ml vs. 355 ml,  $p<0.001$ ). Mortality rate was higher at PDAC cases (5% vs. 0% vs. 0%,  $p=0.01$ ). After the 21 procedures, these outcomes were improved and no differences in by primary disease were observed. Multivariable analysis showed that within 20 surgeries were independent risk factors of longer operative time (HR2.6,  $p=0.013$ ) and higher blood loss (HR2.0,  $p=0.049$ ).

**Conclusions** To stabilize the surgical outcome of OPD for malignant disease, at least 20 surgeries should be performed at a certified institution during surgeon training.

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**Trial registration** Clinical trial number: Not applicable.

**Keywords** Education, High-volume hospital, Learning curve, Pancreaticoduodenectomy

## Background

Pancreaticoduodenectomy (PD) is one of the challenging procedures characterized by high complication and mortality rates that requires advanced skills and specialized anatomical knowledge of hepato-biliary-pancreatic (HBP) surgeons.

While it is crucial that HBP surgeons perform open PD (OPD) safely and certainly, the number of surgeries that should be performed during the surgeon training period remains uncertain.

The required number of surgeries experienced needed to achieve a stable procedure varies depending on the background of the surgeon or the institution. Previous analyses of the learning curve for OPD have been limited to a single surgeon [1–4] or a single center [5–9], and a considerable number of studies used an arbitrary split-group approach (e.g., postgraduate year, 50 cases), rather than a statistical calculation (e.g., Cumulative Sum analysis).

This multicenter, cohort study aimed to investigate the learning curve of OPDs performed by board-certified HBP surgeons during their training periods at board-certified institutions of the board certification system of the Japanese Society of Hepato-Biliary-Pancreatic Surgery (JSHBPS).

## Methods

### Study participants

The study included total of 334 adult patients who underwent OPD by 14 surgeons between January 2008 and December 2022 from five medical institutions (Okayama University Hospital, Okayama Saiseikai General Hospital, National cancer center hospital east, Japanese Red Cross Society Himeji Hospital, and Tottori Municipal Hospital). All institutions were board-certified training institutions for the JHPBS during the training period [10, 11]. Of five hospitals, four were “Training Institution A” that performs more than 50 cases of highly advanced surgery for Hepatobiliary and Pancreatic field in a calendar year, and one was “Training Institution B” that performs more than 30 such surgeries in a calendar year.

### Postoperative management

The patients were mobilized the day after surgery. A liquid diet on day 3 and a solid diet on day 4 were offered if tolerated. Drain fluid amylase level and drain fluid culture were measured on postoperative day 1 and 3; and drain was removed within day 5 according to the patient’s clinical conditions, in absence of sinister appearance of the effluent. Somatostatin analogs were not routinely used.

The following demographic and clinical data were reviewed through medical records: sex, age, preoperative diagnosis, surgical procedure, operative time, blood loss, and length of postoperative hospital stay (LOS). In this study, discharge was Included transfers to other hospital.

Postoperative complications in 90 days after the intervention were defined as those of Clavien-Dindo class IIIa or higher [12]. Postoperative pancreatic fistulas (POPFs) were assessed according to the International Study Group of Pancreatic Surgery (ISGPS) [13].

In this study, the primary endpoint was operative time, and the secondary endpoints were, blood loss, hospital stay, mortality rate, and surgical complications.

### Statistical analysis

Clinical variables were compared using the Mann-Whitney U test for continuous data and Pearson’s correlation coefficient for categorical data. Continuous variables are presented as medians and interquartile range (IQR). Values of  $p < 0.05$  were considered significant.

CUSUM analysis was performed to assess the change by number of experiences for operative time and to identify the number of procedures necessary to reach optimal performance [14]. A chronological arrangement of all cases from the first to the last by the trainee was performed. CUSUM values were calculated according to the following formula:  $CUSUM = \sum (x_i - \mu)$ , where  $x_i$  was the operative time of the individual case and  $\mu$  was the median operative time of the trainee. Finally, the CUSUM values were plotted on the vertical axis according to their case number on the horizontal axis. Flexion point could be determined by visual interpretation of the chart.

Risk factors for operative time and blood loss of top 25% for each trainee identified by univariable and multivariable analyses. Variables found to be associated with operative time and blood loss on univariable analysis ( $p < 0.05$ ) were entered into a stepwise logistic regression model for multivariable analysis of risk factors.

All statistical analyses were performed using JMP version 14 (SAS Institute Inc., Cary, NC, USA).

## Results

The background characteristics of the 14 HBP surgeons are summarized in Table 1. All participants were male, board-certified surgeons in gastroenterology with around 12 years of postgraduate experience at the beginning of the training. Three surgeons (21%) had received HBP training at two institutions during their training period.

Of the five hospitals in this study, “Institution A” performed about 100 to 200 cases of highly advanced HBP

**Table 1** Summary of HBPs trainees

	All (N=14)
<b>Years of post-graduate experience at HBPs training start</b> , y, median (IQR)	12 (10-13)
<b>Sex</b>	
Female, n (%)	0 (0)
Male, n (%)	14 (100)
<b>Training period</b> , y, median (IQR)	5 (4-5)
<b>Number of training institutions trainees belonged to</b>	
One, n (%)	11 (79)
Two, n (%)	3 (21)
<b>Number of OPD procedures performed during the training period</b> , n, median (IQR)	25.5 (19-28)
<b>Board certified training institution</b>	
institution A (>50 high level HBP surgeries per year), n (%)	13 (93)
institution B (>30 high level HBP surgeries per year), n (%)	1 (7)

HBPs: hepatobiliary pancreatic surgery, IQR; Interquartile Range, OPD; open pancreaticoduodenectomies

surgery with two board-certified instructors, and “Institution B” performed about 30 to 40 surgeries with one board-certified instructor. About the number of OPDs, Institution A had about 40 to 80 cases and Institution B had about 10 OPDs per year. Trainees performed highly advanced HBP surgeries including about 26 OPDs during their training periods (median 5 years) under the guidance of instructors at training institutions.

Finally, all trainees submitted videos of OPD or highly advanced hepatectomy for assessment of the applicant's surgical skills for the JHPBS and passed this evaluation.

The enrolled patients' characteristics and the surgical outcomes of the OPD cases are summarized in Table 2. Patients were categorized into three groups based on number of surgeries performed at each surgeons (group 1 (1–10), group 2 (11–20), group 3 (21≤)). The most frequent primary disease was pancreatic ductal adenocarcinoma ( $n=113$ , 34%), followed by ampulla or duodenal tumor ( $n=70$ , 21%), IPMN ( $n=67$ , 20%), bile duct cancer ( $n=50$ , 15%), low-malignant pancreatic tumor ( $n=18$ , 5%), and others ( $n=16$ , 5%).

In the total cohort, the median operative time was 455 (IQR: 397–519) minutes, blood loss was 450 (IQR: 234–716) ml, and the postoperative hospital stay was 28 (IQR: 21–38) days.

There were 6 (1%) in-hospital deaths. Clinical POPFs were seen in 96 cases (29%), delayed gastric emptying was seen in 29 (9%), and bile leakage was found in 13 (4%).

The operative time ordered by the number of cases was shown in Fig. 1. The number of trainees decreased after 11 cases because trainees who have passed the board-certified examination were removed from this study.

In CUSUM analysis of operation time including all trainees, the flection point was found after the 20 procedures (Fig. 2).

Cases and outcomes were compared before and after the 20 cases (Table 3). After 20 procedures, the PDAC rate was significantly higher (31% vs. 45%,  $p=0.024$ ), operative time was significantly shorter (461 min vs. 425 min,  $p=0.021$ ), and blood loss was significantly lower (470 ml vs. 340 ml,  $p=0.038$ ). On the other hand, no differences in these outcomes by before and after 10 procedures were observed. (supplemental Table e1). No significant differences between within 20 and after 21 procedures were found in the complication rate (53% vs. 48%,  $p=0.424$ ) or rate of in-hospital deaths (1.5% vs. 1.4%.  $p=0.945$ ). This trend was similar to subgroup analysis on Institution B only (supplemental Table e2).

The subgroup analysis depend on primary diseases is shown in Table 4. OPD cases were classified three groups: PDAC, another malignant tumor (bile duct cancer, ampullary cancer, gastric cancer), and benign/low malignant diseases (intraductal papillary mucinous neoplasm, neuroendocrine neoplasm, solid pseudopapillary neoplasm, gastrointestinal stromal tumor, chronic pancreatitis) Up to 20 surgeries, PDAC and another malignant tumor had longer operative time than benign/low malignant diseases (486 min vs. 472 min vs. 429 min,  $p<0.001$ ), and higher blood loss (500 ml vs. 502 ml vs. 355 ml,  $p<0.001$ ). Mortality rate was higher at PDAC cases (5% vs. 0% vs. 0%,  $p=0.01$ ) and all complication rates were higher at another malignant tumor (35% vs. 62% vs. 52%,  $p=0.04$ ). After the 21 procedures, operative time and blood loss were improved and no differences in by primary disease were observed: (430 min vs. 445 min vs. 410 min,  $p=0.328$ ), (345 ml vs. 400 ml vs. 315 ml,  $p=0.642$ ). Mortality and complication rate were similar between three groups.

In the sub analysis of PDAC, the percentage of PDAC was significantly increased in every 5 OPDs, and frequency of preoperative biliary drainage was also increased. (Supplemental Table e3)

However, operative time and blood loss of OPDs for PDAC were significantly improved after 21 procedures. (Supplemental Table e4)

The factors predicting top 25% of operative time and intraoperative bleeding for each trainee's surgeries were analyzed. The results are summarized in Table 5. Multivariable analysis showed that male,  $BMI \geq 25$ , vascular resection, and within 20 surgeries were independent risk factors of longer operative time ( $p=0.011$ ,  $=0.010$ ,  $<0.001$ ,  $=0.013$  respectively). And, multivariable analysis also showed that male,  $BMI \geq 25$ , and within 20 surgeries were independent predictors of a higher blood loss ( $p=0.012$ ,  $<0.001$ ,  $=0.049$  respectively). In the PDACs cases, logistic regression analysis showed that younger

**Table 2** Summary of clinical characteristics and surgical outcomes of 334 OPD cases: total cohort and groups based on case number of each surgeon

	Total	Group 1 (1-10)	Group 2 (11-20)	Group 3 (>20)	p value
<b>Number of pancreaticoduodenectomies</b>	334	140	123	71	
<b>Training institution</b>					
institution A, n (%)	303 (91)	130 (93)	113 (92)	60 (85)	0.122
institution B, n (%)	31 (9)	10 (7)	10 (8)	11 (15)	
<b>Age y, median (IQR)</b>	70 (63-76)	69 (62-75)	70 (63-77)	71 (63-76)	0.393
<b>Sex</b>					
Female, n (%)	137 (41)	58 (41)	42 (34)	37 (52)	0.049
Male, n (%)	197 (59)	82 (59)	81 (66)	34 (48)	
<b>BMI kg/m<sup>2</sup> (IQR)</b>	22 (20-25)	22 (21-25)	22 (20-25)	22 (20-24)	0.866
<b>Disease</b>					
PDAC, n (%)	113 (34)	37 (26)	44 (36)	32 (45)	0.204
Ampulla of Vater/duodenal tumor, n (%)	70 (21)	33 (24)	27 (22)	10 (14)	
IPMN, n (%)	67 (20)	35 (25)	20 (16)	12 (17)	
Bile duct cancer, n (%)	50 (15)	20 (14)	21 (17)	9 (13)	
Pancreatic NEN/SPN/SCN	18 (5)	10 (7)	4 (3)	4 (6)	
Others, n (%)	16 (5)	5 (4)	7 (6)	4 (6)	
<b>Preoperative biliary drainage yes, n (%)</b>	144 (43)	49 (35)	59 (48)	36 (51)	0.037
<b>Combined vascular resection yes, n (%)</b>	54 (16)	16 (11)	24 (20)	14 (20)	0.136
<b>Operative time min, median (IQR)</b>	455 (397-519)	465 (394-519)	459 (405-532)	425 (382-491)	0.056
<b>Blood loss ml, median (IQR)</b>	450 (234-716)	500 (263-743)	450 (215-815)	340 (200-560)	0.090
<b>Blood transfusion n (%)</b>	32 (10)	14 (10)	16 (13)	2 (3)	0.066
<b>Hospital deaths n (%)</b>	5 (1.5)	2 (1.4)	2 (1.6)	1 (1.4)	0.989
<b>Surgical complications of Clavien-Dindo <math>\geq</math> IIIa</b>					
All	166 (50)	66 (47)	66 (54)	34 (48)	0.541
POPF $\geq$ grade B, n (%)	96 (29)	42 (30)	38 (31)	16 (23)	0.423
DGE, n (%)	27 (8)	10 (7)	9 (7)	8 (11)	0.540
SSI, n (%)	19 (6)	10 (7)	6 (5)	3 (4)	0.611
Bile leak, n (%)	13 (4)	5 (4)	6 (5)	2 (3)	0.749
Abdominal bleeding, n (%)	6 (2)	1 (1)	5 (4)	0 (0)	0.055
<b>LOS days, median (IQR)</b>	28 (21-38)	28 (19-38)	28 (22-39)	24 (19-39)	0.229

PDAC: Pancreatic Ductal Adenocarcinoma, IPMN: Intraductal Papillary Mucinous Neoplasm, NEN: Neuroendocrine Neoplasm, Neoplasm

SPN: Solid Pseudopapillary Neoplasm, SCN: Serous Cyst

POPF: Postoperative Pancreatic Fistula, DGE: Delayed Gastric Emptying, SSI: Surgical Site Infection

LOS: length of postoperative hospital stay

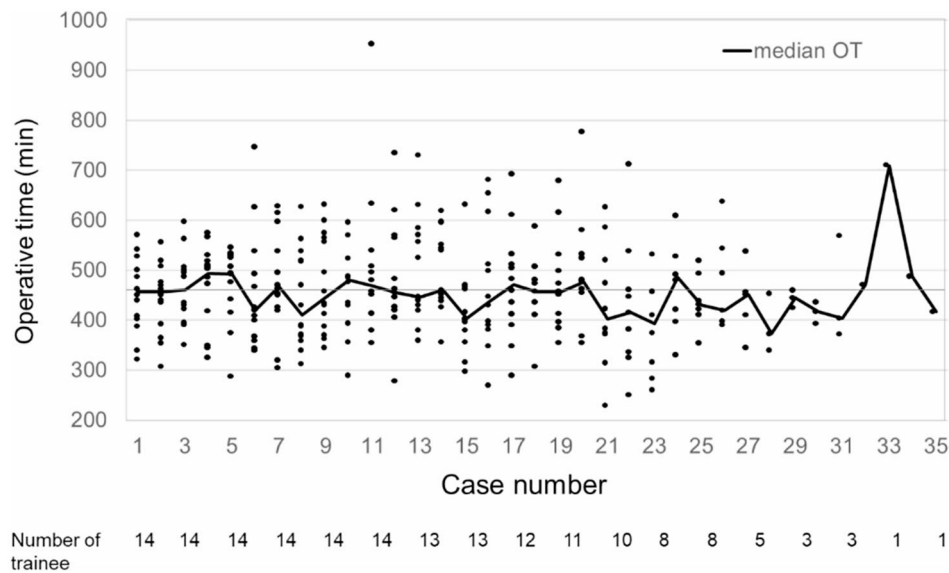
than 65 years, male, BMI  $\geq$  25, vascular resection, and within 20 surgeries were independent risk factors of longer operative time, and only within 20 surgeries was the independent predictors of higher blood loss (supplemental Table 5).

## Discussion

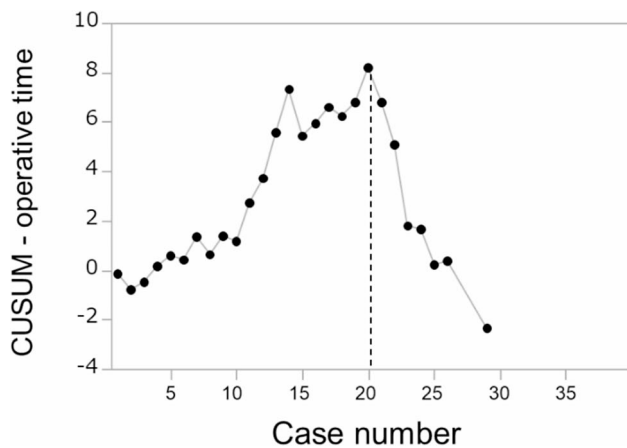
This is the first multicenter study to analyze the OPD learning curve during the training period of gastrointestinal surgeons who later became board-certified HBP expert surgeons. In the field of laparoscopic or robotic PD, multicenter analyses and clinical trials have been reported previously [15–20]. On the other hand, there has been no standard for the number of OPDs performed before stabilization of safety-related outcomes for HBP experts.

The results of learning curve analyses varied by training institution or outcome (such as operative time, bleeding, and surgical complications) [21]. The JSHBPS has established a certification system to certify expert HBP surgeons since 2008 [11], and its usefulness and safety has been reported [10, 22–25]. The quality of the present study was assured by these JSHBPS-certified institutions and by accepting as participants only expert HBP surgeons who had been certified through a video evaluation process with a pass rate of around 40%. Because the aim of the present study was to determine the cut-off for number of surgeries performed needed to adequately learn a safe surgical procedure, blood loss was set as the primary outcome [26].

The postoperative complication and mortality rates were comparable to the national average in Japan, even



**Fig. 1** Operative time of the OPD procedure. Horizontal axis shows case number of OPD procedure for trainee



**Fig. 2** CUSUM analysis of the operative time. The inflection point was found after the 20th procedure

though this study's patient population consisted of those treated during the HBP surgeons' training period [25, 27].

The CUSUM analysis showed that, despite the high individual or institutional variability of surgical outcomes for OPD, the operating time decreased after 20 procedures performed in many HBP trainees. The inflection point at 20 surgeries performed was lower than that in previous studies, which reported 30 (range: 20–50) surgeries performed during training as being necessary for ensuring safe OPD procedures [9, 28, 29]. This might be attributable to the fact that participants in the present study were limited to those who were experts in gastrointestinal surgery at board-certified institutions with standardized OPD procedures.

In addition to the skill of each surgeon, the institutional environment such as volume of surgery at single

institutions, number of tutors, and the frequency of other surgical experience over the period also has a significant impact on learning curve. In this study, while institution B had a low number of HBP surgery and OPD compared for Institution A, the experienced number of OPDs at trainee did not change during institutions. The reason for this might be that the larger hospital has more trainees and the number of OPD cases was more dispersed.

The problems in evaluating surgical outcomes of OPD are that the technique for pancreatic cancer is significantly different from that for benign/low-malignant tumor, resulting in variability in surgical difficulty. Furthermore, as the percentage of PDAC patients increases with the number of experienced cases, the improvement of surgical outcome by learning may be counteracted by the difficulty of cases.

In this study, the proportion of advanced PDAC which required preoperative biliary drainage increased along with the training period progressed, as trainee performed more difficult OPD. However, operative time and blood loss of OPDs for PDAC were significantly improved after 21 procedures.

In the subgroup analysis of PDAC case, logistic regression analysis showed that not only patients factor such as younger than 65 years, male, and  $BMI \geq 25$  but also vascular resection and number of cases were independent risk factors of longer operative time.

We investigated comparison between the primary disease and found that, during the learning curve, PDAC cases had longer operative time, higher blood loss and higher risk of hospital death than case of benign/low-malignant tumor. However, after 21 cases, the dramatic improvement was shown in operative time and blood loss

**Table 3** Comparison of clinical characteristics and surgical outcomes before/after 20 cases

	Within 20 cases (1-20)	After 21 cases (≥21)	p value
<b>Number of pancreaticoduodenectomies</b>	263	71	
<b>Age</b> , median (IQR)	69 (62-76)	71 (63-76)	0.547
<b>Sex</b>			
Female, n (%)	100 (38)	37 (52)	0.032
Male, n (%)	163 (62)	34 (48)	
<b>BMI</b> kg/m <sup>2</sup> (IQR)	22 (20-25)	22 (20-24)	0.612
<b>Disease</b>			
PDAC, n (%)	81 (31)	32 (45)	0.024
Others, n (%)	182 (69)	39 (55)	
<b>Preoperative biliary drainage</b> yes, n (%)	108 (42)	36 (50)	0.175
<b>Combined vascular resection</b> yes, n (%)	40 (15)	14 (20)	0.388
<b>Operative time</b> min, median (IQR)	461 (402-523)	425 (382-491)	0.021
<b>Blood loss</b> ml, median (IQR)	470 (250-779)	340 (200-560)	0.038
<b>Blood transfusion</b> n (%)	30 (11)	2 (3)	0.029
<b>Hospital deaths</b> n (%)	4 (1.5)	1 (1.4)	0.945
<b>Surgical complications of Clavien-Dindo ≥IIIa</b>			
All	140 (53)	34 (48)	0.424
POPF ≥ grade B, n (%)	80 (30)	16 (23)	0.193
DGE, n (%)	21 (8)	8 (11)	0.383
SSI, n (%)	20 (8)	3 (4)	0.318
Bile leak, n (%)	11 (4)	2 (3)	0.598
Abdominal bleeding, n (%)	6 (2)	0 (0)	0.199
<b>LOS</b> days, median (IQR)	28 (22-38)	24 (19-39)	0.141

PDAC: Pancreatic Ductal Adenocarcinoma, IPMN: Intraductal Papillary Mucinous Neoplasm, NEN: Neuroendocrine Neoplasm, SPN: Solid Pseudopapillary Neoplasm, SCN: Serous Cyst Neoplasm

POPF: Postoperative Pancreatic Fistula, DGE: Delayed Gastric Emptying, SSI: Surgical Site Infection

LOS: length of postoperative hospital stay

**Table 4** Comparison of surgical outcomes and primary diseases before/after 20 cases for PDAC, other malignant tumors, and benign or low-malignant diseases

	Within 20 cases			p value	After 21 cases			p value
	PDAC	Other malignant tumors	Benign or low-malignant diseases		PDAC	Other malignant tumors	Benign or low-malignant diseases	
<b>Number of pancreaticoduodenectomies</b>	81	100	82		32	19	20	
<b>Age</b> y, median (IQR)	70 (65-76)	71 (62-77)	66 (59-72)	0.003	72 (65-76)	74 (65-79)	66 (59-72)	0.022
<b>Sex</b>								
Female, n (%)	33 (41)	39 (39)	28 (34)	0.665	19 (59)	11 (58)	7 (35)	0.194
Male, n (%)	48 (59)	61 (61)	54 (66)		13 (41)	8 (42)	13 (65)	
<b>BMI</b> kg/m <sup>2</sup> (IQR)	22 (20-25)	22 (21-24)	22 (21-25)	0.752	21 (19-23)	22 (21-25)	23 (22-24)	0.038
<b>Preoperative biliary drainage</b> yes, n (%)	42 (52)	64 (64)	2 (3)	<0.001	21 (66)	14 (74)	1 (5)	<0.001
<b>Combined vascular resection</b> yes, n (%)	31 (38)	7 (7)	2 (3)	<0.001	14 (44)	0 (0)	0 (0)	<0.001
<b>Operative time</b> min, median (IQR)	486 (430-544)	472 (410-532)	429 (378-477)	<0.001	430 (397-494)	445 (375-471)	410 (337-458)	0.328
<b>Blood loss</b> ml, median (IQR)	500 (303-840)	502 (280-884)	355 (140-578)	<0.001	345 (205-568)	400 (215-550)	315 (81-618)	0.642
<b>Blood transfusion</b> n (%)	9 (11)	18 (18)	3 (4)	0.010	1 (3)	1 (5)	0 (0)	0.089
<b>Hospital deaths</b> n (%)	4 (5)	0 (0)	0 (0)	0.010	0 (0)	0 (0)	1 (5)	0.274
<b>Surgical complications of Clavien-Dindo</b>								
<b>≥ IIIa</b>								
All	35 (43)	62 (62)	43 (52)	0.041	13 (41)	9 (47)	12 (60)	0.396
POPF ≥ grade B, n (%)	14 (17)	38 (38)	28 (4)	0.007	4 (3)	6 (32)	6 (30)	0.185
DGE, n (%)	8 (10)	7 (7)	6 (7)	0.750	4 (13)	2 (11)	2 (10)	0.955
SSI, n (%)	3 (4)	15 (15)	2 (2)	0.002	2 (6)	0 (0)	1 (5)	0.551
Bile leak, n (%)	2 (2)	4 (4)	5 (6)	0.509	1 (3)	0 (0)	1 (5)	0.634
Abdominal bleeding, n (%)	0 (0)	4 (4)	2 (2)	0.199	0 (0)	0 (0)	0 (0)	1.000
<b>LOS</b> days, median (IQR)	28 (18-389)	30 (24-41)	26 (20-35)	0.062	23 (17-32)	33 (6-41)	25 (18-33)	0.043

PDAC: Pancreatic Ductal Adenocarcinoma,

POPF: Postoperative Pancreatic Fistula, DGE: Delayed Gastric Emptying, SSI: Surgical Site Infection

LOS: Length Of Postoperative Hospital Stay

**Table 5** Logistic regression analysis to examine risk factors for top 25% of operative time and intraoperative bleeding for each trainee's surgeries

		Top 25% of operative time				Top 25% of blood loss			
		Univariate		Multivariate		Univariate		Multivariate	
		HR	P value	HR	P value	HR	P value	HR	P value
Age	≥65 y		0.083				0.703		
Sex	male	2.0	0.011	2.2	0.008	2.1	0.006	2.0	0.012
BMI	≥25 kg/m <sup>2</sup>	2.2	0.010	2.5	0.005	2.7	<0.001	2.8	<0.001
Disease	PDAC	2.0	0.009		0.225		0.730		
Preoperative biliary drainage	yes		0.290				0.196		
Combined vascular resection	yes	3.8	<0.001	4.2	<0.001		0.267		
Number of procedures	within 20 cases	2.3	0.013	2.6	0.019	2.2	0.026	2.0	0.049

BMI: Body Mass Index, PDAC: Pancreatic Ductal Adenocarcinoma

for PDAC cases, and safety was ensured regardless of the disease. Finally, we found that not only patient's factor such as male, obesity, and vascular resection, but also the experience of 20 surgeries obviously affects surgical outcome of OPD during HBP training period. These results mean that in HBP training, difficulty cases should be performed later in the training period to ensure patient safety.

The limitations of this study are the few procedures per surgeon and individual differences in experience doing OPD at the start of training. There was no female trainee during study period in our institutions. This may be because female surgeons in Japan have few opportunities to receive surgical training especially HBPs surgery. [30]

## Conclusions

The hepato-biliary-pancreatic surgery training at certified institutions was done safely. To stabilize the surgical outcome of OPD, at least 20 surgeries should be performed at certified institutions during surgeon training. In addition, difficult cases should be experienced step by step.

## Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12893-024-02677-9>.

Supplementary Material 1  
Supplementary Material 2  
Supplementary Material 3  
Supplementary Material 4  
Supplementary Material 5

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## Author contributions

T. F: Analysis and interpretation of data, drafting of manuscript. Y.U: study conception and design. T. M: analysis. K.T, M.H, R.Y, Y.E, K.Y, K.M, D.N and T.F: Acquisition of data.

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## Data availability

The datasets generated and/or analyzed during the current study are not publicly available due to data privacy policy at our facility but are available from the corresponding author on reasonable request.

## Declarations

### Ethics approval and consent to participate

This study conformed to the Declaration of Helsinki on Human Research Ethics standards and was approved by the Okayama University Hospital Institutional Ethics Board (2112-040). The need for written informed consent was waived by the Okayama University Hospital Institutional Ethics Board because of the retrospective design of the study.

### Consent for publication

Not applicable.

### Competing interests

The authors declare no competing interests.

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