Original Article

Critical evaluation of quality of hepatopancreatic surgery in a medium-volume center in Finland using the Accordion Severity Grading System and the Postoperative Morbidity Index

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Background: Hepatopancreatobiliary surgery is prone to complications. Methods are needed to monitor surgical outcomes and enable comparison between institutions.

Methods: Complications were collected prospectively and reviewed using the modified Accordion Severity Grading System (MASGS) and the Postoperative Morbidity Index (PMI).

Results: This study included 527 consecutive patients receiving either pancreatic or liver resection in 2000–2017 in Central Finland Central Hospital. The PMI was 0.177 for all patients, and 0.192, 0.094, 0.285, and 0.129 for patients receiving major pancreatic (n=218), minor pancreatic (n=93), major liver (n=73), and minor liver (n=143) resection, respectively. The rates of postoperative pancreatic fistula (POPF) after pancreaticoduodenectomies (n=200) were 6.5% for grade B and 5.5% for grade C; rates for biliary leak were 1.0% (grade A), 2.5% (grade B), and 0.5% (grade C). Similarly, the rates for delayed gastric emptying (DGE) were 2.8% (grade A), 15.6% (grade B), and 3.7% (grade C). Postoperative hepatic dysfunction occurred in 2.3%, major surgical site bleeding in 2.3%, and biloma in 7.9% of patients after liver resection. Ninety-day mortality rates were 3.7% and 1.1% in major and minor pancreatic resections, and 8.2% and 0.7% in major and minor liver resections. Major complications occurred in 13.3% and 3.3% in pancreatic, and 19.2% and 6.3% in liver resections, respectively.

Conclusions: Major pancreatic and hepatic surgery are associated with significant morbidity and burden in our center, comparable with previous population-based studies. PMI is an informative way to monitor surgical outcomes and enable comparison between institutions.

Keywords: Pancreas; liver; surgery; complications; Accordion Severity Grading System; Postoperative Morbidity Index (PMI); benchmark

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Introduction

Hepatopancreatic resections constitute a field of surgery prone to complications (1-3). These procedures demand high acuity from the surgeons, as well as from the entire process, from administration to discharge and during the following weeks. Benefits of high annual center and surgeon volume have led to centralization of major surgical operations to achieve the best possible results (2,4,5).

The Postoperative morbidity index (PMI) is a quantitative severity weighting system; it uses the modified Accordion Severity System (MASGS) to grade the severity of complications gathered from American College of

Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) complication data, and then weights each complication (6). This quantitative measure was first applied to several surgical procedures such as appendectomy, laparoscopic colectomy, and hepatectomy in 2011 (7), and to distal pancreatectomies in 2013 (8). In 2015, a quantitative benchmark for morbidity in pancreaticoduodenectomy (PD) was established using PMI (1), and the complication burden of 64 total pancreatectomies was described using the same methods (9). The established scoring system enables the assessment and comparison of surgical results between institutions, highlights targets for improvement, and may further determine benchmark complication cut-offs for results to be achieved (1,2).

Pancreatic and hepatic surgery, especially major procedures including PD (1) or major (≥3 segments) resection, carry high complication burden even in low-risk patients (1-3,10). Distal pancreatic resection and minor (≤2 segments) hepatic resection are less prone to severe complication (3). There is high variability in the number of complications and survival between the best and worst performing major surgical hospitals (1-3), indicating the need for routine quantitative benchmarking in all hospitals in which major surgery is performed in order to improve performance and reduce variation in outcomes.

The aim of this study was to compare different hepatopancreatic procedures by means of a quantitative scoring system in a medium-volume center. The complication profile and burden were compared with benchmark studies published earlier (1,2,9). The secondary aim was to critically evaluate the rationale of major surgery performed in our center and targets for improvement.

Methods

Study design

This was a retrospective cohort study. Included patients had received either pancreatic or liver resection in 2000–2017 at Central Finland Central Hospital. Data about complications were collected prospectively and re-reviewed retrospectively by another researcher. The histopathological diagnoses included mainly malignant diseases, such as ductal adenocarcinoma of pancreas, colorectal liver metastases, and hepatocellular carcinoma.

Procedural data

Pancreaticoduodenectomies and total pancreatectomies are considered major pancreatic resections; distal pancreatic resections are considered minor resections. Similarly, liver resections comprising three or more segments of the liver are considered major resections, and the rest are considered minor resections. All major resections were open operations; 19.6% of minor resections were performed with a minimally invasive approach. The standard Whipple technique was used in 15.5% and pylorus-preserving technique in 84.5% of pancreaticoduodenectomies. Of major liver resections, 71.2% were hemihepatectomies or extended hemihepatectomies. Simultaneous bowel resection was performed in 19.2% of major and 19.6% of minor liver resections (*Tables 1*,*2*).

Assignment of complication severity grades, complication burden, and PMI

To enable comparison of our results with the results published by others, we scored the complications as described by Vollmer *et al*. in the benchmark study (1). Therefore, for each patient who developed a postoperative complication within 30 days, a complication grade from 1 to 6 was assigned according to the rules of the MASGS (6), which is nearly analogous with the commonly used Clavien-Dindo classification (11). When a patient developed more than 1 complication, they were assigned the grade of the most severe complication, referred to as the highest grade complication. When other NSQIP complications of lesser severity occurred in the same patient, they were referred to as not highest grade (NHG) complications. The number and severity of complications based on MASGS and NSQIP are presented separately for major and minor pancreatic and hepatic procedures (*Tables 3-6*).

After grading highest grade complications from 1 to 6 according to the MASGS, the complications were weighted using the previously derived severity grade-related utility weights (*Tables 3-6*). The PMI is calculated by dividing the burden of all highest grade complications by the number of patients in the study, thus providing a population-level measure for morbidity (*Table 7*). To be clear, PMI could vary between zero (no patient suffered a complication) and 1.0 (all patients died in 30 days).

Table 1 Characteristics of patients undergoing major and minor pancreatic resection

Characteristics	Major resection, n=218	Minor resection, n=93
Classic Whipple procedure, n	31	–
Pylorus preserving Whipple, n	169	
Total pancreatectomy, n	18	–
Distal pancreatic resection, n	–	78
Enucleation, n	–	15
Minimally invasive, n	–	28
Simultaneous resection of superior mesenteric/portal vein, n	23	–
Age yrs [median, IQR]	67 [60–73]	60 [50–71]
BMI kg/m^2 [median, IQR]	25.5 [22.9–28.3]	26.0 [22.2–30.9]
Male, n (%)	116 (53.2)	33 (35.5)
ASA status, n (%)		
Grade I	12 (5.5)	13 (14.0)
Grade II	96 (44.0)	49 (52.7)
Grade III	102 (46.8)	29 (31.2)
Grade IV	8 (3.7)	2 (2.2)
Jaundice, n (%)	163 (74.8)	–
Biliary stent, n (%)	154 (70.6)	–
Weight loss, n (%)	101 (46.3)	3 (3.2)
Comorbidities		
Charlson comorbidity index		
Median [IQR]	4 [3–5]	3 [2–4]
0	18 (8.3)	9 (9.7)
1–2	17 (7.8)	28 (30.1)
3	36 (16.5)	17 (18.3)
4	53 (24.3)	17 (18.3)
5	56 (25.7)	14 (15.1)
6	33 (15.1)	5 (5.4)
7–9	5 (1.9)	2 (2.2)
Diabetes, n (%)	48 (22.0)	16 (17.2)
Coronary artery disease, n (%)	36 (16.5)	9 (9.7)
Peripheral vascural disease, n (%)	5 (2.3)	2 (2.2)
Pulmonary disease, n (%)	17 (7.8)	13 (14.0)
Congestive heart failure, n (%)	5 (2.3)	1 (1.1)
Rheumatic disease, n (%)	5 (2.3)	1 (1.1)
Hepatic disease, n (%)	5 (2.3)	1 (1.1)

Table 1 (*Continued*)

Table 1 (*Continued*)

Characteristics	Major resection, n=218	Minor resection, n=93
Renal disease, n (%)	5 (2.3)	4 (4.3)
Other malignancy, n (%)	9 (4.1)	1 (1.1)
Histology, n (%)		
Ductal adenocarcinoma	127 (58.3)	16 (17.2)
Cholangiocarcinoma	19 (8.7)	–
Ampullary carcinoma	18 (8.3)	–
Neuroendocrine tumour	5 (2.3)	29 (31.2)
Other malignancy	20 (9.2)	9 (9.7)
Benign	30 (13.8)	39 (41.9)

Table 2 Characteristics of patients undergoing major and minor liver resection

Characteristics	Major resection, n=73	Minor resection, n=143
<3 segments, n (%)	21 (28.8)	–
>4 or more , n (%)	52 (71.2)	–
Non anatomic or wedge, n (%)	–	71 (49.7)
1–2 segments, n (%)	–	72 (50.3)
Minimally invasive, n (%)	–	28 (19.6)
Simultaneous bowel resection, n (%)	14 (19.2)	28 (19.6)
Neoadjuvant treatment, n (%)	34 (46.6)	48 (33.6)
Age yrs [median, IQR]	65 (56–70]	66 (59–73]
BMI kg/m^2 [median, IQR]	24.2 (22.5–28.6]	25.8 (21.6–29.7]
Male, n (%)	38 (53.4)	72 (50.3)
ASA status, n (%)		
Grade I	10 (13.7)	13 (9.1)
Grade II	34 (46.6)	66 (46.2)
Grade III	29 (39.7)	61 (42.7)
Grade IV	0 (0.0)	3 (2.1)
Comorbidities		
Charlson comorbidity index		
Median [IQR]	3 [1–4]	3 [2–5]
0	8 (11.0)	7 (4.9)
1–2	26 (35.6)	48 (33.6)
3	11 (15.1)	18 (12.6)
4	11 (15.1)	22 (15.4)

Table 2 (*Continued*)

Table 2 (*Continued*)

Characteristics	Major resection, n=73	Minor resection, n=143
5	4 (5.5)	14 (9.8)
6	6 (8.2)	6 (4.2)
7–11	7 (9.6)	18 (12.6)
Diabetes, n (%)	17 (23.3)	20 (14.0)
Coronary artery disease, n (%)	10 (13.7)	17 (11.9)
Peripheral vascural disease, n (%)	1 (1.4)	2 (1.4)
Pulmonary disease, n (%)	3 (4.1)	15 (10.5)
Congestive heart failure, n (%)	3 (4.1)	3 (2.1)
Rheumatic disease, n (%)	2 (2.7)	1 (0.7)
Hepatic disease, n (%)	1 (1.4)	5 (3.5)
Renal disease, n (%)	1 (1.4)	3 (2.1)
Other malignancy, n (%)	5 (6.8)	3 (2.1)
Neoadjuvant treatment, n (%)		
No	36 (49.3)	93 (65.0)
Yes	37 (50.7)	50 (35.0)
Histology, n (%)		
Colorectal cancer metastasis	44 (60.3)	79 (55.2)
Other cancer	27 (37.0)	55 (38.5)
Benign	2 (2.7)	9 (6.3)

Assignment of non-NSQIP complications

For patients who underwent PD (n=200), the rates of postoperative pancreatic fistula (POPF), biliary leaks, and delayed gastric emptying (DGE) were collected prospectively. POPFs were classified according to International Study Group of Pancreatic Fistula (ISGPF) updated definition as grade B or grade C fistula (12,13). Biliary leakage was graded according to International Study Group of Liver Surgery (ISGLS) grading system (14). DGE was classified according the International Study Group of Pancreatic Surgery (15). Postoperative hepatic dysfunction was defined as prolonged hyperbilirubinemia (unrelated to obstruction or leak), ascites, and/or encephalopathy.

The study was approved by the Central Finland Hospital District. Because of the observational nature of the study, patient informant consent was not required.

Results

Baseline characteristics of the study population

In all, 527 consecutive patients that had undergone pancreatic or liver resection were included in this study. A total of 218 major and 93 minor pancreatic resections were performed during the study period. The histological diagnosis was pancreatic ductal adenocarcinoma in 127 (58.3%) and 16 (17.2%), other cancer in 62 (28.9%) and 38 (40.9%), and benign disease in 30 (13.8%) and 39 (41.9%) patients, respectively (*Table 1*).

Seventy-three major and 143 minor hepatic resections were performed. The histological diagnosis was colorectal cancer metastasis in 44 (60.3%) and 79 (55.2%), other cancer in 37.0% and 38.5%, and benign disease in 2.7% and 6.3% of patients, respectively (*Table 2*). Simultaneous bowel

Table 3 Complications associated with major pancreatic resections (n=218)

Complication	Frequency of all complications (n)	Accordion severity grade							Frequency of highest grade complications (n)
		NHG	1	2	3	4	5	6	
Bleeding	11	4			4	2	1		7
Superficial incisional SSI	0								0
Organ space SSI	40	7	1	3	17	11	1		33
Sepsis	13	4		7		2			9
Urinary tract infection	3	1		2					2
Pneumonia	4	2		1		1			2
On ventilator >48 h	0								0
Septic shock	0								0
Unplanned intubation	2	2							0
Deep venous thrombosis	5	2				3			3
Deep incisional SSI	3		1	1		1			3
Wound disruption	4		2			2			4
Death	7							7	7
Acute renal failure	2	1				1			1
Myocardial infarction	2				1	1			2
Pulmonary embolism	1	1							0
Cardiac arrest requiring CPR	0								0
Progressive renal insufficiency	0								0
Other occurrence	20	3	4	6	8	2			17
Stroke/CVA	1	1							0
Coma	0								0
Peripheral nerve injury	0								0
Craft prothesis/flap failure	1	1							0
All complications	119	29	8	20	30	26	3	7	90
Burden									
Weighted burden by grade			(0.11)	(0.26)	(0.37)	(0.60)	(0.79)	(1.00)	
Burden by grade			0.88	5.20	11.1	15.60	2.37	7.00	Total 42.15
% Burden			2	12	26	37	6	17	100

Table 4 Complications associated with minor pancreatic resections (n=93)

Complication	Frequency of all complications (n)	Accordion severity grade							Frequency of highest grade complications (n)
		NHG	1	2	3	4	5	6	
Bleeding	2	1			1				1
Superficial incisional SSI									
Organ space SSI	16	3		1	11		1		13
Sepsis	1	1							
Urinary tract infection	1			1					1
Pneumonia	2			2					2
On ventilator >48 h									
Septic shock									
Unplanned intubation									
Deep venous thrombosis	1			1					1
Deep incisional SSI	1		1						1
Wound disruption									
Death	1							1	1
Acute renal failure									
Myocardial infarction									
Pulmonary embolism	1	1							
Cardiac arrest requiring CPR									
Progressive renal insufficiency									
Other occurrence	7	4	1		1	1			3
Stroke/CVA									
Coma									
Peripheral nerve injury									
Craft prothesis/flap failure									
All complications	33	10	2	5	13	1	1	1	23
Burden									
Weighted burden by grade			(0.11)	(0.26)	(0.37)	(0.60)	(0.79)	(1.00)	
Burden by grade			0.22	1.30	4.81	0.60	0.79	1.00	Total 8.72
% Burden			3	15	55	7	9	11	

Table 5 Complications associated with major liver resections (n=73)

Complication	Frequency of all complications (n)	Accordion severity grade							Frequency of highest grade complications (n)
		NHG	1	2	3	4	5	6	
Bleeding	7	2	0	4	1	0	0	0	5
Superficial incisional SSI	5	1	1	3	0	0	0	0	4
Organ space SSI	11	2	0	1	3	3	2	0	9
Sepsis	8	7	0	1	0	0	0	0	1
Urinary tract infection	3	1	0	2	0	0	0	0	2
Pneumonia	11	3	0	2	6	0	0	0	8
On ventilator >48 h	0	0	0	0	0	0	0	0	0
Septic shock	0	0	0	0	0	0	0	0	0
Unplanned intubation	5	4	0	0	0	1	0	0	1
Deep venous thrombosis	0	0	0	0	0	0	0	0	0
Deep incisional SSI	3	0	0	0	3	0	0	0	3
Wound disruption	3	0	1	2	0	0	0	0	3
Death	5	0	0	0	0	0	0	5	5
Acute renal failure	1	1	0	0	0	0	0	0	0
Myocardial infarction	1	1	0	0	0	0	0	0	0
Pulmonary embolism	1	0	0	0	0	1	0	0	1
Cardiac arrest requiring CPR	0	0	0	0	0	0	0	0	0
Progressive renal insufficiency	0	0	0	0	0	0	0	0	0
Other occurrence	14	9	1	1	1	0	2	0	5
Stroke/CVA	1	1	0	0	0	0	0	0	0
Coma	1	1	0	0	0	0	0	0	0
Peripheral nerve injury	0	0	0	0	0	0	0	0	0
Craft prothesis/flap failure	0	0	0	0	0	0	0	0	0
All complications	80	33	3	16	14	5	4	5	47
Burden									
Weighted burden by grade			(0.11)	(0.26)	(0.37)	(0.60)	(0.79)	(1.00)	
Burden by grade			0.33	4.16	5.18	3.00	3.16	5.00	Total 20.83
% Burden			2	20	25	14	15	24	

Table 6 Complications associated with minor liver resections (n=143)

Complication	Frequency of all complications (n)	Accordion severity grade							Frequency of highest grade complications (n)
		NHG	1	2	3	4	5	6	
Bleeding	6	2	0	2	2	0	0	0	4
Superficial incisional SSI	3	0	0	2	0	1	0	0	3
Organ space SSI	19	2	0	1	15	1	0	0	17
Sepsis	4	3	0	0	1	0	0	0	1
Urinary tract infection	4	2	0	2	0	0	0	0	2
Pneumonia	9	1	0	7	0	0	1	0	8
On ventilator >48 h	1	1	0	0	0	0	0	0	0
Septic shock	0	0	0	0	0	0	0	0	0
Unplanned intubation	1	1	0	0	0	0	0	0	0
Deep venous thrombosis	1	1	0	0	0	0	0	0	0
Deep incisional SSI	4	0	0	1	3	0	0	0	4
Wound disruption	2	0	0	2	0	0	0	0	2
Death	1	0	0	0	0	0	0	1	1
Acute renal failure	1	1	0	0	0	0	0	0	0
Myocardial infarction	0	0	0	0	0	0	0	0	0
Pulmonary embolism	2	0	0	1	1	0	0	0	2
Cardiac arrest requiring CPR	0	0	0	0	0	0	0	0	0
Progressive renal insufficiency	0	0	0	0	0	0	0	0	0
Other occurrence	11	5	1	2	2	1	0	0	6
Stroke/CVA	1	0	0	0	0	1	0	0	1
Coma	0	0	0	0	0	0	0	0	0
Peripheral nerve injury	0	0	0	0	0	0	0	0	0
Craft prothesis/flap failure	0	0	0	0	0	0	0	0	0
All complications	70	19	1	20	24	4	1	1	51
Burden									
Weighted burden by grade			(0.11)	(0.26)	(0.37)	(0.60)	(0.79)	(1.00)	
Burden by grade			0.11	5.20	8.88	2.40	0.79	1.00	Total 18.38
% Burden			1	28	48	13	4	5	

Table 7 PMI and average burden in complication-bearing cases by operation

Operation	n	Overall PMI	Complication-bearing cases		Average burden in complication bearing cases
			n	%	
Major pancreas	218	0.193	90	41	0.468
Minor pancreas	93	0.094	23	25	0.379
Major hepatic	73	0.285	47	64	0.443
Minor hepatic	143	0.129	51	36	0.360
Total	527	0.171	211	40	0.427

PMI, Postoperative Morbidity Index.

resection was performed in 19.2% and 19.6% of patients, respectively (*Table 2*).

The mean annual number of pancreatic resections was 11 between 2000–2007 and increased to 22 from 2008–2017. Respective figures in liver surgery were 6 and 17. Patient characteristics, including comorbidities using the Charlson Comorbidity Index (CCI), are presented in *Tables 1*,*2*.

Major pancreatic resections

The frequency of NSQIP complications by severity grade is shown in *Table 3*. In all, 41.1% of patients suffered at least one NSQIP complication, and 16.9% had more than one complication. Major complications (MASGS 4-6) occurred in 13.3% of cases. The overall number of complications was 171. The most frequently encountered complications were organ space surgical site infection (n=40) and other occurrence (n=20). Other occurrence consisted of complications like chylus leak, arterial thrombosis, arrythmia, and postoperative ileus.

Minor pancreatic resections

The frequency of NSQIP complications by severity grade is shown in *Table 4*. In all, 24.7% of patients suffered at least one NSQIP complication, and 9.8% had more than one complication. Major complications (MASGS 4-6) occurred in 3.3% of cases. The overall number of complications was 33. The most frequently encountered complication was organ space surgical site infection (n=16).

Major liver resections

The frequency of NSQIP complications by severity grade is shown in *Table 5*. In all, 64.4% of patients suffered at least one NSQIP complication, and 17.8% had more than one complication. Major complications (MASGS 4-6) occurred in 19.2% of cases. The overall number of complications was 80. The most frequently encountered complications were organ space surgical site infections (n=11), pneumonia (n=11), and bleeding (n=7).

Minor liver resections

The frequency of NSQIP complications by severity grade is shown in *Table 6*. In all, 35.7% of patients suffered at least one NSQIP complication, and 9.8% had more than one complication. Major complications (MASGS 4-6) occurred in 6.3% of cases. The overall number of complications was 70. The most frequently encountered complications were organ space surgical site infections (n=19) and pneumonia (n=9).

Burden of complications and Postoperative Morbidity Index

The weighted burden of NSQIP complications separately for major and minor pancreatic and hepatic procedures is presented in the end of *Tables 3-6*. The PMI for all 527 patients was 0.177, as shown in *Table 7*. The PMI for patients who received major pancreatic resection was 0.192, and the PMI for patients receiving minor pancreatic resection, major liver resection, and minor liver resection was 0.094, 0.285 and 0.129, respectively.

Non-NSQIP complications

We also collected procedure-specific outcomes, not accrued by NSQIP methodology, to enable comparison of our results with those of other hospitals.

For patients who received PD (n=200), the POPF rates were 6.5% for grade B and 5.5% for grade C. The biliary leak rates were 1.0% for grade A leakage, 2.5% for grade B leakage and 0.5% for grade C leakage. The DGE rates were 2.8% for grade A, 15.6% for grade B and 3.7% for grade C.

For patients who received liver resection, major surgical site bleeding occurred in 5 (2.3%) and biloma occurred in 17 (7.9%) patients. Postoperative hepatic dysfunction occurred in 5 (2.3%) patients. In patients undergoing major hepatic resection, median (IQR) laboratory values at postoperative day 3 were as follows: alkaline phosphatase 98 [57–176], alanine aminotransferase 350 [274–546], bilirubin 28 [17–46], ammonia 43 [31–64], and INR 1.6 [1.5–1.9]. Preoperative albumin level was 37 [36–40]. Respectively, values in patients with minor hepatic resection were: alkaline phosphatase 79 [57–130], alanine aminotransferase 299 [135–527], bilirubin 14 [10–22], ammonia 34 [19–43], and INR 1.4 [1.2–1.6]. Preoperative albumin level was 38 [35–40].

The median [IQR] duration of stay was 12 [8–17] days for major pancreatic resections, 7 [6–10] days for minor pancreatic resections, 9 [7–14] days for major liver resections, and 7 [6–11] days for minor liver resections.

The 30-day readmission rate was 9.6% for patients with major pancreatic resections, 4.3% for those with minor pancreatic resections, 17.8% for those with major liver resections, and 7.0% for those with minor liver resections. The 30-day mortality rates were 3.2% and 1.1% in major and minor pancreatic resections, respectively, and 6.8% and 0.7% in major and minor liver resections, respectively. The 90-day mortality rates were 3.7% and 1.1% in major and minor pancreatic resections, respectively, and 8.2% and 0.7% in major and minor liver resections, respectively.

Complications over time

To compare differences in complication rates over time we divided data into two equal sized groups (2000–2010, 2011–2017). In major pancreatic resections overall complication rates in former and latter time period were 41.5% and 41.1%, P=0.957. Major complications occurred in 10.6% and 15.3%, P=0.313, respectively. After minor pancreatic resections overall complication rates were 20.4% and 29.5%, P=0.308, and major complication rates 2.0% and 4.5%, P=0.495, respectively.

In major liver resections overall complication rates in former and latter time period were 72.7% and 45.0%, P=0.017. Major complications occurred in 24.2% and 15.0%, P=0.318, respectively. After minor liver resections overall complication rates were 32.2% and 40.5%, P=0.313, and major complication rates 8.5% and 4.8%, P=0.368, respectively.

Discussion

This study is, to our knowledge, the first to compare different hepatopancreatic procedures using a quantitative severity weighting system. PMI was found informative, giving a simple value that includes information about both the number and the severity of complications for comparison with other procedures or institutions. In general, the quality of surgery in our center was in line with that reported earlier in the literature (16). However, the complication burden level measured with PMI in the benchmark studies was not fully achieved. Postoperative mortality was in line with that reported earlier in the literature (17-19).

Particularly, the PMI of 0.192 for major pancreatic resections was relatively high compared with the results of the institutions involved in Vollmer's benchmark study (1) or the results Strasberg *et al.* reported in 2011 (7). Vollmer *et al.* reported PMI varying between 0.097–0.239 depending on institution, whereas Strasberg *et al.* reported PMI 0.150 for a small sample of patients who underwent PD. In the present study, the proportion of complications "other occurrence" was significantly higher (16.8%) compared to papers mentioned earlier. "Other occurrence" consisted of complications like chylus leak, arterial thrombosis, arrythmia, and ileus in the present study. The low proportion of "other occurrence" (0.2%) in the benchmark study by Vollmer *et al.* indicates the possibility that such complications were ignored when focusing on NSQIP. Moreover, 5% of pancreaticoduodenectomies in the present study were performed with extended lymphadenectomy, a procedure that is known to be associated with higher complication rates (20). Nevertheless, the rate of pancreatic-specific non-NSQIP complications were congruent with rates reported earlier in the literature (1,21). Similarly, the overall morbidity of 41.1% in our study is equal to or lower than rates reported earlier in literature (10,16). The postoperative morbidity of patients who underwent minor pancreatic resection was low or equal when compared with the results reported earlier (8,22,23).

Strasberg *et al.* reported PMI 0.145 in 52 major hepatic resections (7), which is significantly lower than PMI 0.285 in our study. However, simultaneous bowel resection

was performed in 19% of patients in our study, which is associated with higher complication rates and more serious complications (7,24). Furthermore, variations have been reported in complication rates after liver surgery in liver donors and recipients of liver transplant, with overall complications ranging from 27% to 80% and major complications ranging from 6% to 42% (2,25). Liver donors are, however, young and healthy people; in contrast, patients undergoing liver resection for malignant disease tend to be older, have comorbid conditions, and are often receiving neoadjuvant chemotherapy. Our postoperative mortality rate (2.8%) after liver surgery was in agreement with the range of 1.8–5.6% reported in population-based studies from Sweden and the United States, with ratios of major and minor resections very similar to our study (26). Furthermore, population-based studies (such as ours) tend to have higher morbidity and mortality rates than single-center reports, possibly due to selective reporting (26).

Textbook outcomes, defined as no postoperative surgical complications, prolonged hospital stays, or readmissions, have been recently reported for minor and major pancreatic and liver resections classified similarly to those in our study (3). In the study by Merath *et al.*, textbook outcome was not achieved in 75.3% of patients who underwent major pancreatic resection and in 52.2% who underwent minor pancreatic resection. Respective values among patients with major and minor liver resection were 66.7% and 53.2% (3). This corresponds to or exceeds our overall complication values of 41.1%, 24.7%, 64.4%, and 35.7%, respectively. The 30-day readmission rate of patients who underwent major pancreatic resection was 9.6% in the present study. This is lower than in the benchmark study (1), but can be partly explained by longer hospital stays in our study. In patients who underwent major and minor liver resection, the median hospital stays were 9 and 7 days, respectively, and 30-day readmission rates were 17.8% and 7%, respectively. These numbers are comparable with registry data on hepatopancreatobiliary surgery from the United States, where 7-day hospital stays and 17% readmission rates were reported (27). In all, 30.1% of minor pancreatic resections were done in a minimally invasive manner, a notably high rate taking into account that the first laparoscopic pancreatic resection was done at our center in 2007. We observed no major changes in complication rates over time, except some improvements in major liver resections.

Organ space surgical site infections were the most common complications in both pancreatic and liver surgeries. Infected pancreatic fistula is the obvious cause for the high number of organ space surgical site infections after pancreatic resections, and simultaneous bowel and liver surgery after liver resections. No single complication type differed significantly from previous reports, and therefore an easy solution to improve postoperative morbidity could not be found. Both major pancreatic and liver resections were associated with heavy burdens of complication, showing PMIs twice as high as in minor resections.

Our results should be interpreted with some caution, however. The major weakness of this study is the relatively small number of patients compared to large international patient series. The quantitative complication scoring system enables comparison between different operations and centers with exact thresholds for what actually constitutes a complication, but it also lacks data on procedure-specific complications (such as POPF and DGE after pancreatic surgery, and biloma formation and liver failure after hepatic surgery). These limitations have been recognized previously (28). For this reason, we reported procedure-specific complications separately as non-NSQIP complications, according to Vollmer *et al.* (1). The strengths of this study include prospective data collection, double checking of the hospital records by another researcher not responsible of treating these patients, and complete follow-up data. Moreover, all patients from a single geographic area were included in the study, making selection bias unlikely and illustrating the real-life situation. Treatment of late complications is conducted in our center, which is the only hospital in the area.

In conclusion, PMI appears to be an informative method to monitor outcomes in pancreatic and hepatic surgery enabling demonstrative comparison between various procedures and institutions. Our results are comparable with previous population- and registry-based results, but improvements are needed to achieve reported benchmark levels.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/jgo.2020.04.03). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The research was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Central Finland Hospital District. Because of the observational nature of the study, patient informant consent was not required.

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