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Transatlantic registries of pancreatic surgery in the United States of America, Germany, the Netherlands, and Sweden: Comparing design, variables, patients, treatment strategies, and outcomes

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ABSTRACT

Background: Registries of pancreatic surgery have become increasingly popular as they facilitate both quality improvement and clinical research. We aimed to compare registries for design, variables collected, patient characteristics, treatment strategies, clinical outcomes, and pathology.

Methods: Registered variables and outcomes of pancreatoduodenectomy (2014–2017) in 4 nationwide or multicenter pancreatic surgery registries from the United States of America (American College of Surgeons National Surgical Quality Improvement Program), Germany (Deutsche Gesellschaft für Allgemein- und Viszeralchirurgie - Studien-, Dokumentations- und Qualitätszentrum), the Netherlands (Dutch Pancreatic Cancer Audit), and Sweden (Swedish National Pancreatic and Periampullary Cancer Registry) were compared. A core registry set of 55 parameters was identified and evaluated using relative and absolute largest differences between extremes (smallest versus largest).

Results: Overall, 22,983 pancreatoduodenectomies were included (15,224, 3,558, 2,795, and 1,406 in the United States of America, Germany, the Netherlands, and Sweden). Design of the registries varied because 20 out of 55 (36.4%) core parameters were not available in 1 or more registries. Preoperative chemotherapy in patients with pancreatic ductal adenocarcinoma was administered in 27.6%, 4.9%, 7.0%, and 3.4% (relative largest difference 8.1, absolute largest difference 24.2%, $P < .001$). Minimally invasive surgery was performed in 7.8%, 4.5%, 13.5%, and unknown (relative largest difference 3.0, absolute largest difference 9.0%, $P < .001$). Median length of stay was 8.0, 16.0, 12.0, and 11.0 days (relative largest difference 2.0, absolute largest difference 8.0, $P < .001$). Reoperation was performed in 5.7%, 17.1%, 8.7%, and

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11.2% (relative largest difference 3.0, absolute largest difference 11.4%, $P < .001$). In-hospital mortality was 1.3%, 4.7%, 3.6%, and 2.7% (relative largest difference 3.6, absolute largest difference 3.4%, $P < .001$).
Conclusion: Considerable differences exist in the design, variables, patients, treatment strategies, and outcomes in 4 Western registries of pancreatic surgery. The absolute largest differences of 24.3% for the use of preoperative chemotherapy, 9.0% for minimally invasive surgery, 11.4% for reoperation rate, and 3.4% for in-hospital mortality require further study and improvement. This analysis provides 55 core parameters for pancreatic surgery registries.

Introduction

To facilitate assessment of quality and outcome of pancreatic surgery, several nationwide and multicenter registries have been established in recent years. Many cohort studies are performed with registry data, which are used as the basis for daily practice, clinical guidelines, and development of prospective studies around the world. It is, however, unclear to what extent data from these various registries are comparable. To ascertain adequate external validity of reports from these registries, differences in registry variables (eg, various variable definitions, selection of inclusion), patient and treatment characteristics, and outcomes should not go unnoticed.

Registry design may vary considerably. A previous European project identified a common dataset for 11 European pancreatic cancer registries.[1] Of the 8 registries which provided data, only 3 covered surgical details of which 2 were incomplete for the shared items in this project (eg, type of resection, vascular resection, and postoperative complications). To provide insight in surgical practice variation and potentially improve postoperative outcomes of pancreatic surgery worldwide, a comparison among registries with surgical details with a more homogenous patient group outside of Europe is, therefore, essential.

Various Western countries have developed registries on pancreatic surgery. Our aim was to compare differences in (1) collected variables and definitions; (2) patient, tumor, and surgical treatment characteristics; and (3) clinical and pathological outcomes. Based on this comparison, a core-parameter set for registries on pancreatic surgery aimed to improve uniform data acquisition worldwide is provided. With this effort, outcomes can be compared more accurately, and clear benchmarks can be set worldwide. This comparison may ultimately lead to reduced practice variation and improvement of outcomes globally.

Methods

Study design

Comparison of 4 registries on pancreatic surgery with a focus on pancreatoduodenectomy from the United States (American College of Surgeons National Surgical Quality Improvement Program)[2]: multicenter, 147 centers in 2017, including several Canadian hospitals); Germany (Deutsche Gesellschaft für Allgemein- und Viszeralchirurgie - Studien-, Dokumentations- und Qualitätszentrum [DGAV StuDoQ|Pancreas][3]: multicenter, 54 centers in 2017); the Netherlands (Dutch Pancreatic Cancer Audit [DPCA][4]: nationwide, 17 centers in 2017); and Sweden (Swedish National Pancreatic and Periampullary Cancer Registry[5]: nationwide, 6 centers in 2017). Registries for pancreatic surgery from Australia, Canada, France, Japan, and Norway were also assessed, but data were not yet sufficiently available, or registries were still under construction. The primary aim of this study was to assess the design of the registries and, secondly, to explore the data captured in the 4 countries. We compared differences in (1) collected variables and definitions; (2) patient, tumor, and treatment characteristics; and (3) patient outcomes. This study was designed in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.[6]

Study population

The study population included all adults who underwent pancreatoduodenectomy for all indications during a 4-year period (2014–2017) and were registered in 1 of the 4 described registries.

Core parameters

First, a literature search was performed to identify important risk factors and outcomes (TM), which were then discussed in the study team. Thereafter, a panel of core parameters was established by identifying key variables from the existing pancreatic surgery registries by all coauthors. This effort was followed by reviewing availability of these key variables per registry. Second, definitions of the key variables were compared to assess whether an accurate comparison among registries was possible. Data of all registries were extracted by anonymized export, and the panel of core parameters from all datasets were merged for analysis. Core parameters were divided into baseline and preoperative characteristics, treatment characteristics, surgical outcomes, and pathological outcomes.

Parameter differences owing to various metric systems were resolved by converting the data, such as weight in ounces into kilograms or height in inches into meters. Several parameters were recategorized so that data could be combined, such as functional health status as independent, partially dependent, or totally dependent and pancreatic duct size as $\leq$3 and >3 millimeter. Pancreatic surgery specific complications (ie, pancreatic fistula, postpancreatectomy hemorrhage, delayed gastric emptying, bile leakage) were (newly) categorized according to the International Study Group of Pancreatic Surgery and Liver Surgery criteria[7–11] as accurately as possible, as not all registries recorded these complications according to these definitions. The reoperation and readmission parameters differed in interval (30 days postsurgery vs 30 days postdischarge) yet were combined.

Statistical analysis

Characteristics are presented as proportions with percentages in case of categorical data or as mean ± standard deviation or median with interquartile ranges in case of normally or not-normally distributed data, respectively. Statistical comparisons were done by analysis of variance or χ^2 test as appropriate. Because of the large dataset (>20,000 cases), even minimal differences were statistically significant; therefore, the relative and absolute largest differences (RLD, ALD) between the smallest and largest outcomes among the 4 registries also were presented. RLD is a ratio and ALD an absolute percentage difference. Because the primary aim was to compare design and variables, no multivariable analysis was performed.

Fig 1. Availability of 55 core parameters during 2014 to 2017 in 4 registries on pancreatic surgery in Western countries. Diagonal stripes: available in registry. Dots: not available in registry. *COPD*, chronic obstructive pulmonary disease; *ICU*, intensive care unit; *PD*, pancreatoduodenectomy; *POD*, postoperative day.

Table I
Comparison of surgical outcomes in 4 registries on pancreatic surgery in Western countries

	United States (NSQIP) N = 15,224	Germany (StuDoQ) N = 3,558	Netherlands (DPCA) N = 2,795	Sweden (SNPPCR) N = 1,406	Relative largest difference	Absolute largest difference	Patient subgroups
ICU admission, *n* (%)	NA	363 (10.2)	345 (12.3)	68 (4.8)	2.6	7.5%	All patients
Missing		15 (0.4)	61 (2.2)	77 (5.5)			
Surgical site infection, *n* (%)	1,569 (10.3)	416 (11.7)	138 (4.9)	80 (5.7)	2.4	6.8%	All patients
Missing	0 (0.0)	86 (2.4)	954 (34.1)	0 (0.0)			
Pneumonia, *n* (%)	599 (3.9)	250 (7.0)	98 (3.5)	189 (13.4)	3.8	9.9%	All patients
Missing	0 (0.0)	13 (0.4)	960 (34.3)	79 (5.6)			
Pancreatic fistula grade B/C, *n* (%)	1,658 (10.9)	490 (13.8)	394 (14.1)	222 (15.8)	1.4	4.9%	All patients
Missing	140 (0.9)	15 (0.4)	23 (0.8)	1 (0.1)			
Post pancreatectomy hemorrhage grade B/C, *n* (%)	NA	336 (9.4)	231 (8.3)	122 (8.7)	1.1	1.1%	All patients
Missing		14 (0.4)	47 (1.7)	0 (0.0)			
Delayed gastric emptying grade B/C, *n* (%)	2,559 (16.8)	270 (10.4)	527 (18.9)	104 (7.4)	2.6	11.5%	All patients
Missing	239 (1.6)	14 (0.4)	32 (1.1)	0 (0.0)			
Bile leak grade B/C, *n* (%)	NA	181 (5.1)	144 (5.2)	66 (4.7)	1.1	0.5%	All patients
Missing		0 (0.0)	42 (1.5)	0 (0.0)			
Radiologic intervention performed, *n* (%)	1,955 (12.8)	NA	489 (17.5)	NA	1.4	4.7%	All patients
Missing	138 (0.9)		86 (3.1)				
Organ failure, *n* (%)	927 (6.1)	363 (10.2)	209 (7.5)	68 (4.8)	2.1	5.4%	All patients
Missing	0 (0.0)	15 (0.4)	122 (4.4)	77 (5.5)			
Reoperation, *n* (%)	866 (5.7)	607 (17.1)	242 (8.7)	157 (11.2)	3.0	11.4%	All patients
Missing	0 (0.0)	35 (1.0)	98 (3.5)	79 (5.6)			
Length of stay, median days (IQR)	8.0 (6.0–12.0)	16.0 (13.0–24.0)	12.0 (8.0–19.0)	11.0 (8.0–17.0)	2.0	8.0	Excluding patients with in-hospital mortality
Missing, *n* (%)	45/15,028 (0.3)	3/3,378 (0.1)	24/2,679 (0.9)	24/1,238 (1.9)			
Readmission, *n* (%)	2,518 (16.5)	295 (8.3)	465 (16.6)	NA	2.0	8.3%	All patients
Missing	10 (0.1)	36 (1.0)	154 (5.5)				
In-hospital mortality, *n* (%)	196 (1.3)	168 (4.7)	102 (3.6)	38 (2.7)	3.6	3.4%	All patients
Missing	0 (0.0)	12 (0.3)	14 (0.5)	130 (9.2)			
Clavien-Dindo classification, *n* (%)							
No complications or Clavien Dindo <3	12,141 (79.7)	2,421 (68.0)	1,863 (66.7)	1,034 (73.5)	1.6	11.2%	All patients
Clavien Dindo ≥3	3,083 (20.3)	1,122 (31.5)	867 (31.0)	295 (21.0)			
Missing	0 (0.0)	15 (0.4)	65 (2.3)	77 (5.5)			
Time between resection-death in patients with in-hospital mortality, median days (IQR)	10.0 (6.0–16.0)	19.5 (10.0–33.8)	13.0 (6.5–25.5)	23.0 (16.5–44.5)	2.3	13	Of patients with in-hospital mortality
Missing, *n (%)*	0/196 (0.0)	0/168 (0.0)	1/102 (1.0)	1/38 (2.6)			

P values were all < .001.
IQR, interquartile range; *NSQIP*, National Surgical Quality Improvement Program; *StuDoQ*, Studien-, Dokumentations- und Qualitätszentrum; *DPCA*, Dutch Pancreatic Cancer Audit; *SNPPCR*, Swedish National Pancreatic and Periampullary Cancer Registry.

Missing data have been described and not imputed. All calculations were performed with SPSS (IBM Corporation, Armonk, NY).

Results

Identified core parameters

In total, we selected 55 core parameters. Figure 1 shows the core parameters per registry. Design of the registries varied among the countries because 20 out of 55 (36.4%) core parameters were not available in 1 or more registries, including pancreatic duct size, pancreatic gland texture, abdominal drain placement during surgery, intensive care unit admission, postpancreatectomy hemorrhage, bile leak, readmission, and resection margin (Fig 1).

For all variable definitions (including discrepancies) and details per registry and combined variable definitions for this study, see Supplementary Table S2. The core parameter set of 55 variables, including detailed variable definitions, is provided in Supplementary Table S3. Bilirubin, annual pancreatoduodenectomy volume per center, drain fluid amylase postoperative days 1 and 3, and organ space infection were not sufficient for analyses in this study but were included in the suggested core parameter set.

Baseline and preoperative characteristics

Supplementary Table S1 demonstrates the comparison of the core parameters among the 4 registries. Overall, 22,983 pancreatoduodenectomies were included (15,224 from the United States vs 3,558 from Germany vs 2,795 from the Netherlands vs 1,406 from Sweden). Body mass index (BMI) (27.3, 25.6, 25.2, and 25.4 kg/m^2, RLD 1.1, ALD 2.1) and American Society of Anesthesiologists (ASA) (77.7%, 48.2%, 22.5%, and 27.2% ASA III–IV, RLD 3.5, ALD 55.2%) were highest in the United States (both *P* < .001). Patients from the United States and Germany more often suffered from diabetes mellitus (25.8%, 25.7%, 20.3%, and 19.7%, RLD 1.3, ALD 6.1%) and hypertension (52.9%, 56.3%, 30.3%, and 46.9%, RLD 1.9, ALD 26.0%, both *P* < .001). Preoperative biliary drainage was performed most often in Sweden (48.9%, 35.9%, 48.4%, and 61.0%, RLD 1.7, ALD 25.1%, *P* < .001). Preoperative chemotherapy in patients with pancreatic ductal adenocarcinoma was used most often in the

United States (27.6%, 4.9%, 7.0%, and 3.4%, RLD 8.1, ALD 24.2%, $P < .001$).

Treatment characteristics

Laparoscopic or robotic procedures (including conversion) were performed mostly in the Netherlands (7.8%, 4.5%, 13.5%, and unknown, RLD 3.0, ALD 9.0%, $P < .001$). Pylorus preservation occurred in 37.8%, 71.1%, 58.5%, and 23.3% (RLD 3.1, ALD 47.8%, $P < .001$). Additional venous and/or arterial resection was done most commonly in the United States and Sweden (17.2%, 11.3%, 14.9%, and 18.5%, RLD 1.6, ALD 7.2%, $P < .001$). In all countries, a pancreaticojejunal duct-to-mucosa anastomosis was the most frequent type of pancreatic reconstruction (82.2%, 60.8%, 56.4%, and 51.4%, RLD 1.6, ALD 30.8, $P < .001$).

Surgical outcomes

A comparison of surgical outcomes in the 4 registries is provided in Table I. Clinically relevant pancreatic fistulae were mostly registered in Sweden, while rates of postpancreatectomy hemorrhage were similar among the countries. Reoperation was performed mostly in Germany and Sweden. Complications of Clavien-Dindo grade ≥3 were reported mostly in Germany and the Netherlands. Median length of stay was lowest in the United States, whereas the United States and the Netherlands had the most readmissions. In-hospital mortality was the lowest in the United States.

Pathological outcomes

Pancreatic or periampullary (ie, duodenal, ampulla of Vater, distal bile duct) adenocarcinoma was the indication for resection in 70.1%, 67.9%, 75.0%, and 76.9% of patients (RLD 1.1, ALD 9.0%, $P < .001$). The majority of patients with pancreatic or periampullary carcinoma had a stage T3 tumor (69.7%, 64.7%, 61.5%, and 66.6%, RLD 1.1, ALD 8.2%, $P < .001$) with positive regional lymph nodes (63.2%, 64.4%, 66.3%, and 70.6%, RLD 1.1, ALD 7.4%, $P < .001$). The tumor stage was most often categorized as stage IIB (43.3%, 44.3%, 52.1%, and 57.9%, RLD 1.3, ALD 14.6%, $P < .001$).

Discussion

Nationwide or multicenter registries on pancreatic surgery are becoming increasingly popular and produce large amounts of data, which may have global clinical implications for quality control. This first transatlantic comparison of 4 large registries from Western countries demonstrated that over one-third of the identified 55 core parameters were not available in 1 or more registries. Furthermore, considerable differences exist in patients and treatment characteristics and outcomes. The absolute largest differences were 6.1% for diabetes mellitus, 24.3% for the use of preoperative chemotherapy for pancreatic cancer, 9.0% for minimally invasive surgery, 11.4% for reoperation rate, 8 days for median length of stay, and 3.4% for in-hospital mortality.

Interestingly, various parameters that are important predictors of outcomes in pancreatic surgery (eg, pancreatic duct size, pancreatic gland texture, postpancreatectomy hemorrhage, resection margin) were not registered in 1 or more registries.[12,13] The differences are partly because of the various development strategies of the registries. In 2004, the American College of Surgeons National Surgical Quality Improvement Program for pancreatic surgery was built from the initial Veterans Affairs National Surgical Quality Improvement Program (NSQIP), in which data on major operations were captured with the aim to provide feedback and reduce postoperative morbidity and mortality.[2] Subsequently, members of the Americas Hepato-Pancreato-Biliary Association Research Committee developed 24 pancreas-specific variables. These variables were trialed at 43 institutions in 2012, made optional for more institutions in 2013, and required at institutions targeting pancreatectomy in 2014. The German DGAV StuDoQ| Pancreas registry was based on guidelines and the literature, which was reviewed by a panel of surgeons and led to national expert consensus in 2013.[3] The design of the Dutch DPCA in 2013 was based on a systematic literature search, cross-checks with existing registries, international consensus, and national consensus through the Dutch Pancreatic Cancer Group.[4] The Swedish registry was developed in 2010 after literature research and consensus of a panel of experts.[5] The validity of the registries was described in previous studies.[2–5,12] The suggested core parameter set should not only be used as a tool to develop new pancreatic surgery registries, but also to adapt existing registries to improve worldwide uniform data capturing and selection of patients.

For “hard” outcome parameters, such as in-hospital mortality, a uniform definition was easily made. Many other variables could be converted or newly categorized. For example, functional health status was defined as the 5-tier Eastern Conference Oncology Group 0 to 4 classification in the DPCA and Swedish registry, yet as a 3-tier classification (independent/partially dependent/totally dependent) in NSQIP and StuDoQ. Therefore, the combined variable definition was restricted to the 3-tier classification. Another example was the pancreatic duct size definition. In NSQIP the lowest cutoff value was <3 millimeters, while it was ≤3 millimeters in StuDoQ. A lowest cutoff value of ≤3 millimeters was chosen, which led to misclassification of several patients from NSQIP. Although these new categories led to some information loss or misclassification, the data still became comparable. Some variables, however, were difficult to combine. For instance, although ASA scores should have an unambiguous definition, the absolute largest difference was 49% for ASA 3 classification (71% vs 22%). This large variation could point to different interpretation by anesthesiologists or data managers or registration bias. In addition, heart failure was present in 11% in Germany and 33% in Sweden, but 0.4% in the United States and 1% in the Netherlands. A previous meta-analysis showed that the prevalence of all type heart failure was 5% to 15% in older adults,[14] and these rates are expected to be lower in patients undergoing a pancreatoduodenectomy. The 2 higher rates are the result of ambiguous definitions by which other diseases (eg, rhythmic disorders) are included in addition to heart failure, as was reported in the data dictionaries of these registries. This finding indicates the importance of not only implementing key parameters but also using identical definitions in the separate registries.

Patients from the Netherlands and Sweden seem healthier than from the United States and Germany, as they have lower BMI and ASA scores and less diabetes mellitus and hypertension. This is confirmed by previous studies that also demonstrated higher BMI, diabetes, and hypertension in the US population.[15] These findings support the suggestion that patients from the Netherlands and Sweden may be healthier as a whole. However, we cannot exclude that selection has occurred (ie, sicker patients in the Netherlands and Sweden not offered surgery). A second explanation for the observed difference could be differences in patient selection between countries. For example, chronic pancreatitis was the indication for resection in 10% of the German patients compared to 3% to 4% in the other countries. Therefore, we believe the first step is to harmonize registries before an accurate comparison can be made.

Several interesting differences in treatment strategies were identified among the registries. Preoperative chemo(radio)therapy was used in 28% of patients with pancreatic adenocarcinoma in the

United States, while this rate ranged from 3% to 7% in the other 3 countries. In many European countries, preoperative chemo(radio) therapy is currently only administered in a study setting,[16,17] which explains these differences. For the United States, this management strategy may explain the higher rate of hard-fibrotic pancreatic textures (40% United States vs 31%–35% in Europe), with potentially less pancreatic fistula (11% vs 14%–16%), and less in-hospital mortality (1% vs 3%–5%).[18] In addition, the presence of several very-high-volume centers in the United States (eg, performing >300 pancreatoduodenectomies annually) may also have contributed to the low in-hospital mortality rate.[19] Unfortunately, center volume was not available as a parameter for this study and should therefore be taken into account in future analyses.

In Germany, the highest reoperation rate was found (17% vs 6%–11%), which is in line with a previously reported reoperation rate of 16%.[20] The reasons for reoperation were not reported. According to a recent report, reoperation is mostly performed for severe pancreatic fistula.[21] Compared to the United States, clinically relevant pancreatic fistulae were seen more often in Germany (14% vs 11%). However, as the Netherlands as well as Sweden have similar rates of pancreatic fistula as Germany (14%–16% vs 14% in Germany), but lower reoperation rates (9%–11% vs 17% in Germany), cultural differences may have played a role. The different reoperation rates could be related to the strategy to treat pancreatic fistula. The United States, the Netherlands, and Sweden may primarily treat pancreatic fistula with percutaneous catheter drainage whereas Germany with relaparotomy. However, this information is not recorded in the registries so this hypothesis could not be tested.

Germany had the lowest readmission rate (8% vs 16%–17%). Whereas the Netherlands used a 30-day postdischarge interval for readmission, Germany and the United States both used a 30-day postsurgery interval. Because the Netherlands and the United States have similar readmission rates, the lower rate in Germany is probably not explained by the different definitions. A systematic review found an overall 30-day readmission rate of 17% to 21%, with postoperative complications and severe complications as strong predictors of readmission.[22] However, (severe) postoperative complications occurred in various rates among the countries, thus this issue does not seem to have a direct relation with readmission in this study. Most likely, the longer length of stay in Germany (16 vs 8–12 days) contributed to the lower readmission rate. In addition, these outcomes may be explained by factors that are difficult to assess, such as cultural, geographical, insurance, health system payment and reimbursement differences, and mentality toward discharge of patients.

Some limitations of this study should be noted. First, whereas NSQIP and StuDoQ are multicenter registries, both the DPCA and SNPPRC are nationwide registries. In the United States and Germany, this difference probably resulted in a selection and registration bias because relatively more higher-volume centers participate in these registries. Currently in the United States, approximately two-thirds of the pancreatectomies performed annually are captured, and in Germany this rate is approximately one-fifth. These varying procedures for inclusion and selection of patients between multicenter versus nationwide registries may be a (partial) underlying cause of several found differences. Unfortunately, annual center volume for pancreatoduodenectomy was not available in the NSQIP and Swedish audit so the extent of this difference cannot be assessed. Second, in some instances, observed differences may be the result of definition variations among registries. This study group is now in the process of adding missing variables and reducing variations in definition by changing these per country according to our suggested core parameter set. Third, all comparisons were made in the current very large dataset by which minimal differences were statistically significant yet were not always clinically relevant. Fourth, some variables could not be compared, such as drain fluid amylase. For example, some countries may determine this at postoperative day 1, whereas others at day 3 or both days. Definitions and clinical practice were too different for a valid comparison. In the future, consensus should be reached on drain fluid amylase before a comparison can be made between countries. Fifth, registries from several countries (see Methods section) were not mature enough for inclusion or more than 50% to 75% of variables from the core parameter set was missing, and a valid comparison was not possible. This study group aims to stay in touch with these countries to expand their database according to the core parameter set and possibly include them in future studies.

In conclusion, this comparison showed that even in 4 Western countries the design of 4 pancreatic surgery registries differs. Furthermore, differences in patient selection and characteristics, treatment strategies, and outcomes exist, which requires further study and improvement. Harmonizing registries provides an opportunity to compare outcomes accurately, set clean benchmarks, and combine and extrapolate data from different countries. Ultimately, reducing practice variation may improve outcomes globally.

Conflict of interest/Disclosure

The authors have no conflicts of interest to declare.

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Supplementary materials

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References

1. de Leede EM, Sibinga Mulder BG, Bastiaannet E, et al. Common variables in European pancreatic cancer registries: The introduction of the EURECCA pancreatic cancer project. *Eur J Surg Oncol*. 2016;42:1414–1419.
2. Pitt HA, Kilbane M, Strasberg SM, et al. ACS-NSQIP has the potential to create an HPB-NSQIP option. *HPB (Oxford)*. 2009;11:405–413.
3. Wellner UF, Klinger C, Lehmann K, Buhr H, Neugebauer E, Keck T. The pancreatic surgery registry (StuDoQ|Pancreas) of the German Society for General and Visceral Surgery (DGAV) - presentation and systematic quality evaluation. *Trials*. 2017;18:163.
4. van Rijssen LB, Koerkamp BG, Zwart MJ, et al, and the Dutch Pancreatic Cancer Group. Nationwide prospective audit of pancreatic surgery: design, accuracy, and outcomes of the Dutch Pancreatic Cancer Audit. *HPB (Oxford)*. 2017;19: 919–926.
5. Tingstedt B, Andersson B, Jonsson C, et al. First results from the Swedish National Pancreatic and Periampullary Cancer Registry. *HPB (Oxford)*. 2019;21: 34–42.
6. von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP, and the STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. *Int J Surg*. 2014;12:1495–1499.
7. Bassi C, Butturini G, Molinari E, et al. Pancreatic fistula rate after pancreatic resection. The importance of definitions. *Dig Surg*. 2004;21:54–59.
8. Bassi C, Marchegiani G, Dervenis C, et al, and the International Study Group on Pancreatice Surgery (ISGPS). The 2016 update of the International Study Group (ISGPS) definition and grading of postoperative pancreatic fistula: 11 years after. *Surgery*. 2017;161:584–591.

9. Wente MN, Veit JA, Bassi C, et al. Postpancreatectomy hemorrhage (PPH): an International Study Group of Pancreatic Surgery (ISGPS) definition. *Surgery*. 2007;142:20–25.
10. Wente MN, Bassi C, Dervenis C, et al. Delayed gastric emptying (DGE) after pancreatic surgery: a suggested definition by the International Study Group of Pancreatic Surgery (ISGPS). *Surgery*. 2007;142:761–768.
11. 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;149:680–688.
12. McMillan MT, Allegrini V, Asbun HJ, et al. Incorporation of procedure-specific risk into the ACS-NSQIP Surgical Risk Calculator improves the prediction of morbidity and mortality after pancreatoduodenectomy. *Ann Surg*. 2017;265:978–986.
13. Mungroop TH, Klompmaker S, Wellner UF, et al, and the European consortium on Minimally Invasive Pancreatic Surgery (E-MIPS). Updated Alternative Fistula Risk Score (ua-FRS) to include minimally invasive pancreatoduodenectomy: Pan-European validation. *Ann Surg*; 2019. Availble from: https://doi.org/10.1097/sla.0000000000003234.
14. van Riet EE, Hoes AW, Wagenaar KP, Limburg A, Landman MA, Rutten FH. Epidemiology of heart failure: the prevalence of heart failure and ventricular dysfunction in older adults over time. A systematic review. *Eur J Heart Fail*. 2016;18:242–252.
15. Einarson TR, Acs A, Ludwig C, Panton UH. Prevalence of cardiovascular disease in type 2 diabetes: a systematic literature review of scientific evidence from across the world in 2007-2017. *Cardiovasc Diabetol*. 2018;17:83.
16. Zhan HX, Xu JW, Wu D, et al. Neoadjuvant therapy in pancreatic cancer: a systematic review and meta-analysis of prospective studies. *Cancer Med*. 2017;6:1201–1219.
17. Versteijne E, van Eijck CH, Punt CJ, et al, and the Dutch Pancreatic Cancer Group (DPCG). Preoperative radiochemotherapy versus immediate surgery for resectable and borderline resectable pancreatic cancer (PREOPANC trial): study protocol for a multicentre randomized controlled trial. *Trials*. 2016;17:127.
18. Cooper AB, Parmar AD, Riall TS, et al. Does the use of neoadjuvant therapy for pancreatic adenocarcinoma increase postoperative morbidity and mortality rates? *J Gastrointest Surg*. 2015;19:80–86;discussion 86-87.
19. Hata T, Motoi F, Ishida M, et al. Effect of hospital volume on surgical outcomes after pancreaticoduodenectomy: A systematic review and meta-analysis. *Ann Surg*. 2016;263:664–672.
20. Mackay TM, Wellner UF, van Rijssen LB, et al, and the Dutch Pancreatic Cancer Group and DGAV StuDoQ|Pancreas. Variation in pancreatoduodenectomy as delivered in two national audits. *Br J Surg*. 2019;106:747–755.
21. Smits FJ, van Santvoort HC, Besselink MG, et al, and the Dutch Pancreatic Cancer Group. Management of severe pancreatic fistula after pancreatoduodenectomy. *JAMA Surg*. 2017;152:540–548.
22. Fisher AV, Fernandes-Taylor S, Campbell-Flohr SA, et al. 30-day readmission after pancreatic resection: A systematic review of the literature and meta-analysis. *Ann Surg*. 2017;266:242–250.