



International differences in the selection and outcome of minimally invasive and open distal pancreatectomy: A transatlantic analysis



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ABSTRACT

Background: The efficacy and safety of minimally invasive distal pancreatectomy have been confirmed by randomized trials, but current patient selection and outcome of minimally invasive distal pancreatectomy in large international cohorts is unknown. This study aimed to compare the use and outcome of minimally invasive distal pancreatectomy in North America, the Netherlands, Germany, and Sweden.

Methods: All patients in the 4 Global Audits on Pancreatic Surgery Group (GAPASURG) registries who underwent minimally invasive distal pancreatectomy or open distal pancreatectomy during 2014–2020 were included.

Results: Overall, 20,158 distal pancreatectomies were included, of which 7,316 (36%) were minimally invasive distal pancreatectomies. Use of minimally invasive distal pancreatectomy varied from 29% to 54% among registries, of which 13% to 35% were performed robotically. Both the use of minimally invasive distal pancreatectomy and robotic surgery were the highest in the Netherlands. Patients undergoing minimally invasive distal pancreatectomy tended to have a younger age (Germany and Sweden), female sex (North America, Germany), higher body mass index (North America, the Netherlands, Germany), lower comorbidity classification (North America, Germany, Sweden), lower performance status (Germany), and lower rate of pancreatic adenocarcinoma (all). The minimally invasive distal pancreatectomy group had fewer vascular resections (all) and lower rates of severe complications and

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mortality (North America, Germany). In the multivariable regression analysis, country was associated with severe complications but not with 30-day mortality. Minimally invasive distal pancreatectomy was associated with a lower risk of 30-day mortality compared with open distal pancreatectomy (odds ratio 1.633, 95% CI 1.159–2.300, $P = .005$).

Conclusions: Considerable disparities were seen in the use of minimally invasive distal pancreatectomy among 4 transatlantic registries of pancreatic surgery. Overall, minimally invasive distal pancreatectomy was associated with decreased mortality as compared with open distal pancreatectomy. Differences in patient selection among countries could imply that countries are in different stages of the learning curve.

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Introduction

Minimally invasive distal pancreatectomy (MIDP) is increasingly being performed around the world over the last few decades.¹ The results from randomized trials indicate that MIDP is a safe method with a shorter time to functional recovery, shorter hospital stay, and less blood loss than open distal pancreatectomy (ODP), while having a comparable rate of severe complications.^{2,3} Patients in these randomized trials have reported improved or comparable quality of life as well as better cosmetic satisfaction after MIDP,^{4,5} and the cost-effectiveness of laparoscopic distal pancreatectomy (LDP) has been shown to be acceptable with commonly used financial thresholds for the Western world.^{6,7} The oncologic safety of the minimally invasive method for pancreatic ductal adenocarcinoma (PDAC) was uncertain for some time.⁸ However, the recently published international DIPLOMA randomized trial reported a noninferior rate of R0 resection in the MIDP group as well as comparable lymph node yield and survival.⁹ Further, the recent Brescia international guidelines on minimally invasive pancreatic surgery recommended considering the use of MIDP in benign, premalignant as well as malignant lesions (PDAC) when performed by experienced surgeons in high-volume centers.¹⁰

Robotic distal pancreatectomy (RDP) is a more recent alternative to LDP. Although no randomized trials have yet compared RDP to LDP, evidence from nonrandomized studies indicates that RDP is associated with a lower rate of conversion and a higher rate of spleen preservation while having comparable severe morbidity and short-term mortality as LDP.¹¹ A 2021 European multicenter study that matched 402 RDPs to 402 LDPs also reported a longer operation time and longer hospital stay but fewer readmissions for the robotic procedure.¹²

As the use of minimally invasive surgery increases, multicenter or national registries will continue to be important tools to evaluate progress and clinical results over time. The Global Audits on Pancreatic Surgery Group (GAPASURG) collaboration of registries in North America, the Netherlands, Germany, and Sweden offers a unique opportunity to investigate international differences in pancreatic surgery.¹³

The aim of this study was to describe patient selection and the use of MIDP and ODP in the 4 GAPASURG registries and to compare operative and postoperative outcomes while comparing countries and operation techniques. The primary outcomes were the rates of MIDPs performed per country and year. The main hypothesis was that there would be a difference in the rates of MIDP performed per country and year.

Methods

Study design

A retrospective cohort study was performed on the data of the GAPASURG collaboration of 4 pancreatic registries¹: the multicenter American College of Surgeons National Surgical Quality

Improvement Program (NSQIP) in the United States and Canada, involving 170 centers in 2020, is estimated to cover approximately 70% of pancreatic resections in the 2 countries^{2,14}; the multicenter Deutsche Gesellschaft für Allgemein-und Viszeralchirurgie- Studien-, Dokumentations-und Qualitätszentrum (DGAV StuDoQ Pancreas Registry) in Germany, involving 67 centers in 2020, is estimated to cover approximately 20% of pancreatic resections in Germany^{3,15}; the nationwide Dutch Pancreatic Cancer Audit (DPCA) in the Netherlands, with 100% coverage compared with the national cancer registry^{16,17}; and ⁴ the validated Swedish National Pancreatic and Periapillary Cancer Registry in Sweden, with a 94% coverage rate since 2014 compared with the national cancer registry.^{18,19} This study was designed in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Guidelines.²⁰ The study protocol was approved by the Swedish Ethical Review Authority, reference number 2022-01005-01, and the ethics committee of the University of Lübeck, reference number 19-243A. For the other countries, the need for ethical approval was waived.

Participants

All patients in the 4 registries who underwent distal pancreatic resection in 2014–2020 were included. Data were compared among countries and operation methods.

Variables

A full list of variables accessed from the registry is available as [Supplementary Table S1](#). Postoperative pancreatic fistula (POPF), postpancreatectomy hemorrhage, and delayed gastric emptying were defined according to the International Study Group for Pancreatic Surgery definitions, including only grade B/C complications.^{21–23} Severe complications were defined as a Clavien-Dindo grade IIIa or higher.²⁴ As Clavien-Dindo grade was not available from NSQIP and DPCA, it was extrapolated manually from complications and reinterventions. Vascular resection included all arterial and venous resections apart from splenic vessels. Textbook outcome was defined as the absence of POPF (bile leak), postpancreatectomy hemorrhage grade B/C, Clavien-Dindo grade \geq IIIa, readmission, and in-hospital or 30-day mortality, according to van Roessel et al.²⁵ Sex was defined as legal sex at the time of surgery.

Statistical analyses

Statistical analyses were performed using SPSS Statistics for Windows, version 28.0 (IBM, Armonk, New York). Categorical variables were compared using the χ^2 test or Fisher exact test, as appropriate, and numerical variables were compared using analysis of variance with Bonferroni post hoc correction, Kruskal-Wallis test, the nonpaired Student t test, or the Mann-Whitney U test, as appropriate. First, to compare patient selection for MIDP and the outcomes of MIDP, outcomes were compared among and within

countries. Second, to investigate the predictors of the use of MIDP, a multivariable logistic regression analysis was performed with backward selection. Factors included were demographic and preoperative variables available in all 4 registries that had $P < .05$ in the univariable analysis. Third, multivariable analyses were performed for severe complications and mortality. Factors included were preoperative and operative variables available in all 4 registries that had $P < .05$ in the univariable analysis. Moreover, to determine whether outcomes after MIDP differed among countries, the same analysis was performed in the subgroup of patients who underwent MIDP. Finally, outcomes were compared among patients who had undergone laparoscopic versus robotic resection. Variables missing in 1 or more registries were not included in the multivariable analyses.

Results

During the study period, 20,158 distal pancreatectomies were recorded in the 4 registries. The operative approach was not specified for 1,574 patients, who were therefore excluded, leaving 18,584 patients for the analyses (Figure 1).

Use of MIDP

The primary outcome of the proportion of MIDP in the 4 participating registries varied from 29% in Germany to 54% in the Netherlands over the whole study period ($P < .001$) (Table 1, Figure 2).

Baseline characteristics

Comparing all patients among the 4 countries regardless of operation method, patients in Germany and Sweden tended to be older, and all countries had a larger proportion of females than males (52%–55%). Significant large differences were seen in the rate of patients with an Eastern Cooperative Oncology Group (ECOG) performance status ≥ 2 and the rate of American Society of Anesthesiologists (ASA) score ≥ 3 , which varied from 24% in the Netherlands to 72% in the United States. Significant differences were also seen in the volume of hospitals performing distal pancreatectomies; the rates of robotic resections, conversions, severe complications, and POPF; length of stay; the distribution of diagnoses; and mortality (Table 1).

Patient selection for MIDP

When comparing which patients were selected for MIDP in the different countries, in all countries except the Netherlands, women more often underwent minimally invasive surgery (significant for North America and Germany). All countries displayed a higher body mass index (BMI) in the minimally invasive group (significant everywhere except Sweden), as well as lower rates of ASA score ≥ 3 (significant everywhere except the Netherlands), preoperative weight loss, neoadjuvant treatment, and diagnosis of PDAC. There was a tendency of younger age among the patients undergoing MIDP (Germany and Sweden), as well as patients with lower ECOG performance status (Germany) and patients without a diagnosis of diabetes (all except the Netherlands), heart failure (North America and Germany), or hypertension (Germany and Sweden) (Table II and Supplementary Table S2). In the multivariable analysis of individual predictors for the use of minimally invasive surgery, country, BMI, ASA score, weight loss, neoadjuvant chemotherapy, and diagnosis were significant (see Supplementary Table S3).

Postoperative outcomes

With regard to operative outcomes, MIDP was associated with less blood loss (the Netherlands and Sweden), fewer splenectomies (all), less delayed gastric emptying grade B/C (all), and a shorter length of stay (all). The minimally invasive group also underwent fewer vascular resections (all), had fewer R1 resections (all), and had lower rates of severe complications and mortality (North America and Germany). The rate of clinically relevant POPF was higher in the MIDP group in the Netherlands and North America (Table III and Supplementary Table S4).

Taking all patients into account, open surgery was identified as an independent predictor of severe morbidity and 30-day or in-hospital mortality in the multivariable regression analyses. Country of operation was a significant factor in the analysis of severe complications, but not for mortality (see Table IV). The full univariable and multivariable analyses are detailed in Supplementary Tables S5 and S6. When doing the same analyses on only MIDP patients, country of operation was not an independent predictor of worse outcomes (see Supplementary Tables S7 and S8).

Laparoscopic vs robotic resection

When comparing methods of minimally invasive resection, RDP resulted in lower conversion and splenectomy rates and a longer operation time than LDP. There were no significant differences in complications, readmissions, or mortality. Length of stay was marginally shorter in the RDP group (Table V).

Discussion

This transatlantic cohort study investigating the use of MIDP in 3 Northern European countries and North America showed a relatively large difference among countries in the proportion of patients undergoing MIDP. The Netherlands was the only country where a majority of resections were done minimally invasively, reaching this point in 2015. In multivariable analysis, MIDP was associated with lower 30-day mortality as compared to ODP. To our knowledge, this is the largest international study to date on this subject, and currently the only study associating MIDP with reduced mortality.

In the selection of patients for MIDP, there was a tendency of healthier patients to undergo minimally invasive surgery. This was most pronounced in Germany and Sweden, as shown, for example, by their younger age, lower ASA scores, lower rates of diabetes, and

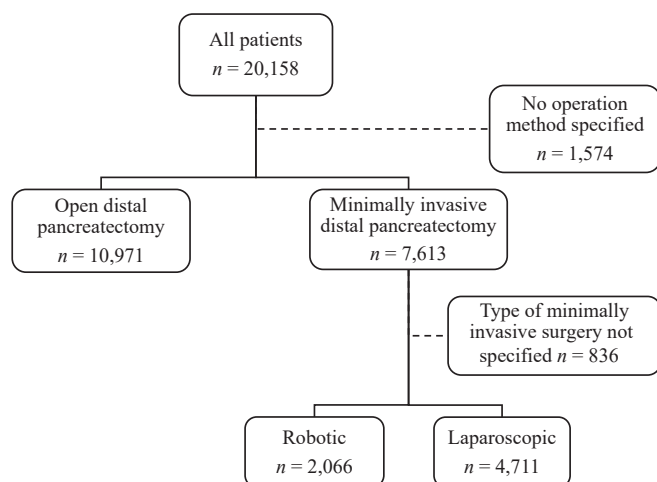


Figure 1. Flow chart of patients after distal pancreatectomy in the 4 European and North American registries.

Table 1
Overview of patients undergoing distal pancreatectomy, compared among the 4 registries

	All patients (<i>P</i> = 18,584)	North America (<i>P</i> = 13,247)	The Netherlands (<i>P</i> = 1,320)	Germany (<i>P</i> = 2,916)	Sweden (<i>P</i> = 1,101)	<i>P</i> value	Absolute largest difference, %	Missing data, %
Operation method, <i>n</i> (%)						<.001		0
Minimally invasive	7,613 (41)	5,741 (43)	709 (54)	836 (29)	327 (30)		25	
Open	10,971 (59)	7,506 (57)	611 (46)	2,080 (71)	774 (70)		25	
Type of MIDP, <i>n</i> (%)				—*		<.001		0*
RDP	2,066 (30)	1,773 (31)	251 (35)		42 (13)		22	
LDP	4,711 (70)	3,968 (69)	458 (65)		285 (87)		22	
Conversion rate, <i>n</i> (%)	1,582 (21)	1,230 (21)	99 (14)	200 (24)	53 (16)	<.001	10	0
Sex, <i>n</i> (%)						.020		0
Female	10,064 (54)	7,248 (55)	723 (55)	1,504 (52)	589 (53)		3	
Male	8,520 (46)	5,999 (45)	597 (45)	1,412 (48)	512 (47)		3	
Age, mean ± SD	62 ± 14	61 ± 14	61 ± 14	64 ± 14	64 ± 14	<.001	3	0
ECOG performance status, <i>n</i> (%)						<.001		2
0–1	17,931 (96)	13,122 (99)	1,002 (76)	2,794 (96)	1,013 (92)		23	
≥2	381 (2)	104 (1)	90 (7)	114 (4)	73 (7)		6	
ASA score, <i>n</i> (%)						<.001		0.2
1–2	7,100 (38)	3,736 (28)	985 (75)	1,580 (54)	799 (73)		47	
≥3	11,438 (62)	9,500 (72)	317 (24)	1,330 (46)	291 (26)		48	
Yearly DP volume of hospital, <i>n</i> (%)		—*				<.001		1*
<10	1,820 (34)		454 (34)	1,277 (44)	89 (8)		36	
10–20	1,705 (32)		339 (26)	1,177 (40)	189 (17)		23	
20–30	1,228 (23)		527 (40)	199 (7)	502 (46)		39	
>30	553 (10)		0 (0)	263 (9)	290 (26)		17	
Operation time, mean ± SD	234 ± 107	237 ± 109	222 ± 81	—*	204 ± 91	<.001	33	6*
Clavien-Dindo ≥ IIIa, <i>n</i> (%)	3,730 (20)	2,674 (20)	270 (20)	665 (23)	121 (11)	<.001	12	0.4
POPF grade B/C, <i>n</i> (%)	2,362 (13)	1,280 (10)	270 (20)	696 (24)	116 (11)	<.001	14	1
Length of stay, d, median (IQR)	6 (5)	6 (4)	7 (5)	13 (10)	8 (6)	<.001	7	1
Mortality, <i>n</i> (%)	213 (1)	137 (1)	18 (1)	50 (2)	8 (1)	.008	1	0.3
Diagnosis, <i>n</i> (%)						<.001		3
PDAC	6,038 (32)	4,309 (33)	383 (29)	964 (33)	382 (35)		6	
NET	3,735 (20)	2,805 (21)	278 (21)	458 (16)	194 (18)		5	
Cystic lesions	3,617 (19)	2,645 (20)	348 (26)	590 (20)	34 (3) [†]		23	
Chronic pancreatitis	1,335 (7)	906 (7)	103 (8)	256 (9)	70 (6)		3	
Other	3,315 (18)	2,168 (16)	192 (15)	621 (21)	334 (30)		15	

ASA, American Society of Anesthesiologists; DP, distal pancreatectomy; ECOG, Eastern Cooperative Oncology Group; IQR, interquartile range; LDP, laparoscopic distal pancreatectomy; MIDP, minimally invasive distal pancreatectomy; NET, neuroendocrine tumor; PDAC, pancreatic ductal adenocarcinoma; POPF, postoperative pancreatic fistula; RDP, robotic distal pancreatectomy.

* Variable not available in this registry. Missing data are calculated among the registries with the variable available.

[†] Cystic lesions in the Swedish registry may also be listed under PDAC or Other (benign lesions), depending on the histopathologic report.

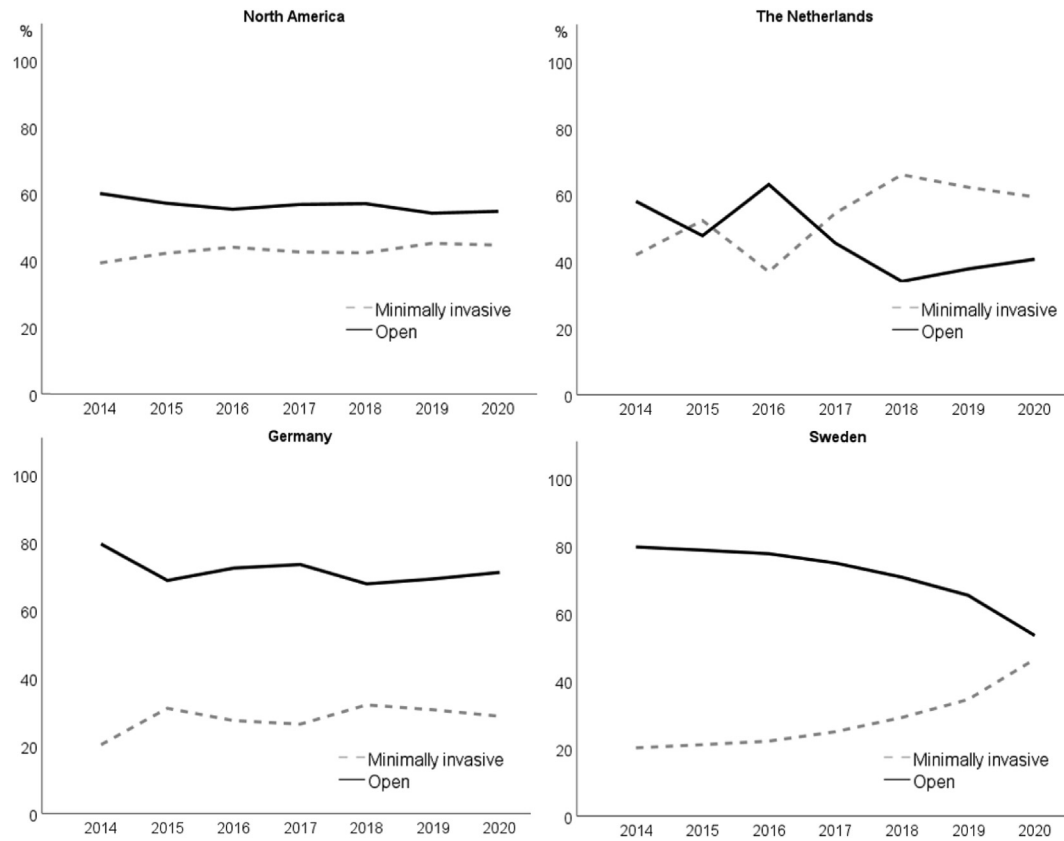


Figure 2. Proportion of minimally invasive versus open distal pancreatectomies performed per country and per year during the study period.

Table II
Demographic and histopathologic data compared between operation methods in the 4 registries

	North America			The Netherlands			Germany			Sweden		
	MIDP (n = 5,741)	ODP (n = 7,506)	P value	MIDP (n = 709)	ODP (n = 611)	P value	MIDP (n = 836)	ODP (n = 2,080)	P value	MIDP (n = 327)	ODP (n = 774)	P value
Sex, n (%)												
Female	3,232 (56)	4,016 (54)	.001	390 (55)	333 (55)	.854	485 (58)	1,019 (49)	<.001	183 (56)	406 (52)	.286
Male	2,509 (44)	3,490 (46)		319 (45)	278 (45)		351 (42)	1,061 (51)		144 (44)	368 (48)	
Age, mean ± SD	61 ± 14	61 ± 14	.444	61 ± 14	61 ± 14	.831	61 ± 15	65 ± 13	<.001	62 ± 16	65 ± 13	.003
BMI, mean ± SD	29 ± 6	28 ± 6	<.001	27 ± 5	26 ± 5	.036	27 ± 5	26 ± 5	<.001	27 ± 5	26 ± 5	.150
ECOG performance status, n (%)			.541			.070			.002			.248
0–1	5,691 (99)	7,431 (99)		556 (78)	446 (73)		817 (98)	1,977 (95)		296 (91)	717 (93)	
≥2	42 (1)	62 (1)		41 (6)	49 (8)		18 (2)	96 (5)		26 (8)	47 (6)	
Weight loss >10%, n (%)	259 (5)	628 (8)	<.0001	61 (9)	73 (12)	.030	82 (10)	337 (16)	<.001	39 (12)	145 (19)	.006
ASA score			<.001			.186			<.001			<.001
1–2	1,864 (32)	1,872 (25)		536 (76)	449 (73)		513 (61)	1,067 (51)		259 (79)	540 (70)	
≥3	3,872 (67)	5,628 (75)		159 (22)	158 (26)		323 (39)	1,007 (48)		63 (19)	228 (29)	
Diabetes, n (%)	1,364 (24)	1,951 (26)	.003	125 (18)	107 (18)	.699	157 (19)	500 (24)	.002	52 (16)	168 (22)	.030
COPD, n (%)	215 (4)	309 (4)	.277	77 (11)	57 (9)	.540	37 (4)	97 (5)	.776	19 (6)	59 (8)	.284
Heart failure, n (%)	15 (0.3)	38 (1)	.027	15 (2)	12 (2)	.953	55 (7)	228 (11)	<.001	—*	—*	—*
Hypertension, n (%)	2,970 (52)	3,778 (50)	.110	—*	—*	—*	414 (50)	1,126 (54)	.022	137 (42)	405 (52)	<.001
Dialysis, n (%)	39 (1)	43 (1)	.439	41 (6)	17 (3)	.014	3 (0.4)	11 (1)	.769	1 (0.3)	13 (2)	.020
Neoadjuvant chemotherapy, n (%)	362 (6)	1,380 (18)	<.001	25 (4)	57 (9)	<.001	15 (2)	199 (10)	<.001	3 (1)	40 (5)	<.001
Diagnosis of PDAC	1,412 (25)	2,897 (39)	<.001†	164 (23)	219 (36)	<.001†	147 (18)	817 (39)	<.001†	78 (24)	304 (39)	<.001†
Radicality, n (%)			—*			.009			<.001			<.001
R0	—*	—*		433 (61)	355 (58)		377 (45)	1,083 (52)		271 (83)	495 (64)	
R1	—*	—*		116 (16)	139 (23)		36 (4)	253 (12)		32 (10)	170 (22)	

ASA, American Society of Anesthesiologists; BMI, body mass index; COPD, chronic obstructive pulmonary disease; DP, distal pancreatectomy; ECOG, Eastern Cooperative Oncology Group; MIDP, minimally invasive distal pancreatectomy; NET, neuroendocrine tumor; ODP, open distal pancreatectomy; PDAC, pancreatic ductal adenocarcinoma.

* Variable not available in this registry.

† P values from comparison of all diagnoses. See [Supplementary Table S2](#).

Table III
Operative and postoperative data compared between operation methods in the 4 registries

	North America			The Netherlands			Germany			Sweden		
	MIDP (n = 5,741)	ODP (n = 7,506)	P value	MIDP (n = 709)	ODP (n = 611)	P value	MIDP (n = 836)	ODP (n = 2080)	P value	MIDP (n = 327)	ODP (n = 774)	P value
Operation time, min mean \pm SD	233 \pm 97	239 \pm 117	.003	219 \pm 76	228 \pm 88	.289	—*	—*	—*	197 \pm 85	207 \pm 94	.116
Vascular resection, n (%)	258 (4)	773 (10)	<.001	23 (3)	69 (11)	<.001	10 (1)	106 (5)	<.001	1 (0.3)	15 (2)	.009
Splenectomy, n (%)	—*	—*	—*	330 (47)	423 (69)	<.001	306 (37)	941 (45)	<.001	232 (71)	755 (98)	<.001
Drain, n (%)	5,044 (88)	6,352 (85)	<.001	638 (90)	559 (91)	.010	—*	—*	—*	315 (96)	735 (95)	.323
Clavien-Dindo \geq IIIa, n (%)	1,104 (19)	1,570 (21)	.017	141 (20)	129 (21)	.501	145 (17)	520 (25)	<.001	30 (9)	91 (12)	.186
Intensive care, n (%)	—*	—*	—*	30 (4)	39 (6)	.069	18 (2)	123 (6)	<.001	4 (1)	22 (3)	.100
Radiologic drain, n (%)	580 (10)	862 (11)	.011	105 (15)	80 (13)	.462	—*	—*	—*	14 (4)	34 (4)	.934
POPF grade B/C, n (%)	603 (11)	677 (9)	.005	173 (24)	97 (16)	<.001	185 (22)	511 (25)	.155	33 (10)	83 (11)	.755
PPH grade B/C, n (%)	—*	—*	—*	35 (5)	23 (4)	.305	26 (3)	100 (5)	.041	12 (4)	26 (3)	.796
DGE grade B/C, n (%)	200 (3)	476 (6)	<.001	17 (2)	28 (5)	.029	9 (1)	99 (5)	<.001	3 (1)	27 (3)	.017
Reoperation, n (%)	147 (3)	288 (4)	<.001	28 (4)	29 (5)	.442	58 (7)	229 (11)	<.001	8 (2)	35 (5)	.104
LOS, d, median (IQR)	5 (2)	6 (4)	<.001	7 (4)	8 (6)	<.001	11 (7)	14 (11)	<.001	6 (4)	8 (6)	<.001
Readmission, n (%)	925 (16)	1,254 (17)	.371	145 (20)	87 (14)	.004	115 (14)	244 (12)	.149	28 (9)	44 (6)	.078
30-d mortality, n (%)	43 (0.7)	94 (1.3)	.005	6 (1)	12 (2)	.081	6 (1)	44 (2)	.008	0 (0)	8 (1)	.114
Textbook outcome, n (%)	—*	—*	—*	439 (62)	395 (65)	.103	541 (65)	1,192 (57)	<.001	248 (76)	569 (74)	.597

DGE, delayed gastric emptying; IQR, interquartile range; LOS, length of stay; MIDP, minimally invasive distal pancreatectomy; ODP, open distal pancreatectomy; POPF, postoperative pancreatic fistula; PPH, postpancreatectomy hemorrhage.

* Variable not available in this registry.

Table IV
Logistic regression analyses of variables significantly associated with severe complications (Clavien-Dindo \geq IIIa) and 30-day mortality

	Severe complications		30-d mortality	
	Adjusted OR (95% CI)	P value	Adjusted OR (95% CI)	P Value
Operation method		.013		.005
MIDP	Ref.		Ref.	
ODP	1.110 (1.023–1.205)		1.633 (1.159–2.300)	
Country		<.001		
The Netherlands	Ref.			
North America	1.016 (0.841–1.228)			
Germany	1.273 (1.042–1.555)			
Sweden	0.557 (0.397–0.781)			
Sex		<.001		
Female	Ref.			
Male	1.284 (1.188–1.389)			
Age			1.055 (1.039–1.070)	<.001
BMI	1.024 (1.017–1.030)	<.001		
ECOG performance status		<.001		<.001
0–1	Ref.		Ref.	
≥ 2	1.964 (1.533–2.516)		3.037 (1.800–5.123)	
ASA score		.014		<.001
1–2	Ref.		Ref.	
≥ 3	1.116 (1.022–1.218)		2.374 (1.547–3.642)	
COPD		<.001		<.001
No	Ref.		Ref.	
Yes	1.469 (1.241–1.737)		2.186 (1.420–3.364)	
Dialysis		.004		<.001
No	Ref.		Ref.	
Yes	1.701 (1.189–2.433)		6.007 (3.004–12.011)	
Vascular resection		<.001		<.001
No	Ref.		Ref.	
Yes	1.953 (1.706–2.236)		2.098 (1.397–3.151)	
Diagnosis		<.001		
PDAC	Ref.			
NET	1.118 (1.001–1.249)			
Cystic lesions	0.948 (0.843–1.067)			
Chronic pancreatitis	1.179 (1.011–1.375)			
Other	1.347 (1.206–1.504)			
DGE	—*			<.001
No or grade A			Ref.	
Grade B or C			2.711 (1.835–4.003)	
Reoperation	—*			<.001
No			Ref.	
Yes			8.094 (5.722–11.451)	

ASA, American Society of Anesthesiologists; BMI, body mass index; COPD, chronic obstructive pulmonary disease; DGE, delayed gastric emptying; ECOG, Eastern Cooperative Oncology Group; MIDP, minimally invasive distal pancreatectomy; NET, neuroendocrine tumor; ODP, open distal pancreatectomy; OR, odds ratio; PDAC, pancreatic ductal adenocarcinoma; Ref., referent.

* Subclassifications of complications were not included in the multivariable analysis of severe complications. Full details on the regression analyses are shown in [Supplementary Tables S5 and S6](#).

Table V

Comparison of robot-assisted and laparoscopic distal resections (excluding patients from the German registry)

	RDP (n = 2,066)	LDP (n = 4,711)	P value
Yearly DP volume of hospital, n (%) ^a			.028
<10	56 (19)	200 (27)	
10–20	80 (27)	158 (21)	
20–30	146 (50)	344 (46)	
>30	11 (4)	31 (4)	
Conversion rate, n (%)	272 (13)	1,110 (24)	<.001
Operation time, min, mean \pm SD	261 \pm 99	218 \pm 92	<.001
Blood loss, mL, median (IQR)	100 (350)	100 (250)	.152
Vascular resection, n (%)	72 (3)	210 (4)	.041
Splenectomy, n (%) ^a	119 (41)	443 (60)	<.001
Drain, n (%)	1,890 (91)	4,107 (87)	<.001
Clavien-Dindo \geq IIIa, n (%)	415 (20)	860 (18)	.070
Intensive care, n (%) ^a	9 (3)	25 (3)	.831
Radiologic drain, n (%)	214 (10)	485 (10)	.901
POPF grade B/C, n (%)	263 (13)	546 (12)	.192
PPH grade B/C, n (%) ^a	12 (4)	35 (5)	.656
DGE grade B/C, n (%)	56 (3)	164 (3)	.089
Infection, n (%)	51 (2)	144 (3)	.172
Pneumonia, n (%) ^a	52 (3)	126 (3)	.505
Reoperation, n (%)	63 (3)	120 (3)	.232
Length of stay, d, median (IQR)	5 (2)	5 (3)	.008
Readmission, n (%)	359 (17)	739 (16)	.074
30-d mortality, n (%)	20 (1)	29 (1)	.117

DGE, delayed gastric emptying; DP, distal pancreatectomy; IQR, interquartile range; LDP, laparoscopic distal pancreatectomy; POPF, postoperative pancreatic fistula; PPH, postpancreatectomy hemorrhage; RDP, robotic distal pancreatectomy.

^a Percentages were calculated from the registries with the variable available.

lower rates of hypertension. These findings may reflect the learning curves in the respective countries, as shown by the differences in rates of MIDP over the study period. A recent nationwide study from the Netherlands outlining the process of implementation of minimally invasive distal pancreatectomy reported increasing rates of ASA III–IV, older age, vascular involvement, and PDAC over time among patients undergoing MIDP, although none of the variables reached statistical significance.²⁶

Training programs in minimally invasive pancreatic surgery are essential to safely implement new methods.^{27–29} Such programs may increase the use of MIDP, decrease conversion rates, and reduce blood loss.²⁸ Although information regarding the availability of training programs is not included in the GAPASURG data set, it is safe to assume that the nationwide structured training program LAELAPS in the Netherlands had an impact on the results. None of the other countries have a national training program for minimally invasive pancreatic surgery, although the ongoing implementation of robotic surgery has led to a larger number of available training programs and a stronger awareness of their importance.²⁹

In the operative and postoperative data, the MIDP group displayed less blood loss, fewer patients with delayed gastric emptying grade B/C, and a shorter hospital stay. This is in line with randomized trials on MIDP.^{2,3,9} Other notable differences between operation methods were the lower rates in some of the registries of severe complications and short-term mortality in the MIDP group. These differences are not in line with randomized trials^{2,3,9} and may be explained by differences in patient selection. The differences found in the rates of vascular resection, R1 resection, and rates of PDAC between methods support this hypothesis. Although MIDP for PDAC was not actively discouraged during the study period,⁸ it was only in 2023 that the DIPLOMA trial provided clear evidence of the oncologic safety of MIDP.⁹ Hence, a further increase in the use of MIDP in patients with malignancy can be expected.

The comparison of robotic to laparoscopic resections showed less conversion, longer operation time, and more spleen-preserving

procedures with the robotic approach, which is largely in line with the results of other studies.^{11,12,30} In contrast to Lof et al,¹² who reported a longer hospital stay after RDP, the present study found a marginally but significantly shorter hospital stay after RDP. Importantly, no significant differences were shown in complication rates between the 2 methods. Of note, no randomized trials are yet available comparing laparoscopic to robotic distal pancreatectomy.

Overall, in the comparison among countries, differences were shown in many preoperative characteristics and postoperative results. Similar differences have been shown previously for pancreatoduodenectomy and total pancreatectomy in the GAPASURG collaboration^{13,31} and corroborate the importance of exploring international differences in surgical outcomes. Large differences were seen in the rates of ECOG performance status and ASA score, with North America deviating from European countries by having the lowest rate of ECOG ≥ 2 combined with the highest rate of ASA ≥ 3 . Interpreting these differences is difficult, but it must be kept in mind that the ASA score is an uncertain measurement that has previously been shown to differ considerably among raters.^{32,33} In the operative data, a large variation was shown in the rates of splenectomy, being as high as 90% in Sweden compared with only 43% in Germany. This did not seem to be due to differences in rates of PDAC among countries but could be related to differences in the rates of robotic surgery, which has previously been shown to reduce splenectomy rates.^{11,12} Drain placement at the time of surgery also varied among countries, with fewer drains placed in North America (85%–88% compared to 90–91% in the Netherlands and 95%–96% in Sweden). This may be explained by the results of a multicenter randomized trial performed in the United States that confirmed the safety of omitting routine drainage in DP.³⁴ The role of routine drainage after DP will be further elucidated by the recently completed binational PANDORINA randomized trial.³⁵

The differences found among countries regarding severe complications and postoperative pancreatic fistula warrant further investigation. No definitive explanation can be found in the present

data, but similar differences have been reported both for pancreatoduodenectomy and total pancreatectomy in the GAPASURG collaboration.^{13,31} Some countries may have a lower threshold to drain subclinical pancreatic leaks, resulting in higher rates of both clinically relevant POPF and Clavien-Dindo IIIa complications by definition.³⁶ These differences could also be connected to differences in the interpretation and reporting of complications among countries. Of note, country of operation was not a significant factor in the multivariable analysis of short-term mortality, although it was a significant factor in severe complications.

Study limitations

The results of this study should be interpreted within the context of several limitations. First, 2 of the participating registries (NSQIP and StuDoQ) are voluntary as opposed to nationwide, so there is a risk of selection bias, where the participating centers might have different selection, volume, and results compared with those not represented. Second, the inconsistency of some variables among registries makes them difficult to compare. Among the more important variables to mention are tumor characteristics, including TNM stage, where the registries collect data using different scoring systems. Third, volume data were not available from North America and were therefore not included in the multivariable analyses. Fourth, there was no information on whether the costs for the different procedures varied among countries, although previous studies from Sweden and the Netherlands have reported similar cost estimations for laparoscopic and open distal pancreatectomy.^{6,7} Nevertheless, the GAPASURG collaboration provides a unique opportunity to evaluate and compare current practices and outcomes of pancreatic surgery in different countries in a large number of patients with detailed data regarding both pre- and postoperative courses.

In conclusion, this large comparison of the use of MIDP among 4 registries in Europe and North America found a difference in the rate of minimally invasive approaches among countries, where the Netherlands has implemented both MIDP overall and robotic resections specifically the most. Differences in patient selection for MIDP among countries imply that the countries are in different stages of the learning and implementation curve but overall suggest a considerable tendency of selecting healthier patients for MIDP. As in previous GAPASURG reports, large variations in preoperative characteristics and postoperative outcomes were reported among countries. However, country of operation was not a significant factor in the multivariable analysis for mortality.

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Conflict of Interest/Disclosure

The other authors have nothing to disclose relevant to this study.

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Supplementary materials

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