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Original Article

Robotic *versus* laparoscopic distal pancreatectomy: multicentre analysis

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Abstract

Background: The role of minimally invasive distal pancreatectomy is still unclear, and whether robotic distal pancreatectomy (RDP) offers benefits over laparoscopic distal pancreatectomy (LDP) is unknown because large multicentre studies are lacking. This study compared perioperative outcomes between RDP and LDP.

Methods: A multicentre international propensity score-matched study included patients who underwent RDP or LDP for any indication in 21 European centres from six countries that performed at least 15 distal pancreatectomies annually (January 2011 to June 2019). Propensity score matching was based on preoperative characteristics in a 1 : 1 ratio. The primary outcome was the major morbidity rate (Clavien–Dindo grade IIIa or above).

Results: A total of 1551 patients (407 RDP and 1144 LDP) were included in the study. Some 402 patients who had RDP were matched with 402 who underwent LDP. After matching, there was no difference between RDP and LDP groups in rates of major morbidity (14.2 *versus* 16.5 per cent respectively; $P = 0.378$), postoperative pancreatic fistula grade B/C (24.6 *versus* 26.5 per cent; $P = 0.543$) or 90-day mortality (0.5 *versus* 1.3 per cent; $P = 0.268$). RDP was associated with a longer duration of surgery than LDP (median 285 (i.q.r. 225–350) *versus* 240 (195–300) min respectively; $P < 0.001$), lower conversion rate (6.7 *versus* 15.2 per cent; $P < 0.001$), higher spleen preservation rate (81.4 *versus* 62.9 per cent; $P = 0.001$), longer hospital stay (median 8.5 (i.q.r. 7–12) *versus* 7 (6–10) days; $P < 0.001$) and lower readmission rate (11.0 *versus* 18.2 per cent; $P = 0.004$).

Conclusion: The major morbidity rate was comparable between RDP and LDP. RDP was associated with improved rates of conversion, spleen preservation and readmission, to the detriment of longer duration of surgery and hospital stay.

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Introduction

Minimally invasive distal pancreatectomy (MIDP) is being used increasingly for benign and low-grade malignant tumours, as supported by the 2019 Miami evidence-based guidelines[1]. Two RCTs, LEOPARD[2] and LAPOP[3], demonstrated less blood loss, less delayed gastric emptying, and shorter time to functional recovery for the minimally invasive approach with no obvious downsides, compared with the open approach. These findings confirmed those of previous cohort studies and systemic reviews[4–7]. Yet, the high rate of conversion to open distal pancreatectomy and lack of clear evidence concerning the oncological outcomes of MIDP hamper further implementation[4,8].

Although MIDP has been implemented over the past decade[9,10], consensus regarding the benefit of the robotic compared with the laparoscopic approach is lacking[11–13]. Several meta-analyses and a propensity score-matched study have suggested comparable surgical outcomes between the two approaches in terms of overall morbidity[14–16] and the rate of postoperative pancreatic fistula[14,17]. However, studies are limited by their retrospective, mainly single-centre design, with a clear risk of selection bias[15]. A multicentre international comparison in experienced pancreatic centres practising one or both modalities is currently lacking.

The present study aimed to compare surgical outcomes of robotic (RDP) and laparoscopic (LDP) distal pancreatectomy for all indications performed in experienced centres using propensity score matching. The primary hypothesis was that the rate of major morbidity would not differ between RDP and LDP.

Methods

This study was conducted according to the STROBE guidelines[18]. The medical ethics review committee of the Amsterdam UMC, location Amsterdam Medical Centre, waived the need for informed consent owing to the retrospective observational study design. All centres participating in the European Consortium on Minimally Invasive Pancreatic Surgery (E-MIPS) were invited to contribute. Participating centres had to perform at least 15 distal pancreatectomies annually. Consecutive patients, aged 18 years or above, who underwent RDP or LDP for benign or malignant disease between January 2011 and June 2019 were included. All participating centres received a database with the required parameters including definitions. Data were then collected locally using prospective collected databases and combined centrally by the study coordinators.

Definitions

Conversion was defined as any resection started as a minimally invasive procedure (laparoscopic or robotic) that required laparotomy or hand assistance for reasons other than trocar placement or specimen extraction[19]. Intended spleen preservation was noted when spleen-preserving distal pancreatectomy was the aim of the surgery at the surgeons' or multidisciplinary teams' discretion based on preoperative imaging. Some tumours, such as intraductal papillary mucinous neoplasm and solid pseudopapillary neoplasm, could have invasive characteristics and were categorized as premalignant. Neuroendocrine tumours were categorized according to the WHO 2010 classification[20] for neuroendocrine neoplasms of the digestive system.

Postoperative morbidity was scored and classified according to the Clavien–Dindo classification[21] of surgical complications and recorded for up to 30 days after surgery. The primary outcome of the study was major morbidity, defined as Clavien–Dindo grade IIIa or higher. For pancreas-specific complications (postoperative pancreatic fistula, delayed gastric emptying and postpancreatectomy haemorrhage), only grade B/C complications were noted, following the most recent definitions of the International Study Group on Pancreatic Surgery[22–24]. Readmissions and deaths were recorded for up to 90 days after surgery.

Statistical analysis

Statistical analysis was performed using IBM SPSS® Statistics for Windows version 26.0 (IBM, Armonk, NY, USA). Student's t test was used for comparison of normally distributed continuous variables, which are reported as mean(s.d.) values. Non-normally distributed variables are presented as median (i.q.r.) values, and compared using the Mann–Whitney U test. Normality of continuous variables was checked visually using histograms. Categorical variables were reported as counts with proportions, and analysed with the χ^2 or Fisher's exact test, as appropriate.

To minimize the impact of selection bias, patients undergoing RDP and LDP were matched using propensity scoring. Propensity scores were based on variables known from literature associated with treatment assignment and included the baseline variables age (continuous), sex, ASA physical status, intention of spleen preservation, and type of tumour (benign, (pre)malignant, pancreatic ductal adenocarcinoma (PDAC) or other type (chronic pancreatitis)). Matching without replacement was done with a 1:1 ratio, based on nearest neighbours and with a caliper width of 0.01 standard deviation. Standardized mean differences (MDs) were calculated for the assessment of distribution of baseline covariables between the two groups[25]. The MD was calculated only for baseline characteristics. A MD on or between −0.1 and 0.1 was considered the optimal balance. After matching, normally distributed continuous data were compared using the paired-samples t test. For non-normally distributed continuous data, the Wilcoxon signed rank test was used. Categorical data were compared using McNemar's test. Additionally, to test whether potential confounders for the primary outcome were not corrected for in the propensity score matching, a multivariable binary logistic regression analysis with backward selection was performed on the unmatched cohort with previously described risk factors associated with major morbidity. The results are reported as odds ratios (ORs) with 95 per cent confidence intervals.

To investigate the selection criteria for RDP, both univariable and multivariable binary logistic regression analyses with backward selection were performed for baseline characteristics in the total cohort. Variables included in the analysis were based on the assumption that RDP, a more novel technique, was performed for younger patients, with a lower ASA grade, and more often for non-malignant tumours. Because RDP has been shown to preserve the spleen more often in small studies, this was considered as well.

Two sensitivity analyses were performed. First, hospitals that performed fewer than 15 RDP or LDP procedures per year on average in 2017 and 2018 were excluded. These two complete years were chosen because the annual number of MIDPs increased during the study period in all participating centres, and there were only 6 months in 2019. Second, patients operated on in one of the two countries with the longest hospital stay were excluded to investigate the impact on hospital stay of differences in healthcare systems. The level of statistical significance was set at a two-sided $P < 0.050$.

Results

Of 1551 MIDPs, 407 (26.2 per cent) were RDP and 1144 (73.8 per cent) were LDP procedures (Table 1). RDP was performed in 11 and LDP in 19 of the 21 centres. Use of RDP increased from 22.7 per cent (80 of 353) in 2011–2013 to 32.2 per cent (185 of 575) in 2017–2019 ($P < 0.001$) (Fig. S1). Overall, 59.4 per cent of patients were women (921 of 1551), mean(s.d.) age was 59(26) years, and mean(s.d.) BMI was 25.7(4.9) kg/m^2. In 406 of 563 patients (72.1 per cent) with intended spleen preservation, the spleen was preserved successfully. Patients undergoing RDP were younger than those who had LDP (mean(s.d.) age 57(15) *versus* 60(15) years respectively; MD 0.20). Patients undergoing RDP had a lower rate of PDAC (16.0 per cent *versus* 21.1 per cent in the LDP group; MD 0.18) and a higher intended spleen preservation rate (47.3 *versus* 33.5 per cent respectively; MD –0.32) (Table 1).

Potential confounders for primary outcome

In multivariable logistic regression analysis performed to identify potential variables associated with major morbidity, only ASA grade (III–IV) and multivisceral resection were significant (OR 1.66 (95 per cent c.i. 1.12 to 2.46), $P = 0.011$, and OR 3.65 (2.04 to 6.53), $P < 0.001$, respectively) (Table S1).

Selection criteria for robotic distal pancreatectomy

Potential selection criteria for RDP were analysed using univariable analysis in the entire cohort of 1551 patients, including age (less than 65 *versus* 65 years or more), sex (male *versus* female), BMI (continuous), ASA grade (I–II *versus* III–IV), previous abdominal surgery (yes *versus* no), intended spleen preservation (yes *versus* no), tumour size (50 mm or less *versus* more than 50 mm), and tumour type (benign, (pre)malignant, PDAC or other). In multivariable analysis, only ASA grade I–II (OR 1.47 (95 per cent c.i. 1.06 to 2.05); $P = 0.022$) and intended spleen preservation (OR 1.74 (1.33 to 2.29); $P < 0.001$) were associated with the use of RDP (Table S2).

Matched cohort

Of the 407 patients who underwent RDP, 402 (98.8 per cent) could be matched with 402 patients who had LDP. After matching, baseline characteristics were well balanced, indicated by MD values below 0.1 (Table 1). There were no statistically significant differences between the matched RDP and LDP groups for the proportion of resected PDAC (16.2 *versus* 14.9 per cent respectively; MD –0.06), or for mean(s.d.) pathological tumour size (31(19) *versus* 32(21) mm; $P = 0.240$) (Table 2). RDP was associated with a greater number of resected lymph nodes than LDP (median 14 (i.q.r. 7–24)] *versus* 10 (3–18); $P = 0.003$), yet the number of metastatic lymph nodes was similar.

RDP was associated with a higher rate of spleen preservation than LDP (81.4 *versus* 64.2 per cent respectively; $P = 0.001$). The Kimura technique[26] (splenic vessel preservation) for spleen preservation was used more often in the RDP group (92.6 per cent *versus* 73.2 per cent in the LDP group; $P < 0.001$) (Table 3). In addition, RDP was associated with a lower conversion rate (6.7 *versus* 15.2 per cent respectively; $P < 0.001$) and a longer duration of surgery (median 285 (i.q.r. 25–350) *versus* 240 (195–300) min; $P < 0.001$).

Major morbidity was comparable between RDP and LDP: 14.2 *versus* 16.5 per cent respectively ($P = 0.378$). In addition, rates of postoperative pancreatic fistula grade B/C in RDP and LDP groups (24.6 versus 26.5 per cent respectively; $P = 0.543$), reoperation (5.2 *versus* 5.5 per cent, $p = 0.875$) and 90-day mortality (0.5 *versus* 1.3 per cent; $P = 0.268$) were not significantly different. RDP was associated with a longer hospital stay than LDP (median 8.5 (i.q.r. 7–

Table 1 Baseline characteristics for robotic and laparoscopic distal pancreatectomy before and after propensity score matching

	Total cohort				Propensity score-matched cohort			
	RDP ($n = 407$)	LDP ($n = 1144$)	$P^§$	MD†	RDP ($n = 402$)	LDP ($n = 402$)	$P^§$	MD†
Age (years)*	57 (15)	60 (15)	0.002¶	0.20	57 (15)	57 (14)	0.673¶	0.00
Age ≥65 years	145 (35.6)	494 (43.2)	0.008	0.18	144 (35.8)	154 (38.3)	0.465	0.06
Female sex	240 (59.0)	681 (59.5)	0.829	0.01	237 (59.0)	244 (60.7)	0.615	0.04
BMI (kg/m^2)*	25.4 (4.5)	25.9 (5.0)	0.099¶	0.10	25.4 (4.6)	25.9 (5.0)	0.215¶	0.10
≥30.0	67 (17.7)	186 (19.0)	0.595	0.05	67 (17.9)	66 (18.9)	0.743	0.03
Unknown	29	164			28	52		
ASA grade III–IV	93 (23.3)	278 (25.8)	0.257	0.09	92 (22.9)	87 (21.6)	0.672	−0.04
Unknown	7	65			0	0		
Previous abdominal surgery	167 (43.2)	478 (43.7)	0.504	0.04	165 (41.0)	152 (38.3)	0.426	−0.06
Unknown	20	50			0	5		
Preoperative tumour size (mm)*	33 (20)	32 (20)	0.642¶	−0.05	33 (20)	32 (19)	0.399¶	−0.05
Size >50 mm	58 (18.3)	156 (16.0)	0.328	−0.09	58 (18.5)	59 (16.6)	0.529	−0.07
Unknown	90	166			88	47		
Tumour type			0.102	0.08			0.180	−0.10
Benign	210 (51.7)	539 (47.2)			206 (51.2)	212 (52.7)		
(Pre)malignant‡	111 (27.3)	318 (27.9)			111 (27.6)	121 (30.1)		
PDAC	65 (16.0)	241 (21.1)	0.027	0.18	65 (16.2)	60 (14.9)	0.558	−0.06
Other (including chronic pancreatitis)	20 (4.9)	43 (3.8)			20 (5.0)	9 (2.2)		
Unknown	1	3			0	0		
Intended spleen preservation	192 (47.3)	371 (33.5)	<0.001	−0.32	188 (46.8)	190 (47.3)	0.888	0.01
Unknown	1	38			0	0		

Values in parentheses are percentages unless indicated otherwise; *values are mean(s.d.). †Standardized mean difference (MD) between –0.1 and 0.1 was considered optimal variable balance. ‡Includes also invasive intraductal papillary mucinous neoplasm and mucinous cystic neoplasm. RDP, robotic distal pancreatectomy; LDP, laparoscopic distal pancreatectomy; PDAC, pancreatic ductal adenocarcinoma. §χ^2 or Fisher's exact test, except ¶Student's t test.

Table 2 Pathology before and after propensity score matching

	Total cohort			Propensity score-matched cohort		
	RDP (n = 407)	LDP (n = 1144))	P¶	RDP (n = 402)	LDP (n = 402)	P¶
Tumour type			0.011			0.098
Neuroendocrine tumour‡	131 (32.3)	331 (29.0)		129 (32.1)	124 (30.8)	
G1/G2	123 (98.4)	293 (98.3)		121 (98.4)	108 (98.2)	
G3	2 (1.6)	5 (1.7)		2 (1.6)	2 (1.8)	
Unknown	6	33		6	14	
Pancreatic ductal adenocarcinoma	65 (16.0)	241 (21.1)		65 (16.2)	60 (14.9)	
Mucinous cystic neoplasm	61 (15.0)	142 (12.4)		60 (14.9)	44 (10.9)	
Serous cystadenoma	42 (10.3)	87 (7.6)		42 (10.4)	36 (9.0)	
Intraductal papillary mucinous neoplasm	40 (9.9)	144 (12.6)		40 (10.0)	53 (13.2)	
Solid pseudopapillary tumour	23 (5.7)	44 (3.9)		22 (5.5)	24 (6.0)	
Chronic pancreatitis/ pseudocyst	13 (3.2)	43 (3.8)		13 (3.2)	17 (4.2)	
Metastasis (including RCC)	4 (1.0)	37 (3.2)		4 (1.0)	12 (3.0)	
Other cystic lesion	7 (1.7)	24 (2.1)		7 (1.7)	14 (3.5)	
Other malignant tumour	2 (0.5)	14 (1.2)		2 (0.5)	7 (1.7)	
Other	18 (4.4)	35 (3.1)		18 (4.5)	11 (2.7)	
Unknown	1	2		0	0	
Tumour size (mm)*	30(19)	33(21)	0.035#	31(19)	32(21)	0.240#
No. of lymph nodes resected (malignant tumours only)†	14 (6–24)	12 (5–22)	0.073**	14 (7–24)	10 (3–18)	0.003**
No. of lymph nodes (tumour positive only)†	0 (0–2)	0 (0–2)	0.578**	0 (0–2)	0 (0–2)	0.508**
R0 resection for PDAC§	50 of 65 (77)	115 of 293 (64.9)	0.066	40 (69.0)	51 (78.5)	0.231

Values in parentheses are percentages unless indicated otherwise; *values are mean(s.d.) and †median (i.q.r.). ‡Includes insulinoma and glucagonoma, and classified according to WHO 2010 definitions[20]. §R0 defined as microscopic radical resection of at least 1 mm between tumour at transection or retroperitoneal margin. RDP, robotic distal pancreatectomy; LDP, laparoscopic distal pancreatectomy; RCC, renal cell carcinoma; PDAC, pancreatic ductal adenocarcinoma. ¶χ^2 or Fisher's exact test, except #Student's t test. And **Mann–Whitney U test.

12) *versus* 7 (6–10) days; $P < 0.001$) and lower readmission rate (11.0 *versus* 18.2 per cent; $P = 0.004$).

Sensitivity analysis

After excluding the procedures performed in hospitals with an average annual volume of fewer than 15 MIDP procedures in 2017 and 2018, the major morbidity rate remained comparable in RDP and LDP groups (14.9 *versus* 15.8 per cent respectively; $P = 0.745$) (*Table S3*). Other short-term surgical outcomes were also similar to those in the main analysis. The conversion rate was 5.9 *versus* 14.8 per cent respectively ($P < 0.001$).

After excluding all RDP and LDP procedures from the two countries with the longest hospital stay (Germany and France) from the matched cohort, the median duration of hospital stay was 8 (i.q.r. 6–11) *versus* 7 (6–10) days for RDP and LDP respectively ($P < 0.001$) (*Table S4*). RDP was associated with a lower readmission rate (11.6 per cent *versus* 18.8 per cent in the LDP group; $P = 0.009$).

Discussion

This multicentre study including over 1500 MIDPs from 21 European centres found that, after propensity score matching, there was no difference between RDP and LDP in the rate of major morbidity. In addition, the rates of postoperative pancreatic fistula grade B/C and 90-day mortality did not differ significantly between the two procedures. RDP was associated with improved rates of spleen preservation, conversion and readmission, to the detriment of a longer duration of surgery and longer hospital stay.

Use of the robotic approach for abdominal surgery is increasing worldwide[27]. Although some RCTs have indicated superiority, or at least non-inferiority, for robotic compared with open surgery[28,29], additional advantages over a laparoscopic approach have not been well established[30–32]. The first RDP procedure was reported in 2003[33]. Although retrospective single-centre studies[11,13,16] and a national study using the National Surgical Quality Improvement Program database[34] suggested a benefit for RDP in terms of spleen preservation and conversion, only 16 per cent of surgeons are performing RDP according to a recent worldwide survey[35] on minimally invasive pancreatic surgery.

The present multicentre international study found an increased use of RDP with time, from 22.7 per cent in 2011–2013 to 32.2 per cent in 2017–2019. Before propensity score matching, RDP was used more often in younger patients, more often with an intention for spleen preservation, but RDP was used less in patients with PDAC. This may be explained by the fact that this study included the very first and subsequent RDP procedures from 11 centres, whereas the 19 centres contributing LDP were mostly already ahead of the learning curve for this approach. Indeed, single-centre and nationwide studies on the implementation of LDP have shown that, with increasing experience, surgeons extend their indications for the minimally invasive approach, including older patients and more often PDAC[9,36].

However, because RDP is often associated with increased spleen preservation rates[11,37,38], surgeons may have used the

Table 3 Operative details and outcomes before and after propensity score matching

	Total cohort			Propensity score-matched cohort		
	RDP (n = 407)	LDP (n = 1144)	P‡	RDP (n = 402)	LDP (n = 402)	P‡
Operative details						
Duration of surgery (min)*	285 (225–350)	240 (191–300)	<0.001§	285 (225–350)	240 (195–300)	<0.001§
Blood loss (ml)*	150 (100–250)	120 (70–250)	0.956§	150 (100–250)	150 (80–250)	0.717§
Unknown	90	304		86	99	
Blood transfusion	16 (4.5)	34 (3.5)	0.424	16 (4.6)	9 (2.7)	0.196
Unknown	51	185		51	69	
Conversion	27 (6.6)	174 (15.2)	<0.001	27 (6.7)	61 (15.2)	<0.001
Stump closure method			<0.001			<0.001
Stapler	147 (42.0)	823 (75.4)		146 (42.2)	311 (79.3)	
Sutures	115 (32.9)	145 (13.3)		115 (33.2)	35 (8.9)	
Ultrasonic device	85 (24.3)	110 (10.1)		82 (23.7)	42 (10.7)	
Other	3 (0.9)	14 (1.3)		3 (0.9)	4 (1.0)	
Unknown	57	52		56	10	
Splenectomy	246 (60.6)	872 (76.3)	<0.001	246 (61.2)	279 (69.4)	0.014
Spleen preservation intended and actually preserved†	157 (80.5)	249 (64.0)	<0.001	153 (81.4)	122 (64.2)	0.001
Method of spleen preservation			<0.001			<0.001
Splenic vessel preservation (Kimura technique)	114 (92.7)	173 (73.6)		112 (92.6)	82 (73.2)	
Splenic vessel resection (Warshaw technique)	9 (7.3)	62 (26.4)		9 (7.4)	30 (26.8)	
Unknown	38	37		35	11	
Multivisceral resection	13 (3.8)	76 (7.0)	0.036	13 (3.9)	24 (6.2)	0.153
Unknown	68	56		66	16	
Vascular resection	10 (2.9)	12 (1.2)	0.023	10 (3.0)	4 (1.1)	0.077
PV/SMV	2 (0.6)	8 (0.8)		2 (0.6)	2 (0.6)	0.125
Other (e.g. renal vein)	8 (2.4)	4 (0.4)		8 (2.4)	2 (0.6)	
Unknown	68	112		66	39	
Postoperative outcomes						
Major morbidity (Clavien–Dindo grade IIIa or above)	57 (14.1)	175 (15.4)	0.516	57 (14.2)	66 (16.5)	0.378
Postoperative transfusion	24 (7.0)	101 (9.4)	0.178	24 (7.1)	32 (8.3)	0.536
Drain removed (days)*	7 (4–15)	6 (4–14)	0.095§	7 (4–15)	6 (4–13)	0.037§
POPF grade B/C	99 (24.3)	258 (22.6)	0.481	99 (24.6)	106 (26.5)	0.543
Intervention for POPF	35 (8.6)	117 (10.3)	0.336	35 (8.7)	49 (12.3)	0.101
DGE grade B/C	11 (3.0)	16 (1.5)	0.069	11 (3.0)	7 (1.8)	0.282
Postpancreatectomy haemorrhage grade B/C	16 (4.2)	51 (4.7)	0.665	16 (4.2)	20 (5.1)	0.541
Reoperation	21 (5.2)	61 (5.3)	0.899	21 (5.2)	22 (5.5)	0.875
Hospital stay (days)*	8 (7–12)	7 (6–10)	<0.001§	8.5 (7–12)	7 (6–10)	<0.001§
Readmission	44 (10.8)	181 (16.0)	0.011	44 (11.0)	73 (18.2)	0.004
90-day mortality	2 (0.5)	10 (0.9)	0.462	2 (0.5)	5 (1.3)	0.268

Values in parentheses are percentages unless indicated otherwise; *values are median (i.q.r.). †Proportion of actual spleen preservation when intended before surgery. RDP, robotic distal pancreatectomy; LDP, laparoscopic distal pancreatectomy; PDAC, pancreatic ductal adenocarcinoma; PV, portal vein; SMV, superior mesenteric vein; POPF, postoperative pancreatic fistula; DGE, delayed gastric emptying. ‡χ^2 or Fisher's exact test, except §Mann–Whitney U test.

robotic approach more often when spleen preservation is preferred for a patient. Intended spleen preservation was indeed a factor associated with RDP. To adjust for baseline differences between the two modalities, groups were matched by means of propensity scoring, after which these differences were mitigated. Following matching, the present study confirmed previous reported advantages of the robotic approach in terms of a reduced conversion rate and increased spleen preservation[13,16,37,38], even though the PDAC rate was similar in the two groups.

A lower conversion rate is a frequently mentioned advantage of the robotic approach owing to greater dexterity[16] or better visualization[39] with the robot. However, the learning curve aspect of MIDP should also be taken in account. With increasing experience, conversion rates during MIDP decrease, with a cut-off point of 15 consecutive MIDPs[40]. Potentially, the surgeons performing RDP had already gained their initial experience in the minimally invasive approach to distal pancreatectomy and therefore required fewer conversions. Interestingly, after excluding centres performing less than 15 MIDPs annually in the first sensitivity analysis, RDP was still associated with a lower conversion rate, indicating an inherent advantage of the robotic platform.

With improved understanding of the potential sequelae of splenectomy, including the risk of hospitalization and/or mortality from infectious disease, venous thromboembolism, and solid or haematological malignancy[41], spleen preservation is advocated increasingly during distal pancreatectomy[42,43]. In the present study, spleen preservation was intended for over one-third of patients, and succeeded in 72.1 per cent of these procedures. After matching, RDP was associated with a higher spleen preservation rate than was seen during LDP. In addition, splenic vessel preservation (Kimura technique[26]) was used more often in RDP than in LDP, whereas splenic vessel resection (Warshaw technique[44]) was more often applied in LDP. The Warshaw technique is used mainly when the Kimura technique is not feasible due to tumour involving the splenic vessels, intraoperative technical difficulty in preserving the splenic vessels, or persistent blood loss from splenic vessels[37,45,46]. Splenic vessel preservation requires meticulous dissection of the splenic vessels from the pancreas and control of small perforating blood vessels in order to prevent bleeding. The robotic system may facilitate this dissection owing to the articulating instruments and improved control over excessive bleeding[16,38].

Randomized studies comparing RDP with LDP are lacking. Although both modalities were included in the Dutch LEOPARD trial[2], only 5 of 47 minimally invasive procedures in that study were performed using the robotic approach. The LAPOP trial[3] included only LDP. Several other trials are comparing minimally invasive with open distal pancreatectomy (NCT03957135 and NCT03792932). Nevertheless, these trials include only LDP. For pancreatic cancer, the ongoing DIPLOMA trial in patients with pancreatic cancer (ISRCTN44897265) includes both LDP and RDP.

The study has limitations. The inherent drawback of retrospective studies is treatment allocation bias. Although both groups were well balanced after propensity score matching, treatment groups may still differ in unmeasured and unmatched risk factors. For example, details regarding the specific location of the tumour in the pancreatic body or tail or the tumour proximity to the splenic vessels were missing, and this may have influenced the differences in rate of successful spleen preservation. Yet, tumour size of 30 mm or more has been described as the only risk factor for unplanned splenectomy during LDP[42].

The validity of the data on intended spleen preservation can be criticized given the retrospective design of the study, although they were collected from prospective institutional collected databases. Additionally, all patients were counselled before surgery regarding the extension of the operation, including resection of the spleen, and this was registered in patients' files.

RDP is an expensive surgical technique. Unfortunately, a cost or quality-adjusted life-year analysis was not feasible to perform owing to cross-border differences in healthcare systems and missing data, including consumables, imaging, and duration of readmission. Single-centre studies from Europe and the USA have reported similar cost-effectiveness for RDP in comparison with LDP, whereas other studies have shown higher costs for RDP[47–49].

Differences in healthcare systems may have influenced some of the postoperative outcomes, such as hospital stay and readmission rate. In the sensitivity analysis, hospital stay remained significantly longer for RDP than for LDP. A clear explanation for these findings could not be identified as patient characteristics and complication rates were comparable between the two groups. It is possible that the longer hospital stay after RDP prevented some readmissions. Finally, because these data were not available, surgeons' experience and learning curve associated with short-term outcome were not included in the analyses, although this might have influenced the results. Yet, the impact was considered to be minimal due to the multicentre setting, large number of patients, and inclusion of only experienced centres.

Strengths of this study include the multicentre international setting and the large number of procedures, reflecting the state of RDP in experienced European centres. A multicentre international RCT should confirm the findings while stratifying for intended spleen preservation, and with special emphasis on cost-effectiveness.

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Supplementary material

Supplementary material is available at *BJS* online.

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