Original Article

Which method of distal pancreatectomy is cost-effective among open, laparoscopic, or robotic surgery?

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Background: The aim of this study was to analyze the clinical and economic impact of robotic distal pancreatectomy, laparoscopic distal pancreatectomy, and open distal pancreatectomy.

Methods: All consecutive patients who underwent distal pancreatic resection for benign and malignant diseases between January 2012 and December 2015 were prospectively included. Cost analysis was performed; all charges from patient admission to discharge were considered.

Results: There were 21 robotic (RDP), 25 laparoscopic (LDP), and 43 open (ODP) procedures. Operative time was longer in the RDP group (RDP =345 minutes, LDP =306 min, ODP =251 min, P=0.01). Blood loss was higher in the ODP group (RDP =192 mL, LDP =356 mL, ODP =573 mL, P=0.0002). Spleen preservation was more frequent in the RDP group (RDP =66.6%, LDP =61.9%, ODP =9.3%, P=0.001). The rate of patients with Clavien-Dindo > grade III was higher in the ODP group (RDP =0%, LDP =12%, ODP =23%, P=0.01), especially for non-surgical complications, which were more frequent in the ODP group (RDP =9.5%, LDP =24%, ODP =41.8%, P=0.02). Length of hospital stay was increased in the ODP group (ODP =19 days, LDP =13 days, RDP =11 days, P=0.007). The total cost of the procedure, including the surgical procedure and postoperative course was higher in the ODP group (ODP =30,929 Euros, LDP =22,150 Euros, RDP =21,219 Euros, P=0.02).

Conclusions: Cost-effective results of RDP seem to be similar to LDP with some better short-term outcomes.

Keywords: Robotic; distal pancreatectomy; cost-effective; laparoscopic

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Introduction

Pancreatic surgery still represents a challenge for surgeons due to its technical difficulty and high postoperative morbidity (1,2). As for other pathologies, the interest for minimally invasive surgery has increased in recent times, including pancreatic surgery. Nowadays, robotic distal pancreatectomy is considered equivalent to open and laparoscopic approaches (3). As of now, whether or not increased intraoperative costs related to robotic surgery are balanced by reduced complications and length of hospital stay has not been demonstrated. The question also remains unanswered as to who could make up for overall hospitalization costs for a patient managed with a robot-assisted approach.

The aim of this paper is to analyze the clinical impact of robotic distal pancreatectomy, laparoscopic distal pancreatectomy, and open distal pancreatectomy as well as the medical and economic impact of these three surgical procedures.

Methods

All consecutive patients who underwent distal pancreatic resection for benign and malignant diseases between January 2012 and December 2015 in two University Hospitals were included in the study. Patients were selected from a prospective maintained database. Patients who had associated splenectomy were also included in the study. Patients with additional abdominal resection were excluded from the study. All patients were evaluated in a multidisciplinary team meeting. Indications for surgery and surgical approaches were decided upon. All resections were performed by proficient pancreatic surgeons in open, laparoscopic, and robotic surgery. Patients were distributed into three groups, namely open distal pancreatectomy (ODP), laparoscopic distal pancreatectomy (LDP), and robotic distal pancreatectomy (RDP).

Variables examined included age, gender, body mass index (BMI), American Society of Anesthesiologists (ASA) score, comorbidities, tumor type, tumor size, operative time, estimated blood loss (EBL), transfusion, conversion rate, splenic preservation rate, vascular resection, number of harvested nodes, and margin status. Postoperative morbidity and mortality were defined as complications or death occurring within 90 days after surgery. Postoperative complications were defined as any deviation from the normal postoperative course and was classified following the Clavien-Dindo classification (4) (reference). Postoperative pancreatic fistulas (POPF) were defined according to the International Study Group of Pancreatic Fistula (ISGPF) grading system (5). The definition adopted is the one described in 2005, in the same period of the study. Postoperative mortality was defined as any uneventful event occurring within 90 days after the operation.

Cost analysis was performed; all charges from patient admission to discharge were considered. Regarding intraoperative costs of surgeries, all common charges (e.g., surgical drapes, sutures, sterilization) were considered as common costs for all procedures. Costs related to operating room time were based on the evaluation performed by Raft *et al.* (6), who calculated costs per minute at 10 Euros. The cost of one hospital day (in a standard service and/or intensive care unit) was based on the evaluation of the hospital's administration department. Prices of drugs, antibiotics, and intravenous feeding (parenteral nutrition) were evaluated with the hospital's Central Pharmacy. In case of complications, costs of radiological, endoscopic, and percutaneous procedures, as well as the cost of a surgical reoperation, were evaluated depending on the fees established by the CCAM (French medical classification for clinical procedures), which serves as the reimbursement classification for clinicians. This cost is similar in all French Hospitals and it is used for calculation of hospital costs.

Surgical techniques were previously (3) described for ODP, LDP, and RDP. With regards to postoperative management, oral intake was started upon passage of flatus. In all patients, an abdominal drain was routinely placed and then removed if no volume of drain fluid was present after postoperative day 3, or fluid with an amylase content lower than 3 times the serum value was present. In case of POPF, medical treatment was associated with fasting until complete fistula regression.

Statistical analysis

Quantitative variables were presented as medians. Qualitative variables were presented as numbers and percentages. Comparison of quantitative variables was performed using a Mann-Whitney test. Comparison of qualitative variables was performed using Pearson's chi-squared test² or Fisher's exact test depending on numbers. A $P<0.05$ was considered significant. Overall and disease-free survival probabilities were calculated using the Kaplan-Meier method.

Analyses were performed using the 3.2.0 version R software (R Core Team, R Foundation for Statistical Computing, Vienna, Austria).

Results

A total of 89 patients underwent distal pancreatectomy between January 2012 and December 2015 at two institutions. In our series, 21 were robotic (RDP), 25 laparoscopic (LDP), and 43 open (ODP) procedures. Demographic data of the 3 groups were summarized in

Table 1 Demographic and clinical characteristics of included patients

Patient's data	DP robot (n=21)	DP laparoscopy (n=25)	DP open (n=43)	P
Age, years, med [min – max]	53 [27–79]	62.5 [27–83]	65 [38–86]	0.005
Gender, male, n (%)	6 (28.6)	12 (48.0)	22 (51.2)	0.21
BMI (kg/m^2), med [min – max]	25 [18–33]	27.3 [20–41]	24.7 [17–34]	0.1
ASA score 3–4, n (%)	2 (9.5)	5 (20.0)	8 (18.6)	0.07
Previous abdominal surgery, n (%)	15 (71.4)	17 (68.0)	31 (72.1)	0.93
Comorbidity, n (%)	13 (61.9)	23 (92.0)	34 (79.1)	0.06
Diabetes	0 (0)	10 (40.0)	10 (23.3)	0.006
Heart disease	1 (4.8)	5 (20.0)	9 (20.9)	0.27
Thromboembolic history	2 (9.5)	3 (12.0)	2 (4.7)	0.48
Arterial hypertension	4 (19.0)	11 (44.0)	24 (55.8)	0.04
Smoking	5 (23.8)	6 (24.0)	18 (41.9)	0.47
Malignant, n (%)	13 (61.9)	17 (68.0)	34 (79.1)	0.14
Adenocarcinoma	2 (9.5)	8 (32.0)	22 (51.2)	
Neuroendocrine tumor	8 (38.1)	9 (36.0)	3 (7.0)	
Pseudopapillary solid tumor	3 (14.3)	0 (0)	2 (4.7)	
Others	0 (0)	0 (0)	7 (16.3)	
Benign tumor, n (%)	8 (38.1)	8 (32.0)	9 (20.9)	0.14
Intraductal papillary mucinous neoplasm of the pancreas	3 (14.3)	4 (16.0)	4 (9.3)	
Pancreatitis	0 (0)	3 (12.0)	2 (4.7)	
Mucinous cystadenoma	5 (23.8)	0 (0)	3 (7.0)	
Serous cystadenoma	1 (4.8)	1 (4.0)	0 (0)	
Maximal tumor size (cm), med [min –max]	2.6 [0.9–7]	3 [0.9–9]	4 [1–30]	0.20

Table 1. Patients were younger in the RDP group (RDP =53 years, LDP =62.5 years, ODP =65 years, P=0.005), with an inferior rate of diabetic patients (RDP =0%, LDP =40.0%, ODP =23.2%, P=0.006). The rate of malignant disease was 61.9% in RDP, 68.0% in LDP, and 79.1% in ODP groups (P=0.14). Intraoperative data are summarized in *Table 2*. Operative time was longer in the RDP group (RDP =345 min, LDP =306 min, ODP = 251 min, P=0.01). Blood loss was higher in the ODP group (RDP =192 mL, LDP =356 mL, ODP =573 mL, P=0.0002). Spleen preservation (with preservation of vessels) was more frequent in the RDP group (RDP =73.7%, LDP =76.5%, ODP =44.4%, P=0.003), considering patient in which preservation was not in contrast with oncological principles. Postoperative data were summarized in *Table 3*. The rate of patients with Clavien-Dindo ≥ grade III was higher in the ODP group (RDP =0%, LDP =12.0%, ODP =23.3%, P=0.01), especially for non-surgical complications, which were more frequent in the ODP group (RDP =9.5%, LDP =24.0%, ODP =41.9%, P=0.02). Length of hospital stay was increased in the ODP group (ODP =19 days, LDP =13 days, RDP =11 days, P=0.007).

Cost analysis

All data related to cost analysis are presented in *Table 4*. The overall costs of materials used in the operating room were higher in the RDP group (RDP =2,152 Euros, LDP =36 Euros, ODP =26 Euros, P=0.0001). The cost of operating room occupation is lower in the ODP group (ODP =2,517 Euros, LDP =3,066 Euros, RDP =3,456 Euros, P=0.01). Intravenous feeding by means of parenteral nutrition was

Table 2 Intraoperative outcomes

Patient's data	DP robot (n=21)	DP laparoscopy (n=25)	DP open (n=43)	P
Operative time, med [min – max]	345 [170–588]	306 [100–606]	251 [130–450]	0.01
Blood loss, mL, med [min – max]	192 [100–1,000]	356 [100–800]	573 [100–2,000]	0.0002
Blood transfusion, n (%)	1 (4.8)	2 (8.0)	5 (11.6)	0.65
Conversion, n (%)	2 (9.5)	7 (28.0)	–	0.15
Splenic preservation, n (%)	14/19 (73.7)	13/17 (76.5)	4/9 (44.4)	0.003
Associated vascular resection, n (%)	0 (0)	1 (4.0)	1 (2.3)	0.74
Associated digestive resection, n (%)	0 (0)	2 (8.0)	7 (16.3)	0.04
Number of nodes, med [min – max]	12.4 [8–20]	9.4 [0–20]	9.72 [0–28]	0.29
R0 resection, yes n (%)	10[1] (100)	7[2] (70)	31[3] (93.9)	0.07

[1],10/10 R0 resection in case of malignant tumor; [2], 7/10 R0 resection in case of malignant tumor; [3], 31/33 R0 resection in case of malignant tumor.

Table 3 Postoperative data

Patient's data	DP robot (n=21)	DP laparoscopy (n=25)	DP open (n=43)	P
Morbidity ≥ Clavien–Dindo IIIA, n (%)	0 (0)	3 (12.0)	10 (23.3)	0.01
Non-surgical morbidity, n (%)	2 (9.5)	6 (24.0)	18 (41.9)	0.02
Pulmonary, n (%)	1 (4.8)	4 (16.0)	12 (27.9)	0.07
Cardiac, n (%)	0 (0)	0 (0)	1 (2.3)	0.58
Renal, n (%)	0(0)	0 (0)	3 (7.0)	0.19
Other cases, n (%)	1 (4.8)	1 (4.0)	6 (14.0)	0.14
Surgical morbidity, n (%)	7 (33.3)	15 (60.0)	22 (51.2)	0.18
Deep collection	2 (9.5)	5 (20.0)	13 (30.2)	0.16
Wound infection	1 (4.8)	1 (4.0)	2 (4.7)	0.99
Pancreatic fistula	8 (38.1)	14 (56.0)	19 (44.2)	0.11
Grade A	3 (14.2)	6 (24.0)	1 (2.3)	
Grade B	5 (23.8)	6 (24.0)	13 (30.2)	
Grade C	0 (0)	2 (8.0)	5 (11.6)	
Hemorrhage	1 (4.8)	1 (4.0)	3 (6.9)	0.86
Number of transfused red blood cells, mean [min – max]	0.19 [0–4]	0.16 [0–2]	0.2 [0–4]	0.69
Radiological drainage	0 (0)	0 (0)	5 (11,6)	0.17
Embolization	0 (0)	1 (4.0)	0 (0)	0.27
Sphincterotomy	0 (0)	1 (4.0)	2 (4.6)	0.15
Reoperation	0 (0)	1 (4.0)	5 (11.6)	0.17
Mortality (90-day), n (%)	0 (0)	0 (0)	2 (4.7)	0.32
Reanimation stay, days, med [min – max]	0 [0–1]	0 [0–6]	0 [0–36]	0.24
Total hospitalization, days, med [min – max]	11 [7–21]	13 [6–64]	19 [6–67]	0.007

Table 4 Costs [Euros]

Patient's data	RDP, N=21	LDP, N=25	ODP, N=43	P
Materials related to operating room costs, med [min – max]	2,152 [1,879–2791]	36 [36–36]	26 [26–26]	0.0001
Costs related to operative room occupation, med [min – max]	3,456 [1,700–5,880]	3,066 [1,000–6,060]	2,517 [1,300–4,500]	0.01
Perioperative transfusion cost, med [min – max]	27 [0–378]	38 [0–567]	70 [0–1,132]	0.67
Cost of Naropin catheter, med [min – max]	0 [0–0]	0 [0–0]	62 [0–80]	0.0001
Antibiotic therapy cost, med [min – max]	16 [0–80]	38 [0–350]	49 [0–370]	0.19
Parenteral feeding cost, med [min – max]	0 [0–0]	33 [0–240]	110 [0–420]	0.002
Somatostatin treatment, med [min – max]	471 [0–1,980]	633 [0–1,980]	828 [0–1,980]	0.34
Embolization, med [min – max]	0 [0–0]	14 [0–355]	0 [0–0]	0.24
Radiologic drain, med [min – max]	0 [0–0]	0 [0–0]	20 [0–175]	0.06
Endoscopy, med [min – max]	0 [0–0]	17 [0–424]	19 [0–424]	0.001
Reintervention costs, med [min –max]	0 [0–0]	100 [0–2,500]	290 [0–2,500]	0.18
Resuscitation costs, med [min –max]	542 [0–1,900]	532 [0–11,400]	4,286 [0–68,400]	0.24
Hospital stay in standard service, med [min – max]	14,522 [9,660–29,500]	17,608 [8,280–80,040]	22,593 [8,280–64,860]	0.007
Total costs, med [min – max]	21,219 [13,806–36,086]	22,150 [10,951–98,819]	30,929 [9,836–118,866]	0.02

ODP, open distal pancreatectomy; LDP, laparoscopic distal pancreatectomy; RDP, robotic distal pancreatectomy.

more expensive in the ODP group (ODP =110 Euros, LDP =33 Euros, RDP =0 Euro, P=0.002). The cost of hospital stay was more expensive in the ODP group (ODP =22,593 Euros, LDP =17,608 Euros, RDP =14,522 Euros, P=0.007). The total cost of the procedure, including the surgical procedure and postoperative course was higher in the ODP group (ODP =30,929 Euros, LDP =22,150 Euros, RDP =21,219 Euros, P=0.02).

Discussion

The aim of this study was to compare the different surgical approaches in patients who underwent distal pancreatectomy performed by expert surgeons in two high-volume medical centers. This is the first study which has compared the three techniques (open, laparoscopic, and robotic), analyzing the short term as well as the medical and economic aspects of the three approaches, suggesting how robotic distal pancreatectomy is feasible, safe, and globally less expensive than other approaches.

Even if the first robotic distal pancreatectomy was reported more than 10 years ago (7), one can note the limited diffusion of robotic systems and the high cost of procedures. However, as in multiple single center series and meta-analyses (3,8-10), in our bicentric experience, robotic distal pancreatectomy is a safe and reproducible procedure, achieving comparable postoperative outcomes, similar oncological outcomes, and reduced blood loss, despite longer operative times, which can be progressively reduced with a reduction in the learning curve (11,12). Another major data shown in our series is the possibility to perform spleen-preserving robotic distal pancreatectomy (13). In our series, the rate of spleen preservation is higher in the RDP group with 73% of cases, as compared to 44% of cases in the ODP group. The possibility to preserve the spleen should be discussed because splenectomy could be performed for oncological reasons or anatomical reason, or due to intraoperative bleeding. In our series too, we have only 9.5% of adenocarcinoma in the RDP group as compared to 32.5% in the LDP group, and 51.1% in the RDP group. This could substantiate the increased rate of spleen preservation due to the increased presence of non-malignant pathologies in the RDP group. Even if the distribution of spleen-preserving pancreatectomies is different, it is enhanced by an augmented dexterity in the abdominal cavity, made possible by the 360 degrees of freedom of the Endowrist and the 3D view, allowing for an easier dissection as compared to laparoscopic surgery. Another key consideration is that in our series, regarding malignancies, the rate of lymph node clearance is similar among the three approaches (12.4 for RDP, 9.4 for LDP, and 9.7 for ODP, P=0.29). These data are confirmed in the literature (8,9,14,15), and demonstrate how the rate of R0 resections and the rate of harvested lymph nodes are comparable in the ODP, LDP, and RDP groups. In our series, reduced blood loss was observed in the robotic group [192 cc in the RDP group, 356 cc in the LDP group, and 573 cc in the ODP group (P=0.002)]. These meaningful data demonstrate how reduced intraoperative blood loss has an impact on postoperative transfusion.

Avoiding postoperative transfusion could reduce the risk of complications including infection, systemic inflammatory response syndrome, multiple organ failure, and death (16,17).

In the literature, there are few studies which address the cost issues. Waters *et al.* (10) compared operation-related costs, including anesthesia, intraoperative pharmacy, blood bank, and equipment, which were higher in the robotic group ($4,898) as compared to open ($3,510) and laparoscopic groups ($3,072; P=0.04;). Additionally, when amortized (adjusted) costs related to the use of the robot and its associated maintenance are considered, operative costs rose to $6,214 (P=0.01). Alternatively, total costs demonstrated that there was no difference between the 3 approaches with $15,521, $12,900, and $10,588 in ODP, LDP, and RDP groups respectively (P=0.26). Another article by Kang *et al.* (14) analyzed the economic aspect of robotic pancreatic surgery, considering intraoperative costs, and concluded that the cost of surgery was superior for robotic pancreatic surgery as compared to laparoscopic surgery ($8,304.8±870 versus for the RPS group, $3,861.71±724.3 for the LPS group, P=0.001). In this case, the cost of the robot, of robotic devices, and of maintenance was not considered in the overall cost. In our article, we did not consider intraoperative costs strictly, but we also considered hospitalization as a whole from inpatient to outpatient surgery, considering that costs of hospitalization were equal to costs of managing patients who underwent distal pancreatectomy in the three approaches. For that reason, as most series of robotic pancreatic surgery demonstrated, intraoperative costs were higher in robotic surgery. We decided not to consider the initial costs related to the use of the robot and to its maintenance, because in both hospitals initial costs have been cut down by the multidisciplinary use of the device and because the initial cost related to the laparoscopic unit has never been considered in cost-analysis series of laparoscopic surgery. In our bicentric study, we demonstrated how a shorter length of hospital stay, an improved recovery, and a lower rate of postoperative complications (especially postoperative complications requiring extra treatment) could balance overall intraoperative costs.

This is not a large enough study to define robotic pancreatic surgery as globally less expensive than other techniques. However, we strongly believe that the robot, with increasing surgical experience and skills, future perspectives integrating technology such as augmented reality, fluorescence, image fusion (16-24), could be the way to reduce intraoperative and postoperative complications, which could simultaneously reduce the overall costs of hospital stay. This major evaluation, combined with the enhanced possibility to perform even more complex and oncological operations in robotic surgery (13,25-33), could well account for a substantial spread towards the diffusion of robotic pancreatic surgery. Further studies should be completed to assess the role of robotic surgery as compared to other approaches, in order to understand the real benefit for patients as well as the medical and economic impacts of this approach on health economics.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: This study was reviewed and approved by the review board of University of Strasbourg

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