International Journal of Surgery 48 (2017) 300–304

Contents lists available at ScienceDirect

International Journal of Surgery

journal homepage: www.elsevier.com/locate/ijsu

Original Research

Robotic versus laparoscopic distal pancreatectomy: A comparative study of clinical outcomes and costs analysis

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ARTICLE INFO

Keywords:
Distal pancreatectomy
Cost
Robotic surgery

ABSTRACT

Background: The robotic surgery cost presents a critical issue which has not been well addressed yet. This study aims to compare the clinical outcomes and cost differences of robotic distal pancreatectomy (RDP) versus laparoscopic distal pancreatectomy (LDP).

Methods: Data were abstracted prospectively from 2011 to 2017. An independent company performed the financial analysis.

Results: A total of 28 RDP and 26 LDP were included. The mean operative time was significantly lower in the LDP (294 vs 241 min; $p = 0.02$). The main intra and post-operative data were similar, except for the conversion rate (RDP: 3.6% vs LDP: 19.2%; $p = 0.04$) and hospital stay (RDP: 8.9 vs LDP 13.1 days; $p = 0.04$). The mean total costs were similar in both groups (RDP: 9198.64 € vs LDP: 9399.74 €; $p > 0.5$).

Conclusions: RDP showed lower conversion rate and shorter hospital stay than LDP at the price of longer operative time. RDP is financially comparable to LDP.

1. Introduction

In the last decade, there has been an increased interest in minimally invasive surgical techniques, especially in robotics which has become a new technological trend in surgery. The robotic approach has been suggested in order to enhance dexterity in the use of surgical instruments, precision and vision, which are all claimed to be beneficial especially in more challenging procedure such as in the hepato-biliary-pancreatic field [1–3]. Clinical benefit of robotic distal pancreatectomy (RDP) over laparoscopic distal pancreatectomy (LDP) is still under investigation and only few studies have been published [4–10]. On the other hand, even if it is well established that robotic surgery increases operative costs, question of the cost between RDP and LDP has not yet been well investigated. There is only one study by Waters et al. (2010) which found that direct hospital costs were comparable between RDP, LDP and open approach [4]. No further studies have been found in the literature.

We have therefore performed a retrospective comparative study of RDP and LDP performed at our centre with the aim to evaluate the impact of the clinical outcome and costs.

2. Material and methods

2.1. Study population

Our centre is a private university hospital with an integrated comprehensive oncological centre. The robotic programme which started in October 2010 has now performed up to 237 procedures, including colorectal, hepato-pancreato-biliary, gastro-esophageal, and retroperitoneal procedures.

A database of laparoscopic and robotic pancreatic surgeries has been developed, and data have been prospectively recorded from October 2011 up to May 2017.

The study was approved by the institutional review board. Operations were performed using a da Vinci Robotic Surgical System model Si and Xi (Intuitive Surgical, Sunnyvale, CA, USA).

All consecutive cases were conducted by the same group of surgeons who all possess a high degree of experience in both the laparoscopic and robotic approaches.

A consensus for surgical treatment was reached during a weekly multidisciplinary meeting held at our institute with surgeons, oncologists, gastroenterologists, and radiologists.

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https://doi.org/10.1016/j.ijsu.2017.10.075
Received 4 July 2017; Received in revised form 12 September 2017; Accepted 31 October 2017
Available online 06 November 2017

Due to the retrospective nature of the study, informed consent was waived. Following approval by the local ethics committee, demographic, clinical, operative, and pathological details were obtained. Before surgery, each patient underwent a radiological study that included abdominal CT scan, MRI, echoendoscopy, and Positron Emission Tomography (PET). All tumours were classified according to the sixth edition of the TNM staging system. The duration of surgery was calculated as skin-to-skin time.

Complications were defined and classified according to the Clavien-Dindo score [11], and severe complication was defined when ≥ III. Pancreatic fistula was defined as grade A, B or C according to the International Study Group of Pancreatic Fistula (ISGPF) [12].

The main objective was to analyze the two groups in terms of intraoperative outcomes (such as operative time, blood loss, conversion to open surgery), short term outcome (such as complications, hospital stay, reoperation) and pathological data (such as resection margins and retrieved lymphonodes).

2.2. Surgical procedure

The abdomen was insufflated with CO_2 using a Veress needle through a 1 mm diameter left hypocondrium incision. Robotic trocars placement is shown in Video 1, while LDP trocars are placed in a standard position. An assistant trocar was placed in the right hypocondrium in the RDP.

Supplementary video related to this chapter can be found at http://dx.doi.org/10.1016/j.ijsu.2017.10.075.

The gastrocolic ligament was dissected from right to left and adhesions between the pancreas and the posterior surface of the stomach were transected using different energy devices (Laparoscopic LigaSure™ Maryland, Covidien or Robotic articulated ultrasound shield, Intuitive Surgical).

The lower margin of the pancreas is opened and posterior dissection is continued in order to mobilize the distal part of the pancreas from the retroperitoneum. The splenic vessels are identified. In the LDP the pancreas is cut with endoscopic linear stapler (Endo GIA™ Ultra, Covidien), except for 3 cases where the laparoscopic LigaSure™ Maryland (Covidien) is used.

In the RDP approach, the pancreas was cut with an endoscopic linear stapler (Endo GIA™ Ultra, Covidien) in the first 5 cases or by using the Robotic ultrasound shield (Intuitive Surgical) in 4 cases. In the latest cases, instead, the section is performed using the laparoscopic LigaSure™ Maryland (Covidien) device as in the LDP through the assistant trocar up to the proximity of the Wirsung duct which is closed by 3/0 prolene sutures.

A spleen-preserving procedure is considered as the first option in patients with benign diseases. In cases without spleen preservation, the resection is performed en bloc, controlling and ligating the splenic vessels first with the use of hem-o-lok clips. The spleen is then dissected from its lateral attachments and ligaments without dissecting the hilum.

2.3. Cost data

An independent company performed the financial analysis, eliminating the risk of an observer bias. Overall direct hospital costs were collected, with the exception of the acquisition or maintenance of the robotic device.

For each patient, cost data were assessed by gathering all costs of care during the hospital stay (including floor, intensive care unit, operating room, pharmaceutical, post-anaesthesia care unit, laboratory and pathology, and radiology costs).

Operating room costs included the costs of operative time (calculated per minute) and equipment (robotic and laparoscopic instruments, energy devices and staplers) calculated per each surgical procedure.

Costs were not adjusted for inflation. The overall cost included also any 30-day hospital readmissions.

The direct costs of the professionals involved have not been calculated.

Table 1
Base line characteristics.

	Robotic	Laparoscopic	p value
	n = 28	n = 26	
Mean Age (range) years	59.7 (35–73)	61.3 (41–79)	> 0.5
Sex ratio (M/F)	16/12	17/9	> 0.5
Mean BMI (range)	24.1 (19–32)	24.5 (18–31.5)	> 0.5
ASA score, number (%)			> 0.5
I	2 (7.14)	3 (11.5)	
II	23 (82.1)	20 (76.9)	
III	3 (10.7)	3 (11.5)	
Mean tumor size (range), mm	35.4 (12–90)	38.3 (15–95)	> 0.5
Pathology: number (%)			> 0.5
Adenocarcinoma	15 (53.6.)	13 (50)	
Chronic pancreatitis	2	1	
Neuroendocrine	6	7	
IPMN[a]	4	3	
Serous/mucinous cystadenoma	1	2	
Neoadjuvant treatment, number (%)	8 (28.6)	9 (34.6)	> 0.5

[a] IPMN: intraductal papillary mucinous neoplasia.

2.4. Statistical analysis

Data were analyzed using the SPSS statistical programme (SPSS Inc. Chicago, IL, USA). In order to compare the means of the quantitative variables when these followed a normal distribution, a variance analysis and Student's t-test were used. For the rest of the variables, both the Mann-Whitney and Kruskal-Wallis tests were performed. For categorical variables, a Chi-square test was performed. Results with a P value lower than 0.05 were considered statistically significant.

3. Results

3.1. Clinical outcome

A total of 28 RDP and 26 LDP have been included. The patient demographics as well as the pre-operative characteristics were similar in the two groups (see Table 1).

The main operative data are depicted in Table 2 and resulted to be similar in both groups (RDP: 294 min; LDP: 252 min) ($p > 0.5$).

Conversion rate resulted to be significative higher in the LDP (3.6% vs 19.2%; $p = 0.04$). Conversions to an open surgical approach in the RDP group was caused by pneumoperitoneum intolerance. Conversions in the LDP group were due to difficult vascular dissection in 3 cases and 2 cases of per-operative bleeding. As showed in tabe 2, mean estimated blood loss, overall post-operative complication rate as well as major complications according to the Clavien-Dindo [11] classification did not differ between the two groups.

The overall rate of pancreatic leak was 10.7% in the RDP group and 15.4% in the LDP group ($p > 0.5$). Reoperations occurred only in 2 cases of the LDP group due to bleeding from splenic vessels in one case and spleen in the other.

The mean number of hospital stay days was significative higher in the LDP (8.9 days vs 16.9 days, $p = 0.03$). All specimens were free from disease and the mean number of retrieved lymph nodes was 14.2 and 9.6 in the RDP and LDP groups, respectively ($p > 0.5$).

3.2. Cost analysis

As showed in Table 3, the overall mean total cost was similar in both groups (RDP: 9198.64 € versus LDP: 9399.74 €; $P > 0.5$). Cost analysis demonstrated that mean operative cost was slightly higher in the RDP

Table 2
Surgical and post operative outcomes.

	Robotic	Laparoscopic	p value
	n = 28	n = 26	
Mean operative time (range), min	294 (180–600)	241 (140–400)	**0.02**
Conversion, number (%)	1 (3.6)	5 (19.2)	**0.04**
Mean estimated blood loss (range), ml	175 (0–260)	181 (0–550)	> 0.5
Splenectomy, number (%)	5 (17.9)	3 (11.5)	> 0.5
Overall morbidity, number (%)	6 (21.4)	6 (23)	> 0.5
Severe morbidity (Clavien-Dindo ≥ 3)number (%)	2 (7.14)	4 (15.4)	> 0.5
Pancreatic fistula, number (%)	3 (10.7)	4 (15.4)	> 0.5
A	2	2	
B	1	2	
C	0	0	
**Reoperation, number (%)	0	2 (7.7)	> 0.5
Mean hospital stay, days	8.9 (7–20)	13.1 (7–40)	**0.04**
30-days readmission, n (%)			
Margin status R1, n (%)	0	0	> 0.5
Mean number of retrieved nodes (range)	14.2 (5–21)	9.6 (4–18)	> 0.5

Gathered information of patients and calculated the costs of the procedures.

Table 3
Cost analysis including most representative operating costs.

	Robotic	Laparoscopic	p value
	n = 28	n = 26	
Mean operative cost	5304.44 €	5119.36 €	> 0.5
Mean energy device cost	*708.6 €*	*961 €*	0.08
Intuitive ultrasonic shear[a] *(n)*	*17.85 € (4)*	*0*	
Ligasure[b] *(n)*	*823.71 € (24)*	*961 € (26)*	
Mean stapler cost[c] (n)	*69.64 € (5)*	*255 € (17)*	**0.01**
Mean surgical instruments cost[d]	*848 €*	*240 €*	**0.02**
Mean operating room time cost	*529.2 €*	*433.8 €*	> 0.5
Mean hospitalisation cost	3894.2 €	4280.38 €	> 0.5
Mean total cost	9198.64 €	9399.74 €	> 0.5

Bold are for statistical significative results.
[a] Robotic articulated ultrasound shield, Intuitive.
[b] Laparoscopic LigaSure™ Maryland, Covidien.
[c] Including reloads, Endo GIA™ Ultra, Covidien.
[d] Cost per each procedure.

group than the LDP group by almost 200 € (5304.44 € versus 5119.36 €; P > 0.5) per patient. Mean hospitalisation cost was almost 400 € higher in the LDP group, but not significative (3894.2 € versus 4280.38 €; P > 0.5). A detailed analysis of main operative room costs related to laparoscopic and robotic devices showed that operative time-related costs were similar between the two cohorts (529.2 € versus 433.8 €; P > 0.5). In this series, energy devices were used in all cases of both groups and types and number of uses are showed in Table 3. The mean cost of using these devices in the RDP was slightly lower than those used in the LDP (708.6 € versus 961 €; P = 0.08) (Table 3). Compared with RDP, LDP procedures made more frequent use of surgical staplers (RDP: 5 versus LDP: 17; p = 0.001) which lead to a significative higher cost of using staplers in the LDP (255 € versus 69.64 €; P = 0.01). The cost of the robotic instruments add an extra cost of 608 € to the laparoscopy (848 € versus 240 €; P = 0.02).

4. Discussion

The potential improvements of the robotic approach are well known, but the cost remains the major drawback. In several surgical fields, most studies have indicated that the robotic approach has significantly higher costs when compared with the laparoscopic approach [13–15]. However, unlike the clinical outcome, there is a lack of high-level economic studies comparing robotic to conventional laparoscopic surgeries, especially in the hepato-bilbio-pancreatic field where only very few studies addressed this issue [4,16]. One of them, performed by Daskalaki et al. [16], concluded that robotic liver resection is financially comparable to open resection.

Cost versus benefits for health care is an issue whenever a new technology is introduced to a hospital. RDP surgery has become more and more popular during the last decade; therefore cost analysis needs to be better addressed which is the aim of this study by establishing a comprehensive clinical and cost comparison analysis between RDP and LDP.

4.1. Clinical outcome

In the present series, the mean operative time was higher in the RDP (294 vs 241 min; p = 0.02) (Table 2), and this data is in line with that reported by the latest meta-analysis by Zhou J-Yet al. [17] who identified 7 observational studies comparing RDP versus LDP where the overall mean operative time in the RDP and LDP was 247.8 and 229.9 min, respectively. Main reason for prolonged operative time in robotic is the docking manoeuvre and the learning curve of this new approach. However, the experience gained and the latest version of the da Vinci Xi with narrower arms and a more straightforward docking manoeuver, contribute to a decrease in the operative time.

Contrary to this meta-analysis [17], conversion rate in our series was higher in the LDP (3.6% versus 19.2%, p = 0.04). Main reported reason for conversion to open in DP is uncontrolled bleeding from splenic vessels [17]. We can speculate that the muscle tremor filter, a three-dimensional image and incorporates motion scaling may promote the capability of performing complex tasks such as bleeding control in RDP.

The present study indicated that RDP and LDP resulted in similar blood loss, rate of spleen-preservation, morbidity, pancreatic fistula as well as and reoperation rate and main pathological data (Table 2).

Hospital stay in the RDP group was shorter than that in the LDP group (P = 0.04) (Table 2) which is concomitant with all studies included in the meta-analysis of Zhou J-Yet al [17].

4.2. Cost analysis

To the best of our knowledge, there is only one study in the literature reporting the cost analysis of RDP compared with conventional LDP [4]. However, this study has an important limitation being performed 17 years ago, a long period of time during which the robot improved its technology up to the latest Xi generation. Furthermore, some years ago, it was a commonly held belief that the initial and ongoing maintenance costs of the robotic system would not significantly decrease in the future, given that the manufacturing company had a monopoly. However, it is now the case that some manufacturing licenses have expired and new robotic systems produced by different companies are currently in use, resulting in an expected decrease in overall costs. On the other hand, the present study included patients which underwent surgery from 2011, giving a more recent point of view of how RDP costs currently are. Butturini et al. [10] reported only the price of the surgical instruments and did not take into account the operating room functioning and postoperative costs showing that cost of RDP was twice than that of LDP. Furthermore, they did not reported the number of stapler or energy devices used in both groups.

Our study showed that overall costs were similar in both groups. As depicted in Table 3, the slight surplus operative cost of RDP (almost 200 € higher) seems to have been compensated given the decrease of its hospitalisation costs (almost 400 € lower). Main reason for this slight lower hospitalisation cost may be justified by the significative lower hospital stay in the RDP which is an important evaluation index in minimally invasive surgery, even if its cost impact is not equally statistically significative to the stay.

Main finding of this study is that operative costs were not such higher than we expected compared with laparoscopy. Although robotic instruments are clearly more expensive than laparoscopic (848 € versus 240 €; P = 0.02), the reduced number of stapler uses in the RDP group decrease the total operative cost of almost 186 € (Table 3).

At the beginning of our experience with minimally invasive DP, we used staplers to cut the pancreatic parenchyma. But, as showed in the Table 3, in the last period of time we felt more confident by using the laparoscopic LigaSure Maryland, especially in the RDP, where 3/0 prolene sutures are easer placed to better close the pancreatic remnant thanks to the characteristics of twisted robotic arms.

In our opinion, the total operative cost of RDP are quite similar to the LDP if robotic energy devices like the intuitive ultracision or the intuitive stapler are replaced by laparoscopic devices thought the assistant trocar and not using the stapler.

On the other hand, the difference associated with the higher RDP operative time does not appear to have significant effect on the final costs, accounting for almost 6% of total operative costs.

This study has some limitations mainly due to its retrospective nature. However, to date, no randomized unicentric studies are available that address the issue of cost. Unlike LDP group, RDP group includes the first patients were operated on after the acquisition of the robotic system. This aspect may have influenced data in favour of the LRR group. However, there is no selection bias regarding the patients because the two groups were comparable and all cases were consecutive. Moreover, all patients had been offered the robotic approach. Another limitation of this study is that the initial purchase cost of the robotic system has not been included as it would have been difficult to calculate its depreciation value in our setting (where it is used also by urologists and gynaecologists) and therefore define what exactly the amortized cost per patient is.

Most of the robotic cost analysis published in the literature, the financial analyses were performed by the same centres conducting the study [13–15], which may have led to a potential bias. On the contrary in our study, an independent company performed the financial analysis, thus eliminating the risk of an observer bias.

The real cost difference of RDP versus LDP should also be evaluated to include different factors such as the cost to the quality of life, sexual and defecation functions, return to normal activity, etc. However, it is extremely difficult to place a value on these factors, and only prospective scientific studies have the means to take them into account. Furthermore, there are some factors that are almost impossible to value and are extremely difficult to compare with the laparoscopy itself, such as the training efficacy that only the double robotic console can offer or the easier instrument control and more ergonomic position of the surgeon, which are all especially useful for complex procedures such as in the pancreatic field.

5. Conclusion

This report confirms the excellence and similarity of the peri-operative outcomes of patients following RDP and LDP with a lower conversion rate and hospital stay in favour to the RDP, but at the price of a higher operative time.

Furthermore, our study shows that RDP is financially comparable to LDP. Further large, multicenter, prospective randomized controlled trials are needed to confirm our results and to define which patients may have cost-effective advantages of RDP.

Ethical approval

Due to the retrospective nature of the study, informed consent was waived. The study started after the approval of the local ethics committee.

Sources of funding

No funding.

Author contribution

Study conception and design: Ielpo, Vicente, Quijano, Caruso, J Nuñez.

Acquisition of data: Caruso, Ferri, Malavé, Lazzaro, Duran, Alvarez, Fabra, Malavé, Kalivaci, E. Jorge, Ruiz-Ocaña.

Analysis and interpretation of data: Ielpo, Caruso, Vicente, Duran, Quijano, Alvarez, Cubillo, Ferri, J Nuñez.

Drafting of manuscript: Ielpo, Lazzaro, Kalivaci, Caruso, Vicente.

Critical revision: Vicente, Quijano, Diaz, Ferri, Fabra, Malavé, Alvarez, Cubillo, Duran.

Conflicts of interest

No conflict of interest.

Trial registry number

researchregistry1060.

Guarantor

Ielpo B, Vicente E.

Acknowledgements

This study has not been funded in whole or in part by any organisation. This study was performed thanks to the collaboration with the Deloitte Digital España company leaded by Mario de la Peña and Iñaki Moreno.

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