Robotic distal pancreatectomy—current status and learning curves

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Abstract: In recent years, minimally invasive surgery has quickly overtaken conventional open techniques to become the gold-standard approach for many surgical procedures. Robotic assisted laparoscopic pancreatic surgery, positioned as a platform to overcome limitations of laparoscopy, has seen a rapid rise in adoption especially in distal pancreatectomy. Early evidence suggests superiority of the robotic surgery over laparoscopy with reduction in blood loss, conversion to laparotomy and increased rates of splenic preservation. However, limitations of cost and learning curve especially with the adoption of more complex procedures remain. This paper discusses the current literature of robotic distal pancreatectomy and its learning curve.

Keywords: Robotic surgery; distal pancreatectomy; pancreas; learning curve

Since its introduction in the 1980s, minimally invasive surgery and its advancements have drastically changed the landscape of surgery and how it is practiced (1). In the course of three decades, laparoscopy has become the gold-standard approach for many general surgical operations, including cholecystectomies and bariatric surgery. Laparoscopic surgery has been shown to have lower rates of surgical site infections, less post-operative pain and an overall shorter hospital stay as compared to the conventional open technique (2).

In 1994, Cuschieri reported the first laparoscopic pancreatic surgery (3). Although minimally invasive pancreatic surgery was initially slow in gaining acceptance among hepatobiliary and pancreatic surgeons, it is fast becoming a widely accepted approach (4). This is especially so for distal pancreatic resections. As compared to other pancreatic surgeries such as pancreaticoduodenectomy, the lack of anastomoses in distal pancreatectomy make it an especially feasible operation to carry out via a minimally invasive approach (5). A systematic review and meta-analysis by Venkat *et al.* in 2012 showed that there was a decrease in

blood loss, reduced length of hospital stay, and lower overall risk of postoperative complications and wound infections for patients who underwent laparoscopic distal pancreatectomy as compared to open. Furthermore, there was no significant increase in operative time, and oncological outcomes were not inferior to the conventional open technique (6).

Distal pancreatectomy can either be performed with or without splenic preservation. As more evidence surfaces of the important role that the spleen plays in host immunological defenses, an increasing number of spleen-preserving distal pancreatectomies have been attempted, especially for non-malignant tumours of the left pancreas (7). Warshaw described his technique in 1988, where the spleen is preserved but the main splenic artery and vein are resected, leaving the short gastric vessels for splenic perfusion (8). In 1996, Kimura *et al.* described a technique to preserve both the splenic vessels and the spleen (9). Kimura's technique describes a very careful dissection of the pancreas off the splenic vessels, with extra caution taken in ligating the many small tributaries of the splenic vein, making it technically more challenging than the Warshaw

Table 1 Outcomes of distal pancreatectomies

Reference	No. of cases	Conversion to open (%)	Percentage done with spleen preservation (%)	Operative time (mins)	LOS (days)	Cost (USD)	No significant difference
Giulianotti, 2003	5 robotic	–	40 spleen-preserving	–	–	–	–
Hwang, 2013	22 robotic	0	95.5 (81% splenic vessel preservation)	398	7	–	–
Waters, 2010	17 robotic	–	65	298	4	10,588	Blood loss, morbidity
	28 laparoscopic		29	222	6	12,986	
	32 open		12	245	8	16,059	
Liu, 2017	102 robotic	2.9	60 (malignant); 95.5 (benign)	NSD	7.6	–	Blood loss, morbidity, operative time
	102 laparoscopic	9.8	35.5 (malignant); 52.4 (benign)		8.5		
Zhou, 2015 (meta-analysis of 7 studies)	211 robotic	NSD	44.3	247.8	6.9	NSD	Major morbidity, peri-op mortality
	357 laparoscopic		26.5	229.9	8.5		
Gavriilidis, 2016 (meta-analysis of 9 studies)	246 robotic	NSD	NSD	NSD	8.2	–	Major morbidity, peri-op mortality
	391 laparoscopic				10.9		
Wright, 2016 (systematic review of 37 articles)	195 robotic	10.8	–	NSD	NSD	–	Major morbidity, peri-op mortality
	349 laparoscopic	21.7					

LOS, length of stay; NSD, no significant difference.

technique. However, with an increased risk of splenic infarction and gastric varices in the Warshaw technique (5), spleen and vessel preservation should be attempted whenever possible. The most recent meta-analysis by Yongfei *et al.* supports both the laparoscopic Warshaw and Kimura technique as safe spleen-preserving techniques. While the Kimura technique has a longer operative time and blood loss, this is offset by the lower rates of splenic infarction and gastric varices development compared to the Warshaw technique. Significantly, while there are regional variations between surgical techniques preferred for spleen preservation between Western and Eastern centres, there are no significant differences in outcomes between these techniques (10).

The first series of robotic pancreatic resections was published by Giulianotti *et al.* in 2003 with a series of five distal pancreatectomies of which two were spleen-preserving (11). The robotic platform could offer an advantage over conventional laparoscopy in spleen and vessel preserving distal pancreatectomy (*Table 1*). The laparoscopic technique has been shown to have a significant rate of conversion to open (12), possibly owing to the inherent limitations of the laparoscopic platform. These limitations were challenged by the introduction of the robotic system, which offered a three-dimensional and magnified view, instruments that allowed for greater freedom of movement, and elimination of hand tremor, resulting in better stabilization of the camera and working instruments. Waters *et al.* demonstrated a higher spleen preservation rate in robotic distal pancreatectomy as compared to laparoscopic and open techniques (65%, 29% and 12% respectively) (13). Hwang *et al.* described successfully performing 21 out of 22 planned spleen-preserving robot-assisted distal pancreatectomies, where the splenic vessels were conserved in 17 of them (81%) (14). In a review discussing the impact of robotic technology on pancreatic minimally invasive surgery, Joyce *et al.* even suggested that robotic pancreatic surgery, since its introduction, has been more eagerly adopted as compared to the traditional laparoscopic approach, and that robotic assistance seemed to enable surgeons to overcome limitations they felt with the laparoscopic system (15).

There have been several systematic reviews published in recent years comparing robotic versus laparoscopic distal

Table 2 Studies on robotic distal pancreatectomy learning curves

Author, year	No. of cases	Robotic system	No. of surgeons	Method	Learning curve
Napoli, 2015	55 consecutive	–	–	Cumulative sum analysis of operative time	10 cases
Shakir, 2015	100 consecutive	Da Vinci S or Si	3, extensive experience with LDP, no substantial robotic experience	Cumulative sum analysis of operative time	40 cases

LDP, laparoscopic distal pancreatectomy.

pancreatectomy. Gavriilidis *et al.* performed the first meta-analysis including 9 studies and 637 patients (246 robotic and 391 laparoscopic). Their findings showed that the robotic approach showed a shorter hospital length of stay of 1 day. Early results also showed a significant increased readmission rate for the robotic approach although this was based on only three studies. There were no significant differences in conversion rate, post-operative pancreatic fistula, major morbidity and spleen preservation rate (16). The Pittsburgh group did a similar review but only included studies with >40 patients with minimally invasive distal pancreatectomy in their analysis of comparative studies. This showed lower conversion rates to laparotomy and reduced blood loss but similar operative time, length of stay, morbidity and mortality (17). Limitations to these studies include the retrospective nature of these studies with small sample sizes, likely selection bias for simpler cases for the robotic approach and early learning curve of most surgeons in their early experience with robotic surgery.

In the largest comparative minimally invasive distal pancreatectomy series to date, Liu *et al.* compared the robotic *vs.* laparoscopic distal pancreatectomy using propensity score matching of 102 patients in each arm. This showed a reduction in rate of conversion to laparotomy especially in patients with large tumours (>5 cm), improved splenic and splenic vessel preservation rates in moderate tumours (3–5 cm) and a reduction in post-operative hospital stay. There were no differences in operative time, blood loss, transfusion rate and rates of overall morbidity and pancreatic fistula (18). These results suggest that in expert hands, after overcoming the learning curve, the robotic approach may allow for greater rates of completion in "difficult" resections with the reduced need for conversion either to splenic vessel and splenic resection or to laparotomy. Further studies from large centers are awaited to confirm these findings as experience with robotic pancreatic surgery accumulates.

The robotic platform however, is not without its

drawbacks. Lack of tactile feedback may result in excessive force when manipulating delicate tissue, leading to unnecessary trauma (19). Cost has also been an impedance to the widespread usage of the robotic platform. With a high base cost ranging in the millions, expensive maintenance and the need for additional consumables in the form of single-use instruments, robotic surgery has not been adequately shown to be more cost-effective despite its monetary savings with regards to shorter length of hospital stay and productivity gains (20) (*Table 1*). This evidence is conflicting however, as the use of the robotic approach can be shown to be profitable in some hospital settings (21). Furthermore, as some authors suggest, with the wider adoption of the robotic system, market pressures and increased competition from other players may eventually drive the cost of instrumentation and robotic utilization lower (17).

Another drawback is the learning curve needed to become even adept with the robotic surgical system, let alone translating that new expertise into better clinical outcomes for patients. Most studies use the number of cases needed to achieve a plateau in operative time as a variable to examine the learning curve, and current evidence shows a very wide range of results, with little examination of clinical outcomes (*Table 2*). Pernar *et al.* reviewed the literature on robotic surgery learning curves where colorectal cases were shown to have a range of 25–75 cases, 10–95 cases for foregut or bariatric surgery, and 10–80 for solid organ surgery (22).

At this time, insufficient evidence exists to draw a significant conclusion regarding the learning curve for robotic distal pancreatectomy. Napoli *et al.* was able to describe a relatively gentle learning curve of 10 cases, based on reductions in operative time, but was unable to demonstrate any improvement in clinical outcome (23). Shakir *et al.* analyzed the first 100 consecutive robotic distal pancreatectomy cases at a high-volume center. He described a learning curve of 40 cases, and also performed

further analysis of perioperative outcomes comparing the pre-learning curve and post-learning curve cohorts, which showed significant reductions in complication and readmission rates after the learning curve had been reached (24).

In conclusion, current evidence demonstrates clear benefits of minimally invasive distal pancreatectomy over the open technique for indicated cases. There is also data to support robotic distal pancreatectomy over the laparoscopic technique especially when there is a role for spleen and vessel preservation. More high-quality studies on learning curves and the comparison of outcomes of pre- and post-learning curve cohorts could definitely contribute to the ongoing debate of the cost-benefit ratio of the robotic platform as compared to the conventional laparoscopic technique.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/ales.2017.11.05). The authors have no conflicts of interest to declare.

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References

1. Blum CA, Adams DB. Who did the first laparoscopic cholecystectomy? J Minim Access Surg 2011;7:165-8.
2. Morneau M, Boulanger J, Charlebois P, et al. Laparoscopic versus open surgery for the treatment of colorectal cancer: a literature review and recommendations from the Comité de l'évolu- tion des pratiques en oncologie. Can J Surg 2013;56:297-310.
3. Cuschieri A. Laparoscopic surgery of the pancreas. J R Coll Surg Edinb 1994;39:178-84.
4. Merchant NB, Parikh AA, Kooby DA. Should all distal pancreatectomies be performed laparoscopically? Adv Surg 2009;43:283-300.
5. Iacobone M, Citton M, Nitti D. Laparoscopic distal pancreatectomy: up-to-date and literature review. World J Gastroenterol 2012;18:5329-37.
6. Venkat R, Edil BH, Schulick RD. Laparoscopic distal pancreatectomy is associated with significantly less overall morbidity compared to the open technique: a systematic review and meta-analysis. Ann Surg 2012;255:1048-59.
7. Shoup M, Brennan MF, McWhite K, et al. The value of splenic preservation with distal pancreatectomy. Arch Surg 2002;137:164-8.
8. Warshaw AL. Conservation of the spleen with distal pancreatectomy. Arch Surg 1988;123:550-3.
9. Kimura W, Inoue T, Futakawa N, et al. Spleen-preserving distal pancreatectomy with conservation of the splenic artery and vein. Surgery 1996;120:885-90.
10. Yongfei H, Javed AA, Burkhart R, et al. Geographical variation and trends in outcomes of laparoscopic spleen-preserving distal pancreatectomy with or without splenic vessel preservation: A meta-analysis. Int J Surg 2017;45:47-55.
11. Giulianotti PC, Coratti A, Angelini M, et al. Robotics in general surgery: personal experience in a large community hospital. Arch Surg 2003;138:777-84.
12. Daouadi M, Zureikat AH, Zenati MS, et al. Robot-assisted minimally invasive distal pancreatectomy is superior to the laparoscopic technique. Ann Surg 2013;257:128-32.
13. Waters JA, Canal DF, Wiebke EA, et al. Robotic distal pancreatectomy: cost effective? Surgery 2010;148:814-23.
14. Hwang HK, Kang CM, Chung YE, et al. Robot-assisted spleen-preserving distal pancreatectomy: a single surgeon's experiences and proposal of clinical application. Surg Endosc 2013;27:774-81.
15. Joyce D, Morris-Stiff G, Falk GA, et al. Robotic surgery of the pancreas. World J Gastroenterol 2014;20:14726-32.
16. Gavriilidis P, Lim C, Menahem B, et al. Robotic versus laparoscopic distal pancreatectomy – the first meta-analysis. HPB (Oxford) 2016;18:567-74.

17. Wright GP, Zureikat AH. Development of minimally invasive pancreatic surgery: an evidence-based systematic review of laparoscopic versus robotic approaches. J Gastrointest Surg 2016;20:1658-65.

18. Liu R, Liu Q, Zhao ZM, et al. Robotic versus laparoscopic distal pancreatectomy: A propensity score-matched study. J Surg Oncol 2017;116:461-9.

19. Bethea BT, Okamura AM, Kitagawa M, et al. Application of haptic feedback to robotic surgery. J Laparoendosc Adv Surg Tech A 2004;14:191-5.

20. Barbash GI, Glied SA. New technology and health care costs--the case of robot-assisted surgery. N Engl J Med 2010;363:701-4.

21. Geller EJ, Matthews CA. Impact of robotic operative efficiency on profitability. Am J Obstet Gynecol 2013;209:20.e1-5.

22. Pernar LI, Robertson F, Sheu EG, et al. What is the learning curve in robotic general surgery? SAGES 2016 Scientific Session. Available online: https://www.sages.org/meetings/annual-meeting/abstracts-archive/what-is-the-learning-curve-in-robotic-general-surgery/

23. Napoli N, Kauffmann EF, Perrone V, et al. The learning curve in robotic distal pancreatectomy. Updates Surg 2015;67:257-64.

24. Shakir M, Boone BA, Polanco PM, et al. The learning curve for robotic distal pancreatectomy: an analysis of outcomes of the first 100 consecutive cases at a high-volume pancreatic centre. HPB (Oxford) 2015;17:580-6.