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REVIEW ARTICLE

The application of the robotic surgical system in pancreaticoduodenectomy

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Abstract

Owing to the operative complexity, the application of minimally invasive surgery to pancreatic procedures has been delayed. However, with advances in technique, and since the introduction of robotic systems in particular, pancreatic minimally invasive surgery has made much progress. Laparoscopic and robotic technology has been widely adopted. The safety and feasibility of minimally invasive procedures for pancreaticoduodenectomy have been confirmed in many reports. However, even with these advantages, laparoscopic and robotic surgery cannot completely replace laparotomy. Pancreatic surgeons need to master these three operative methods to be able to handle complicated clinical situations.

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Pancreaticoduodenectomy (PD) is a major surgical procedure involving the pancreas, duodenum, common bile duct, pylorus, and jejunum for the treatment of neoplasms of the pancreatic head or ampullary region. PD has always been challenging, mainly because of its technical complexity and the difficulty associated with extensive visceral organ dissection and reconstruction of the digestive tract. Therefore, PD is normally performed using an open approach. With the rapid development of technology, some pancreatic procedures are performed laparoscopically. The use of laparoscopy is relatively restricted in PD because of its intrinsic technical limitations. Distal pancreatectomy accounts for the majority of laparoscopic pancreatic procedures. Compared with its use in urology, gynecology, and other surgical fields, the adaptation of laparoscopy in pancreatic surgery has been relatively slow. In the past 20 years, robotic surgery has rapidly advanced and has been widely adopted in pancreatic surgery because of its unique advantages. This surgical system with its sophisticated devices allows surgeons to attempt more challenging robotic cases of PD. The pancreatic surgery center of Ruijin Hospital was one of the earliest agency to perform pancreatic operations in China. Our center installed the da Vinci surgical system model S in 2010. To date, we have performed nearly 200 cases of robotic PD. We installed the newest Model Si in January 2016, and promptly began performing robotic pancreatic surgeries with the new model.

Development history

PD was first performed in the 19th century. In the 1940s, Whipple [1], Child [2], and other pancreatic surgeons established a standard PD procedure that is still being used today. Near the end of the 20th century, open PD surgery had matured. Laparoscopic technology has been gradually adopted since its invention in the mid-20th century. The first case of laparoscopic surgery was a cholecystectomy, performed by Philippe Mouret [3] in March 1987. The robotic surgical system was invented at the end of the 20th century and has been clinically relevant ever since. The first case of robotic surgery was also a cholecystectomy, performed by Himpens [4] in 1998. Since then, the use of robotic systems has spread quickly to other surgical fields. The complexity of PD

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and limitations of laparoscopic devices impeded further growth of laparoscopic pancreatic surgery. The robotic surgical system provides three-dimensional imaging, thus making the surgical field more real and vivid. The multi-angle rotatable EndoWrist can synchronize itself to the surgeon's hand motion. This device can also filter out hand tremor. These advantages have broadened the application of robotic systems to pancreatic surgery. Giulianotti [5] first reported robotic PD in 2003, only 5 years after the first robotic cholecystectomy had been reported.

New developments in laparoscopic PD

Laparoscopic surgery, with its good surgical outcomes, has been accepted by the majority of patients in the past 20 years and has become the first choice for some operations. Gagner [6] first reported laparoscopic PD in 1994. Uyama [7] first reported laparoscopic mini-laparotomy PD in 1996. With the continuous improvement in laparoscopic techniques and instruments, laparoscopic pancreatic surgery also advanced. Multiple pancreatic centers have reported their use of laparoscopy in PD, including total laparoscopic PD [8–9] and hand-assisted laparoscopic PD [10–11]. In a review [12] of laparoscopic PD, Gagner noted that 146 cases reported from 1994 to 2009 had a 46% conversion rate, and average operative times and blood loss of 439 min and 143 mL, respectively. Since then, there have been multiple reports of laparoscopic PD from other institutions [13–15]. Also meta-analyses comparing open and laparoscopic PD [16] and laparoscopic and robotic PD [17] have been published by many agencies.

New development in robotic PD

The da Vinci surgical system was introduced in 1997 by Intuitive Surgical Inc. (USA), and received the Food and Drug Authority (FDA) operating license in 2000. This surgical system compensated for the shortcomings of traditional laparoscopy. Giulianotti [5] reported the first robotic PD in 2003. In this article, 8 robotic PD procedures were performed in an average of 490 min, with morbidity and mortality rates of 37.5% and 12.5% respectively. Giulianotti [18] performed 60 cases of robotic PD in the USA and Italy from 2003 to 2009. Zureikat [19] performed 30 cases of robotic PD in the USA from 2008 to 2010. As of 2012, Zureikat [20] and colleagues had performed 250 robotic pancreatic surgeries, including 132 cases of robotic PD. Choi [21] reported the first robotic PD in South Korea in 2011. With cases of robotic PD being reported frequently, the safety and feasibility of robotic surgery has also been confirmed. Buchs [22] noted that robotic PD offers remarkable advantages in terms of operative time, blood loss, and number of resected lymph nodes, compared with the results for open PD, with no significant differences in postoperative hospital stay, complications, and mortality rate. Another report by Buchs [23] indicated that robotic PD is also safe for elderly patients. Horiguchi [24] reported that patients who underwent robotic PD had a shorter postoperative hospital stay and earlier resumption of oral intake.

As of December 2011, 2,132 robotic surgical systems have been installed worldwide, with 13 devices installed in China. Zhou and colleagues firstyly reported 8 robotic PD cases in China in 2009, with a mean operative time and mean blood loss of 718 min and 153 mL, respectively. This surgical team reported 44 robotic pancreatic surgeries in 2011, including 16 robotic PD cases. Our pancreatic center also published multiple reports about the technique and experiences with robotic pancreatic surgery [25–26]. Few institutions have the prerequisites to carry out robotic surgery in China. Shanghai Ruijin Hospital and The Second Artillery General Hospital PLA perform relatively large numbers of robotic pancreatic operations. The results for procedures, operative time, blood loss, complications, and mortality rate are similar to those reported by high-volume centers worldwide. Shanghai Ruijin Hospital has completed more than 700 robotic pancreatic surgeries since 2010. A total of 217 robotic PD cases have been performed, with a mean operative time and mean blood loss of 332 min and 378 mL, respectively. Pancreatic fistulas occurred in 24.5% of patients. Of these, 60% were grade A pancreatic fistulas, and recovered without incident after drainage. Our center conducted a prospective study [27] of surgical outcomes comparing open and robotic PD. Results from this study indicate that robotic PD has a longer operative time, but less blood loss, earlier resumption of oral intake, and shorter postoperative hospital stay than open PD does, with no significant differences in mortality and survival rate.

Advantages of robotic PD

The visual field in laparoscopy is 2-dimensional (2D), while the robotic surgical system provides 3-dimensional (3D) visualization, with up to 15× magnification. The 3D image in the console viewer allows surgeons to see anatomical structures in high definition and natural colors, making the visual field more real and vivid. Surgeons can easily distinguish small vessels to reduce bleeding. The end of the laparoscopic instrument can only rotate along one axis and cannot be bent. Dexterous control of the instrument is difficult. With more complicated situations like small operative spaces or deep mass locations, it became problematic to smoothly continue procedures. EndoWrist instruments equipped on 3 robotic arms can bend and rotate to a greater degree than the human wrist. The multi-angle rotatable EndoWrist can synchronize itself with the surgeon's hand motion and can filter out hand tremor. These advantages enable more stable

hemostasis, suturing, and other procedural steps during the operation.

Surgical training is relatively long for laparoscopy. Adapting from the 3D perspective of open surgery to the 2D imaging of laparoscopic surgery can be difficult. Robotic surgery provides 3D vision similar to that in laparotomy. The adaptation period is decreased. Surgeons with previous experience in laparoscopic surgery have an even shorter learning curve. Surgeons can sit and operate through a console system that requires minimal direct contact with the patient, allowing taking breaks during the operation without having to scrub again. These factors help surgeons reduce fatigue and enable concentration for a longer duration.

Prospects

The safety and feasibility of minimally invasive pancreatic surgery, and robotic surgery in particular, have been demonstrated repeatedly. The trend in pancreatic surgery is minimally invasive procedures. However, even with their numerous advantages, laparoscopic and robotic surgery cannot completely replace laparotomy. Pancreatic surgeons need to master these 3 complementary operative methods to be able to manage complicated clinical situations.

References

1. Whipple AO. Pancreaticoduodenectomy for islet carcinoma: a five-year follow-up. Ann Surg, 1945, 121: 847–852.
2. Child CG. Pancreaticojejunostomy and other problems associated with the surgical management of carcinoma involving the head of the pancreas: report of five additional cases of radical pancreaticoduodenectomy. Ann Surg, 1944, 119: 845–855.
3. Polychronidis A, Laftsidis P, Bounovas A, *et al*. Twenty years of laparoscopic cholecystectomy: Philippe Mouret--March 17, 1987. JSLS, 2008, 12: 109–111.
4. Himpens J, Leman G, Cadiere GB. Telesurgical laparoscopic cholecystectomy. Surg Endosc, 1998, 12: 1091.
5. Giulianotti PC, Coratti A, Angelini M, *et al*. Robotics in general surgery: personal experience in a large community hospital. Arch Surg, 2003, 138: 777–784.
6. Gagner M, Pomp A. Laparoscopic pylorus-preserving pancreatico-duodenectomy. Surg Endosc, 1994, 8: 408–410.
7. Uyama I, Ogiwara H, Iida S, *et al*. Laparoscopic minilaparotomy pancreaticoduodenectomy with lymphadenectomy using an abdominal wall-lift method. Surg Laparosc Endosc, 1996, 6: 405–410.
8. Dulucq JL, Wintringer P, Mahajna A. Laparoscopic pancreatico-duodenectomy for benign and malignant diseases. Surg Endosc, 2006, 20: 1045–1050.
9. Palanivelu C, Jani K, Senthilnathan P, *et al*. Laparoscopic pancreaticoduodenectomy: technique and outcomes. J Am Coll Surg, 2007, 205: 222–230.
10. Ammori BJ. Laparoscopic hand-assisted pancreaticoduodenectomy: initial UK experience. Surg Endosc, 2004, 18: 717–718.
11. Kimura Y, Hirata K, Mukaiya M, *et al*. Hand-assisted laparoscopic pylorus-preserving pancreaticoduodenectomy for pancreas head disease. Am J Surg, 2005, 189: 734–737.
12. Gagner M, Palermo M. Laparoscopic Whipple procedure: review of the literature. J Hepatobiliary Pancreat Surg, 2009, 16: 726–730.
13. Delitto D, Luckhurst CM, Black BS, *et al*. Oncologic and perioperative outcomes following selective application of laparoscopic pancreaticoduodenectomy for periampullary malignancies. J Gastrointest Surg, 2016, 20: 1343–1349.
14. Fan Y, Zhao Y, Pang L, *et al*. Successful experience of laparoscopic pancreaticoduodenectomy and digestive tract reconstruction with minimized complications rate by 14 case reports. Medicine, 2016, 95: e3167.
15. Dokmak S, Chérif R, Duquesne I, *et al*. Laparoscopic pancreaticoduodenectomy with reconstruction of the portal vein with the parietal peritoneum. Ann Surg Oncol, 2016, 23: 2664.
16. Battal M, Yilmaz A, Ozturk G, *et al*. The difficulties encountered in conversion from classic pancreaticoduodenectomy to total laparoscopic pancreaticoduodenectomy. J Minim Access Surg, 2016 12: 338–341.
17. Walsh RM, Chalikonda S. How I do it: hybrid laparoscopic and robotic pancreaticoduodenectomy. J Gastrointest Surg, 2016, 20: 1650–1657.
18. Giulianotti PC, Sbrana F, Bianco FM, *et al*. Robot-assisted laparoscopic pancreatic surgery: single-surgeon experience. Surg Endosc, 2010, 24: 1646–1657.
19. Zureikat AH, Nguyen KT, Bartlett DL, *et al*. Robotic-assisted major pancreatic resection and reconstruction. Arch Surg, 2011, 146: 256–261.
20. Zureikat AH, Moser AJ, Boone BA, *et al*. 250 robotic pancreatic resections: safety and feasibility. Ann Surg, 2013, 258: 554–559.
21. Choi SH, Kang CM, Kim DH, *et al*. Robotic pylorus preserving pancreaticoduodenectomy with mini-laparotomy reconstruction in patient with ampullary adenoma: a case report. J Korean Surg Soc, 2011, 81: 355–359.
22. Buchs NC, Addeo P, Bianco FM, *et al*. Robotic versus open pancreaticoduodenectomy: a comparative study at a single institution. World J Surg, 2011, 35: 2739–2746.
23. Buchs NC, Addeo P, Bianco FM, *et al*. Outcomes of robot-assisted pancreaticoduodenectomy in patients older than 70 years: a comparative study. World J Surg, 2010, 34: 2109–2114.
24. Horiguchi A, Uyama I, Miyakawa S. Robot-assisted laparoscopic pancreaticoduodenectomy. J Hepatobiliary Pancreat Sci, 2011, 18: 287–291.
25. Peng CH, Shen BY, Deng XX, *et al*. Early experience for the robotic duodenum-preserving pancreatic head resection. World J Surg, 2012, 36: 1136–1141.
26. Chen S, Zhan Q, Chen JZ, *et al*. Robotic approach improves spleen-preserving rate and shortens postoperative hospital stay of laparoscopic distal pancreatectomy: a matched cohort study. Surg Endosc, 2015, 29: 3507–3518.
27. Chen S, Chen JZ, Zhan Q, et al. Robot-assisted laparoscopic versus open pancreaticoduodenectomy: a prospective, matched, mid-term follow-up study. Surg Endosc, 2015, 29: 3698–3711.

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