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Artificial Intelligence in Gastrointestinal Endoscopy

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AIMS AND SCOPE

The primary aim of *Artificial Intelligence in Gastrointestinal Endoscopy* (AIGE, *Artif Intell Gastrointest Endosc*) is to provide scholars and readers from various fields of artificial intelligence in gastrointestinal endoscopy with a platform to publish high-quality basic and clinical research articles and communicate their research findings online.

AIGE mainly publishes articles reporting research results obtained in the field of artificial intelligence in gastrointestinal endoscopy and covering a wide range of topics, including artificial intelligence in capsule endoscopy, colonoscopy, double-balloon enteroscopy, duodenoscopy, endoscopic retrograde cholangio-pancreatography, endosonography, esophagoscopy, gastrointestinal endoscopy, gastroscopy, laparoscopy, natural orifice endoscopic surgery, proctoscopy, and sigmoidoscopy.

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Robotic pancreaticoduodenectomy: Where do we stand?

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Abstract

Pancreaticoduodenectomy (PD) is a complex operation accompanied by significant morbidity rates. Due to this complexity, the transition to minimally invasive PD has lagged behind other abdominal surgical operations. The safety, feasibility, favorable post-operative outcomes of robotic PD have been suggested by multiple studies. Compared to open surgery and other minimally invasive techniques such as laparoscopy, robotic PD offers satisfactory outcomes, with a non-inferior risk of adverse events. Trends of robotic PD have been on rise with centers substantially increasing the number the operation performed. Although promising, findings on robotic PD need to be corroborated in prospective trials.

Key Words: Pancreaticoduodenectomy; Whipple Procedure; Pancreas; Robotic; Surgery

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Core Tip: The robotic Whipple procedure is a safe and technically feasible surgical operation. Robotic pancreaticoduodenectomy has shown favorable outcomes and is currently increasing in widespread implementation. Prospective trials are needed before this relatively new approach can be fully adopted as a standard of care in patients with pancreatic neoplasms.

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INTRODUCTION

Pancreaticoduodenectomy (PD) or Whipple surgery, is a complex procedure associated with significant morbidity rates[1]. Due to the complexity of this operation, PD's move to a more minimally invasive approach has lagged behind other general surgery procedures[2]. Gagner and Pomp[3], pioneered the laparoscopic PD (LPD) back in 1994, but LPD has not successfully transitioned into routine surgical care[3]. This is partly due to the difficulty associated with LPD in terms of expertise needed to perform the operation and the complexity of teaching the approach. In addition, the LEOPARD-2 trial demonstrated that LPD has a higher 90-d mortality as compared to the open PD (OPD). This eventually led to the discontinuation of the trial[4].

Robotic PD (RPD), which was first performed by Giulianotti *et al*[5], was originally described in 2001. Later in 2003, the same team published a series of 8 robotic-assisted cases[6]. The preliminary results established that RPD is both safe and feasible. Their reported mean operative time was around 8 h (490 min) in this case series.

Following these promising results, an increasing number of surgeons started utilizing the RPD approach. Different than initial reports of LPD, where some showed that LPD does not provide benefit as compared to the open approach, RPD benefits and advantages have been reported with increasing rate since its launch[7,8]. However, the "Miami International Guideline on Minimally Invasive Pancreas Resection" still does not assume minimally invasive PD is equal to OPD due to insufficient data[9].

WHAT IS THE ROBOTIC SURGICAL TECHNIQUE AND ITS CHALLENGES?

Robotic surgery is considered a direct advancement of laparoscopy. The most widely utilized surgical system to perform RPD in specific, as well as in other operations, is the DaVinci system developed by Intuitive Surgical Incorporated[10]. The robotic system provides surgeons increased dexterity employing endo-wristed instruction, three-dimensional stereoscopic views of the surgical field, filtering of user tremors, and it provides pancreatic surgeons the capability to perform extremely complex dissections, sutures, knots and reconstructions with unparalleled precision, magnification and accuracy[11,12].

Variations in robotic Whipple techniques exist between pancreatic surgeons. While some groups undergo the operation completely robotically, other choose to use a cross laparoscopic/robotic approach. Giulianotti *et al*[5] support a performing the operation entirely using the robotic approach, while other groups advocate the "hybrid" approach. The hybrid or cross method entails dissecting first using laparoscopy and then performing the reconstruction part using the robot[13,14]. At the University of Pittsburgh Medical Center, the surgeons employ a robotic exclusive approach, using four robotic ports, two assistant and one retractor port as shown in Figure 1. RPD follows the same steps as Whipple's 1935 description[15]. The gastroduodenal ligament is first dissected to gain access to the lesser sac. Then, the ascending and transverse colon are mobilized. This is followed by a complete Kocher maneuver. Transection of the jejunum and the stomach (in classic Whipple) are then performed using stapling devices. Then, the porta is approached to transect the gastroduodenal artery and the hepatic duct. This is followed by transection of the pancreas at the neck and finally dissecting the uncinate of the mesenteric vessels. The reconstruction phase includes the creation of a pancreaticojejunostomy, followed by hepaticojejunostomy and finally a gastrojejunostomy. Finally, a drain is left behind and the port and extraction sites are closed.

The challenges facing the introduction of RPD are numerous. First, robotic operations are known to still have long operating time as compared to open ones. Second, due to the complexity of the robotic approach, there is an increased need of training (higher learning curve) than the open and other minimally invasive techniques (laparoscopic). Third, robotic surgeries carry a high financial burden to patients, covering bodies and hospitals. This helps favor the open or laparoscopic approach for PD by insuring bodies and patients paying out-of-pocket. Fourth, RPDs require high-end infrastructure, which includes larger operating rooms, more technical staff present (in case any issues arise), and robotic certification by faculty and trainees. Finally, there is an increased difficulty in making prospective randomized trials in robotic operations. This issue arises with the decreased apparel/enrollment into robotic trials due to patient preference of open or laparoscopic approaches.

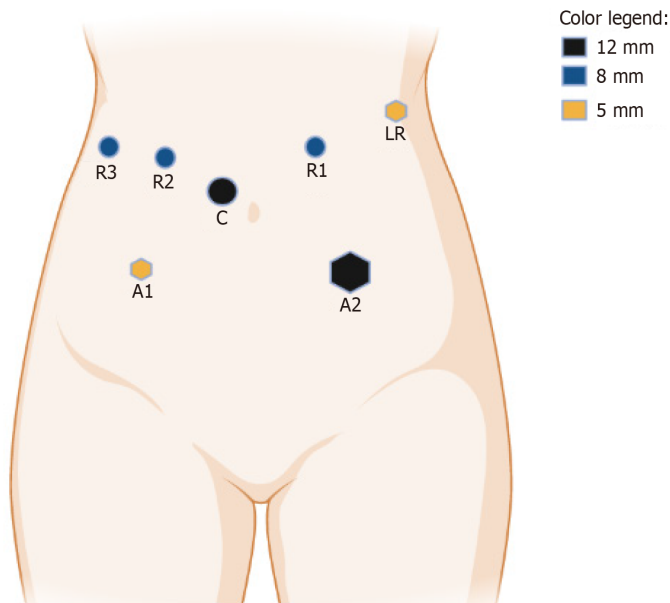


Figure 1 Port placement for robotic pancreaticoduodenectomy. R1: Robotic arm 1; R2: Robotic arm 2; R3: Robotic arm 3; C: Camera; A1: Assistant arm 1; A2: Assistant arm 2. Camera may be inserted through an 8 mm port in the Xi System. It may be inserted through a 12 mm port in the Si System.

WHAT ARE THE TRENDS AND OUTCOMES OF THE ROBOTIC WHIPPLE PROCEDURE?

A recent study exploring the trends of the RPD for pancreatic cancers demonstrated an increasing number of RPDs over the past decade. This was accompanied by a greater reach of RPD where it may be found in community centers across the US, after being present only in a few number of academic medical facilities[16]. Robotic procedures increased from 150 operations/year to around 450 operation/year from 2010-2016[16]. This is likely owing to an increase in the number of graduates from fellowship programs that include robotic pancreas surgery as part of their curriculum, as well as greater experience and "retraining" of experienced pancreatic surgeons in the robotic approach[17-20].

Overall, the robotic method appears to enhance short-term outcomes over time. Between 2010 and 2016, there was a substantial rise in the number of lymph nodes harvested (from 18 to 21), as well as a drop in postoperative mortality (from 6.7 percent to 1.8 percent)[16]. Yan *et al*[21] found that as compared to open PD, RPD had considerably longer operating time, less blood loss, shorter length of stay, and reduced infection rates in a recent meta-analysis comprising 2403 patients (788 robotic and 1615 open). There was no discernible change in lymph node harvesting, reoperation, readmission rate, or death rate[21]. Another meta-analysis by Kamarajah *et al*[22] found that RPD had substantially lower conversion and transfusion rates than LPD, with 3462 participants (1025 robotic and 2437 Laparoscopic). RPD had a substantially shorter hospital stay after surgery, but there was no significant difference in postoperative outcomes or R0 resection rates. Zureikat *et al*[23] demonstrated that RPD was linked with decreased operating time, perioperative blood loss, and postoperative pancreatic fistula development in the largest series of RPD comprising 500 robot-assisted PD. These findings were described early in the group's experience and remained low despite growing complexity of cases. Less frequent conversion to open was also noted. As for long term outcomes, Nassour *et al*[24] identified 17831 PD from the National Cancer Database, of which 626 were RPDs. The median overall survival did not differ between the robotic (22 mo) and open (21.8 mo) approaches. Table 1 highlights RPD findings from a variety of research. In the hands of skilled surgeons, RPD is a relatively safe procedure with excellent perioperative and postoperative results.

Table 1 Outcomes of robotic pancreaticoduodenectomy in selected studies

Ref.	n	OR time (mean in min)	EBL (mean in mL)	Conversion (%)	R0 (%)	LN harvest (mean)	Fistula (%)	Morbidity (%)	Mortality (%)	LOS (mean in days)
Giulianotti <i>et al</i> [28], 2010	60	421	394	18.3	82	18	31.6	NR	3.3	22
Narula <i>et al</i> [29], 2010	5	420	NR	37.5	100	16	0	0	0	9.6
Zhou <i>et al</i> [30], 2011	8	718	153	0	100	NR	25	NR	0	16.4
Lai <i>et al</i> [31], 2012	20	491.5	247	5	73.3	10	35	50	0	13.7
Chalikonda <i>et al</i> [32], 2012	30	476	485	10	100	13.2	6.6	30	3	9.8
Bao <i>et al</i> [33], 2014	28	431	100	14	88	15	29	NR	2	7.4
Boone <i>et al</i> [34], 2015	200	483	250	6.5	92	22	17	67.5	3.3	9
Chen <i>et al</i> [26], 2015	60	410	400	1.7	97.8	13.6	13.3	35	1.7	20
Boggi <i>et al</i> [35], 2016	83	527	NR	1.5	NR	37	33.7	73.5	3	17
Nassour <i>et al</i> [36], 2017	193	399	NR	11.4	NR	NR	20.8	54.9	1	8
Jin <i>et al</i> [37], 2020	17	240	100	0	NR	4	59	66.4	NR	15
Mejia <i>et al</i> [38], 2020	102	352	321	12.7	73	24.2	3.9	31.3	2.9	7
Shi <i>et al</i> [39], 2020	187	279	297	3.7	94	16.6	10.2	35.6	2.1	22.4
Zureikat <i>et al</i> [23], 2021	500	415	250	5.2	85	28	20.2	68.8	1.8	8

EBL: Estimated blood loss; LN: Lymph node; LOS: Length of stay; NR: Not reported; OR: Operation; R0: Margin negative resection.

WHAT IS THE LEARNING CURVE AND FUTURE OF ROBOTIC WHIPPLE PROCEDURE?

The reported learning curves for RPD are currently variable among different institutions. The University of Pittsburgh Medical center reported that 80 RPDs would be required to optimize operative time, 40 cases for an optimal pancreatic fistula rate and 20 cases to improved blood loss and conversion[25]. This was due to the fact that the surgeons at the center had no prior training, mentorship, or guidance in the technique as the robotics program was implemented in 2008. According to Chen *et al* [26], a comparable result can be reached after 40 RPDs. At 40 patients, Zhang *et al* [27] found a comparable learning curve for RPD. The learning curve may be short if adequate training and guidance is performed in surgical formative years. A formal mastery-based curriculum which integrates complex robotic procedures into practice may help in shortening the learning curve.

The future directions of RPD will likely involve the use of robotics in borderline resectable or locally advanced pancreatic lesion cases i.e. more surgically complex cases. This also includes performing complex vasculature reconstructions using the robotic approach. However, in order to develop these surgical techniques, better infrastructure, increased training, and more prospective randomized clinical trials are required. The first step needed is to prove that RPD is noninferior to the open technique in PD with level 1 evidence. This entails increasing the number of prospective trials in order to perform meta-analyses and systematic reviews. Afterwards, increased funding and training can follow, which will allow for further developments of the RPD technique discussed. Additionally, robotic training will need to be introduced and integrated early into residency programs (possibly using simulation labs) to help with the learning curve of future robotic surgeons.

CONCLUSION

Current evidence indicates that RPD is a safe and feasible procedure. The robotic approach overcomes many of technical challenges associated with the laparoscopic Whipple procedure. RPD, in the proper hands, can help patients and surgeons with periampullary lesions achieve good results. More prospective clinical trials are still needed to verify previously published retrospective research on RPD.

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