Review Article

Reduced-port robotic pancreatectomy: a narrative review of the literature

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Background and Objective: Minimally invasive pancreatectomy (MIP) has been increasingly performed in recent years. While the introduction of laparoscopic distal pancreatectomy (LDP) was straightforward, laparoscopic pancreaticoduodenectomy (LPD) was perceived as technically challenging due its complexity. However, robotic surgical innovation made concrete the feasibility of robotic pancreatectomy. These technological reforms have led to surgeons advocating for reduced-port surgery (RPS) for reduced procedure invasiveness. However, there are fewer reports on reduced-port robotic pancreatectomy (RPRP) than on other types of robotic surgery. Minimally invasive surgery (MIS) has lagged behind most in this area due to the complexity of pancreatectomy. In this narrative review, we provide a comprehensive overview of the evolution of RPRP.

Methods: Original manuscripts on RPRP, written in English and published before May 30, 2022, were searched for in the PubMed, Embase and Cochrane databases. Keywords included "single-port", "single-site", or "single-incision" robotic pancreatectomies.

Key Content and Findings: The search revealed seven studies reporting 104 cases of RPRP, including 59 and 45 cases of distal pancreatectomy (DP) and pancreaticoduodenectomy (PD), respectively. Although there were only two studies comparing reduced-port laparoscopic pancreatectomies and open or laparoscopic pancreatectomy, perioperative outcomes were acceptable for both DP and PD. Only five patients in this review required conversion to multi-port or open surgery (4.8%). Although the small number of material papers in this review may not conclusively guide the next steps in this surgery, we found no evidence to disprove the feasibility of RPRP.

Conclusions: Based on the results of further comparative studies with conventional robotic pancreatectomy, we hope that RPRP will become more widely used in the future.

Keywords: Reduced-port surgery (RPS); single-port robotic pancreatectomy; single-site robotic surgery; pancreaticoduodenectomy (PD); distal pancreatectomy (DP)

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Introduction

Minimally invasive surgery (MIS) has shown an upward trend in many surgical fields worldwide. In the pancreatic field, surgical technology has undergone innovative developments in recent decades, including surgery for advanced pancreatic cancer and the introduction of MIS. While open pancreatectomies are systematized, minimally invasive pancreatectomy (MIP) is expected to reduce morbidity and is believed to have significant advantages, such as lower pain, less blood loss, and shorter time to adjuvant therapy (1). However, there remain several limitations, such as the difficulty of the MIP due to the location of the pancreas, which led to fewer laparoscopic pancreatectomies being performed, compared to other abdominal surgeries. Currently, laparoscopic distal pancreatectomy (LDP) is accepted globally, as it is comparable to open surgery in terms of feasibility and safety (1,2). However, general gastroenterological surgeons who commonly perform open pancreaticoduodenectomy (PD) may not be able to perform laparoscopic PD (LPD), because of the complex procedures involved, namely, dissection around the superior mesenteric vein, portal vein, and superior mesenteric artery, and reconstruction with laparoscopic limitations (3-5). Apart from LDP, LPD is still performed by a limited number of expert surgeons worldwide. Robotic surgery involves surgical innovations such as motion scaling, tremor reduction, and an internal articulated wrist (6). In addition to these features, the inclusion of three-dimensional visualization and up to seven degrees of freedom facilitates the performance of robotic distal pancreatectomy (RDP) and robotic PD (RPD).

MIS allows for other perspectives that should be considered in the development of reduced-port surgery (RPS). This technique, which is often called the "single-port" or "single-site" surgery, without depending on the number of lesions, is expected to be less invasive than conventional laparoscopic surgery (7,8). RPS has organically become common worldwide. However, it is associated with technical limitations, including instrumental collisions owing to difficulties in triangulation; numerous procedural improvements and new technologies are necessary to accomplish RPS laparoscopically. However, robotic systems can overcome this issue as they enable flexible articulation of instruments. Although many studies on RPS have been published in various surgical robotics fields (9-11), there are fewer reports of robotic RPS in pancreatic field than those of robotics in other fields because of the complexity and difficulty.

Although reduced-port robotic pancreatectomy (RPRP) is still not widely recognized, several expert surgeons have attempted to perform RPRP in recent years. Most of these attempts are for RDP, but reduced-port RPD (RPRPD) is being performed at a small number of institutions, including ours. Herein, we present the current status and evaluate the feasibility of RPRP in terms of future prospects. We present the following article in accordance with the Narrative Review reporting checklist (available at https://ls.amegroups.com/article/view/10.21037/ls-22-47/rc).

Review strategy

We searched for original manuscripts on RPRP, published before May 30, 2022, in the PubMed, Embase, and Cochrane databases. The following terms were used to perform the search: (I) "robotic" or "robot-assisted"; (II) "pancreatectomy", "pancreatic surgery", "pancreaticoduodenectomy", "pancreatoduodenectomy", or "Whipple"; and (III) "reduced-port", "single-port", "single-site", or "single-incision". The list of potentially matched studies was analyzed. As few reports were expected, the data of studies written in English were analyzed without setting a lower limit on the number of cases or without excluding the pathological outcomes, including case reports. Complications were standardized according to the Clavien-Dindo classification (12), and a postoperative pancreatic fistula (POPF) was defined as a pancreas-specific complication according to the guidelines of the International Study Group on Pancreatic Surgery (13). Two authors independently screened the papers for. Because this was a narrative review, ethical approval was not required. The search strategy was summarized in *Table 1*.

RPRP

Few reports on RPRP exist; we were able to find only seven studies, including one case report (*Tables 2*,*3*). In total, 104 RPRP cases were reported in the literature, including 59 cases of reduced-port RDP (RPRDP) and 45 cases of RPRPD. RPRP was first performed by Kim *et al.*, who reported a single-site plus one-port RDP in 2017 (14). Patient background and reduced-port technique details are presented in *Table 2*. Although the participants in these studies varied in age range, generally, RPRPs were not performed in severely obese patients. *Figure 1* shows the single-port platforms used in the RPRP in this review. During the console time, various commercial single-port

Table 1 The seach strategy summary

Items	Specification
Date of search	June 10, 2022
Databases and other sources searched	PubMed, Embase, Cochrane databases
Search terms used	(I) "robotic" or "robot-assisted"
	(II) "pancreatectomy", "pancreatic surgery", "pancreaticoduodenectomy", "pancreatoduodenectomy", or "Whipple"
	(III) "reduced-port", "single-port", "single-site", or "single-incision"
Timeframe	2010–May 30, 2022
Inclusion and exclusion criteria	Any type of articles written in English, including a case report
Selection process	The articles were screened by the first author

Table 2 Patients' background and details of the reduced-port technique

Author	Year	N	Procedure	Age (years)	BMI (kg/m^2)	Patient selection	Single-port platform	Number of additional port
Kim *et al.* (14)	2017	5	DP	38 [21–56]†	N/A	Benign and low grade malignancy	DVSSP^{TM}	Plus one
Peng *et al.* (15)	2018	10	DP	50.4 [36–67]‡	N/A	Benign and malignancy	LAGIPORT®	Pure single-port
Han *et al.* (16)	2019	13	DP	46.1±14.0§	20.9±4.0†	Benign and low grade malignancy	DVSSP^{TM}	Plus one
Park *et al.* (17)	2020	27	DP	47.3 [21–74]‡	22.6 [15.8–28.8]‡	Benign and low grade malignancy	Glove port®	Plus one
Choi *et al.* (18)	2022	3	DP	70.7 [65–77]‡	27.8 [24.9–30.7]‡	Benign and early staged pancreatic cancer	Uni port® and Da Vinci SP system	Plus one
Chiang *et al.* (19)	2022	45	PD	66 [61–73]†	23$^{\#}$	Malignant tumor	Glove port®	Pure single-port or plus one
Liu *et al.* (20)	2022	1	DP	55	N/A	Serous cystadenoma	Da Vinci SP system	Plus one

†, median [range]; ‡, mean [range]; §, mean ± standard deviation; $^{\#}$, mean. BMI, body mass index; DP, distal pancreatectomy; N/A, not available; DVSSP, Da Vinci single-site platform; PD, pancreaticoduodenectomy.

platforms were adopted to perform RPRP, such as the Glove port® (Nellis, Bucheon, Korea), LAGIPORT® (LAGIS, Taichung), Uni Port® (Dalim Medical, Seoul, Korea), and Da Vinci single-site platform (DVSSP^{TM}, Intuitive Surgical, Sunnyvale, CA, USA), using a small incision through or around the umbilicus. The Da Vinci SP system (Intuitive Surgical, Sunnyvale, CA, USA) was used by two institutions for single-site surgery, including in one case report (20). Interestingly, Choi *et al*. used these platforms for both single-port and additional ports (18).

Regarding RPRDP, there were five reports on the single-site plus one-port technique (14,16-18,20), and only one report on single-port RDP in the narrow sense, that is, a pure single-site surgery, which was performed by Peng *et al.* (15). Han *et al.* evaluated and compared the perioperative outcomes of single-site plus one-port RDP and pure single-site LDP (16). Only Park *et al.* demonstrated a similar technique with multicenter (six centers) outcomes (17). Median patient age less than 60 years in five of seven studies can be attributed to the fact that many patients with benign diseases were included in the studies.

Spleen preservation was performed in 14 (23.7%) patients. Although the spleen preserving distal pancreatectomy (DP) procedure is supposed to be more complicated than

Table 3 Perioperative outcomes

Author	Year	N	Procedure	Spleen preservation*	Operation time (min)	Estimated blood loss (mL)	Complication more than II*	POPF grade > B*	Postoperative hospital stay (days)	Remarks
Kim *et al.* (14)	2017	5	DP	1 (20.0)	165 [120–270]†	5 [0–50]†	N/A	0	6 [5–8]†	1; converted to multi-port
Peng *et al.* (15)	2018	10	DP	2 (20.0)	252.5 [210–295]‡	149.0 [50–250]‡	3 (30.0)	0	4.5 [3–6]‡	–
Han *et al.* (16)	2019	13	DP	1 (7.7)	192±69§	12±22§	5 (38.5)	0	7.4±1.9§	–
Park *et al.* (17)	2020	27	DP	9 (33.3)	201 [118–488]‡	50 [0–700]‡	1 (3.7)	0	7 [4–10]‡	1; converted to multi-port
Choi *et al.* (18)	2022	3	DP	0 (0.0)	215 [135–265]‡	<500	0 (0.0)	0	11 [10–11]‡	–
Chiang *et al.* (19)	2022	45	PD	N/A	325 [290–370]†	300 [155–700]†	7 (15.6)	1 (2.2)	32 [25–50]†	3; converted to open
Liu *et al.* (20)	2022	1	DP	1 (100.0)	55	20	0	0	3	–

Complications were presented as per the Clavien-Dindo classification. *, values are presented as n (%); †, median [range]; ‡, mean [range]; §, mean ± standard deviation. POPF, postoperative pancreatic fistula; DP, distal pancreatectomy; N/A, not available; PD, pancreaticoduodenectomy.

the conventional DP procedure, Yang *et al.* described that the spleen preservation rate was significantly higher in the RPRDP group than in the single-site LDP group (21). Although the details are unknown, the spleen preservation rate of 23.7% in these reports does not lead to preclusion of RPRDP for such cases. Two cases were converted to multi-port RDP (3.4%) because of the difficulty caused by collision and obesity, respectively. The perioperative outcomes are presented in *Table 3*. RPRDP is a safe procedure in terms of operative time, blood loss, serious complications, and hospital stay, and the development of RPRDP is expected to continue.

All RPRPDs were described in only one report (19). Chiang *et al.* compared 45 cases of RPRPD with 13 cases of open PD for malignant tumors and found that the amount of blood loss was lower in the RPRPD group than in the open PD group {300 [95% confidence interval (CI): 155–700] *vs.* 650 mL (95% CI: 300–850), P=0.11} but RPRPD group had the longer operative time correspond to open PD group [325 (95% CI: 290–370) *vs.* 215 min (95% CI: 180–270), P<0.001]. The data for the RPRPD study were collected by a single surgeon who performed pure single-site RDP in Taiwan, and included only patients with malignant tumors of the pancreas or periampullary regions; patients who underwent RPRPD for benign tumors were excluded. Interestingly, Peng *et al.* (15), who also performed pure single-site surgery in RDP, did not require an additional port in 13 of 45 cases (28.9%) of RPRPD. Three patients (6.7%) required conversion to open surgery. Although there is only one previously published report, RPRPD poses no problems regarding operative time, blood loss, or any outcomes, and it is possible that it is not associated with technical issues. Further data accumulation in this regard are expected.

Evolution of MIP

The history of pancreatic resection begins with Whipple's successful PD in 1935 (22). In the 1940s, although surgical procedures were standardized, the associated complications and mortality rates were extremely high. In 1973, Fortner *et al.* proposed a concept that involved resection of the internal organs in the left upper abdomen along with total pancreatectomy, and *en bloc* resection along with the main vessels such as the portal vein, superior mesenteric artery, and celiac axis, as regional pancreatectomy (23).

Laparoscopic pancreatectomy was first reported by Gagner *et al.*, in the form of LPD, in 1994 (24); Cuschieri *et al.* first performed LDP, in 1996 (25). Subsequently,

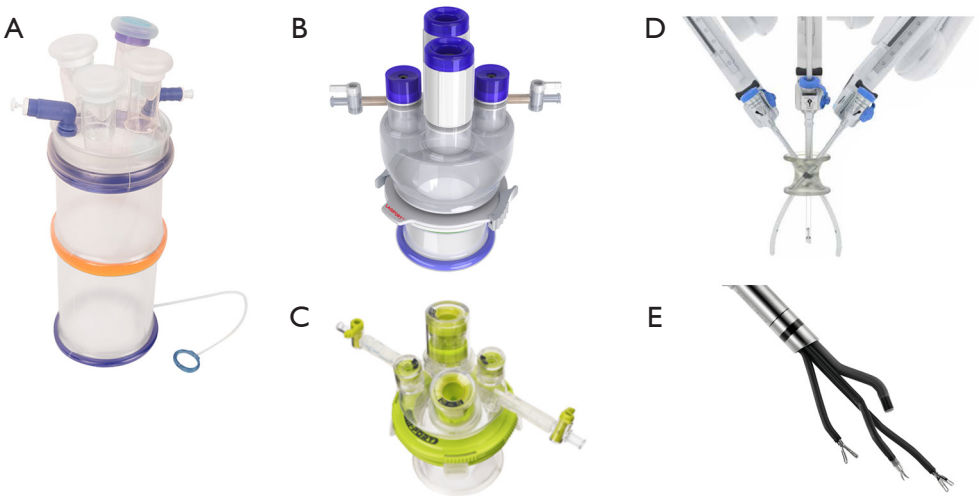

Figure 1 Single-port platforms. (A) Glove port®; (B) LAGPORT®; (C) Uni port®; (D) DVSSP™; (E) Da Vinci SP system®. DVSSP, Da Vinci single-site platform.

laparoscopic pancreatic tumor enucleation and laparoscopic central pancreatectomy have also been reported (26). At that time, laparoscopic surgical devices were inadequate and less recommended. However, the use of laparoscopic surgery has since become widespread. Since the late 2000s, several studies have reported good surgical outcomes for LPD, and the operation time and outcomes have greatly improved (27-29). Currently, even though MIP has been accepted worldwide. MIS in PD remains technically challenging. One meta-analysis reported a higher mortality associated with LPD than with open PD (4).

Concurrent to the initiation of laparoscopic surgery in the late 1980s, the American military undertook development of surgical-assist robots to allow surgeons to operate on the wounded remotely, from the safety of the mainland or on-board ships away from the battlefield. In 2001, a team of surgeons at a New York hospital performed remote-controlled robotic cholecystectomy in a female patient in France (30). Since then, there have been many reports from various fields on the usefulness and expanded indications of robotic surgery, which continues to evolve. Melvin *et al.* reported the first case of RDP after pancreatic surgery (31). Consequently, some reports comparing LDP and RDP have reported that RDP is superior to LDP in terms of operative time, blood loss, and open conversion rate, whereas others have found them to be equivalent (32-36). Following the first report of RPD by Giulianotti *et al.* in 2003, numerous reviews have reported the safety and usefulness of this surgery, as it helps overcome the technical difficulties of laparoscopic pancreatectomy and is beneficial in terms of histopathological outcomes (6,37-41). It is undisputed that robotic surgery is superior to laparoscopic surgery in terms of maneuverability in the pancreatic field, and it has the potential to reduce surgical stress as a sustainable procedure with an ergonomic position.

The first successful case of reduced-port robotic surgery for humans in the urological field was reported by Kaouk *et al.* in 2009 as a single-site surgery (42), followed by several reports in other fields, such as gynecological and colorectal surgery, during the same period (43,44). For some time thereafter, although RPS was used in many areas, RPRP was not readily reported. To the best of our knowledge, the first RPRP was reported by Kim *et al.* in 2017, a decade later than that in other fields (14). Notably, even though few papers have justified it, RPS is rapidly becoming more popular worldwide as first as RPS in other fields.

Outlook

Although the small number of material papers in this review may not conclusively guide the next steps in RPRP, we initially anticipated that it would have a longer operative times than conventional robotic pancreatectomy, and that more patients would require additional ports. Nevertheless, none of the reports showed that RPRP had an inferior performance compared to that of conventional robotic pancreatectomies; however, no comparative studies have

been conducted. Chang *et al.* reported an additional port requirement rate of 8.55% in single-site laparoscopic cholecystectomy (45); however, only five patients in this review required conversion to multi-port technique or open surgery (4.8%). This difference may indicate the feasibility of robotic surgery in pancreatic field.

Various single-port platforms have been used in RPS to reduce the complexity of the procedure. In robotic surgery, single-port platforms are classified into those traditionally used in laparoscopic surgery, and those with a platform made specifically for robotic use. The Da Vinci single-site technology with DVSSP™ has curve-designed cannulas to maximize range of motion and minimize collisions (*Figure 1D*). The Da Vinci SP system delivers three multi-joint instruments and a wristed camera through a single trocar (*Figure 1E*). There are unique to Da Vinci Surgical Systems, although some sealing devices are not available and should be used with caution in pancreatectomies with high bleeding risks. The other single-port devices presented in this review have been conventionally used in laparoscopic surgery (*Figure 1A-1C*). While all robotic instruments can be used in these platforms, the distance between robotic arms tends to be shorter, which facilitates instrumental collision.

The most crucial outcome factor in pancreatectomy is the POPF. The drainage tube allows for essential POPF control, which contributes to the limited feasibility of single-site surgery. Indeed, patients who underwent pure single-site surgery in this review required a new incision for drain placement. As it is possible that one tube will not be sufficient for PD, the RPRPD must be planned accordingly. Additional incisions used to introduce trocars should be used for drain placement; this will lead to the wound form being the same in pure single-site and single-site plus one-port or plus two-port surgeries. At our institution, we consider that two drainage tubes are required for PD; hence, we have been implementing RPRPD using the single-site plus two-port technique. In addition to the single-port on the umbilicus, trocars are placed on the left and right sides of the abdomen, and the robotic arms are set there. In this technique, the final wound is a similar to that formed after single-incision surgery, and instances of instrument collision can be reduced (unpublished). The requirement of additional ports may be determined based on the drainage policies of each institution. As Chiang *et al.* (19) also mentioned, to make the surgical field easier to handle with additional ports, the single-port plus one-port or two-port techniques should be considered for new RPRPD procedures.

While several studies have shown the feasibility of RPRP, there are some issues that prevent RPRP from being widely adopted. First, the disadvantage of RPS is its cost, which is an additional patient fees of several hundred US dollars for a single-port platform. Second, RPS is generally perceived to complicate the procedure, such as the difficulty of triangulation and the tendency of the instruments collisions. Therefore, RPS may be considered unsuitable for RPRP, which is highly difficult procedure. Therefore, further studies on a larger scale and comparative studies with conventional robotic pancreatectomies are warranted to clearly demonstrate the non-inferiority of RPRP.

Conclusions

Only 5 years have passed since RPRP was first reported, and this procedure is still in the developmental period. We hope that many more studies will be reported, including randomized control trials, in the future, and that RPRP will be commonly used worldwide.

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aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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