Review Article

The robotic central pancreatectomy: surgical technique, and literature review

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Abstract: Central pancreatectomy (CP) is an infrequently performed procedure indicated for benign or low-grade pancreatic neck tumours. This parenchyma preserving operation is associated with favourable long term exocrine and endocrine function compared to its traditional alternative, the distal pancreatectomy (DP). Minimally invasive laparoscopic and robotic approaches to the CP confer the benefits of reduced trauma, reduced postoperative pain and better cosmesis. The aim of this paper is to demonstrate a reproducible method of performing the robotic CP (RCP) with pancreatogastrostomy, and then discuss the current literature surrounding this infrequently performed surgery, with the view that despite limited indications, the procedure has a role to play in the management of a subset of pancreatic pathologies. We demonstrate a safe and reproducible RCP method through the case of an otherwise well 20-year-old lady who was diagnosed with a 65mm solid pseudopapillary tumour of the pancreas. We then discuss the available literature supporting the safety and feasibility of the RCP. Compared to DP, the main drawback of RCP is the increased risk of pancreatic fistula (PF), due to the presence of two section planes of the pancreas, the soft remnant pancreas and the small main pancreatic duct. Other surgical complications associated with CP include intrabdominal abscess and fluid collection, pancreatitis, delayed gastric emptying, and splenic vessel injury. However, there is evidence that postoperative endocrine insufficiency is worse with DP compared to CP. Thirteen studies were identified that report on outcomes following RCP. Overall, most studies show no difference in rate of complications, or mortality. Robotic surgery offers numerous technical advantages, including superior three-dimensional visualization, magnification, articulation and dexterity, and longer operating times can be expected to reduce as surgeons gain more experience. We believe that the robotic method described in this paper is relatively safe, and reproducible. Multi-centre large volume trials are needed to further determine safety and efficacy of RCP, and to determine optimal reconstruction type.

Keywords: Pancreatic surgery; central pancreatectomy; robotic surgery

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Introduction

Central pancreatectomy (CP) is an infrequently performed procedure indicated for benign or low-grade tumours of the pancreatic neck. This parenchyma preserving operation has the benefits of better long term exocrine and endocrine function as compared to its traditional alternative, the distal pancreatectomy (DP) (1). Minimally invasive laparoscopic and robotic approaches have been attempted for central pancreatectomies to confer the benefits of reduced trauma, reduced postoperative pain and better cosmesis. Laparoscopic CP is shown in the limited available literature to be as efficacious and safe as open CP with comparatively lesser morbidity, blood loss and shorter hospital stay (2-4). We demonstrate a safe and reproducible robotic CP (RCP) method using the case of an otherwise well 20-year-old lady who was diagnosed with a 65-mm solid pseudopapillary tumour of the pancreas. We then discuss the available literature supporting the safety and feasibility of the RCP.

Surgical technique (see accompanying *Video 1*)

This 20-year-old lady underwent a RCP for a 40-mm solid pseudopapillary tumour of the pancreas.

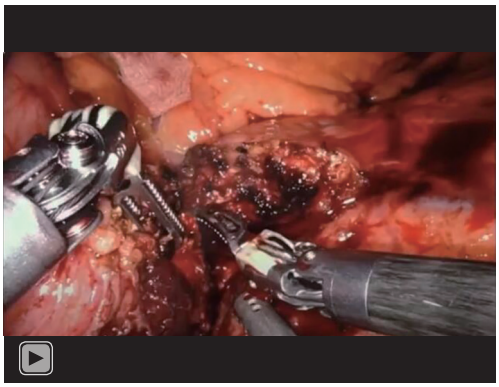
(I) The following ports were inserted; a 5-mm optical separator in left midclavicular line to access peritoneal cavity, 12-mm camera port in supraumbilical midline and a 5-mm port in the left anterior axillary line to retract the liver. The 5-mm port was converted into 8-mm robotic port along with another 8-mm robotic ports in the right upper quadrant, a 5-mm port in the right lower quadrant, and a 12-mm port in the left lower quadrant;

(II) After entry and retraction of the liver, the gastrocolic ligament was divided below the gastroepiploic pedicle, mobilising the greater curve of the stomach. This was followed by application of a stay suture to secure anterior wall of stomach to abdominal wall for retraction, exposing the anterior surface of pancreas;

(III) Intraoperative ultrasound was used to identify the tumour, determining borders and marking the margins of resection;

(IV) The inferior border of the pancreas was mobilised to elevate the pancreatic neck from the splenic vein-superior mesenteric vein confluence;

(V) The common hepatic artery, gastroduodenal artery, and portal vein were exposed at the superior border of the pancreas;



Video 1 The robotic central pancreatectomy with pancreaticogastrostomy: surgical technique.

(VI) A tunnel was created under the neck of the pancreas between the superior mesenteric vein and portal vein;

(VII) The neck of pancreas neck was divided with diathermy (or stapler if the pancreatic body and neck are not bulky), and the central pancreatic segment with the tumour was dissected away from the splenic vein and artery origin;

(VIII) The dissection between pancreatic remnant and splenic vein was continued distally using ultrasound to mark boundaries in order to ensure adequate tumour margins;

(IX) Small arteries arising from the splenic artery supplying the tumour were clipped and divided.

(X) Using a 12-mm EndoCatch (Covidien, New Haven, CT, USA), bag in the left lower quadrant port, the specimen was retrieved and frozen section examination of the margins was performed;

(XI) The pancreatogastrostomy (single anastomosis) was favoured, as opposed to Roux-en-Y pancreatojejunostomy, as the latter entails additional anastomoses in the form of enteroenterostomy. The anterior surface of the pancreas was anchored to the posteroinferior surface of the stomach with V lock sutures;

(XII) A small gastrotomy was created using diathermy, and the fibrous pancreatic capsule and parenchyma was sutured to the all layers of gastric wall with V lock suture. There was no

duct to mucosa anastomosis;

(XIII) Suture was deliberately kept away from the pancreatic duct by placing a small internal stent in the pancreatic duct. A 7-Fr pancreatic duct stent was bridged across the pancreatogastrostomy, an insufflation test may be performed to ensure airtight anastomosis;

(XIV) Haemostatic matrix was then applied to the resection bed and vessels, followed by compaction with a small piece of fibrillar material;

(XV) A gastrografin swallow was performed post-operatively on day three to check for leak before commencing fluid diet.

The patient had 175 mL intraoperative blood loss and an operating time of 182 minutes. She did not require any blood transfusion. Final pathology confirmed a 40-mm pseudopapillary tumour of the pancreas with 0 involved nodes and clear margins. She was discharged 6 days post-operatively following an uneventful recovery. The patient did not develop long-term post-operative complications, including endocrine or exocrine insufficiency, and remained well on follow-up 1 year later.

Discussion

Compared to DP, the main drawback of CP is the increased risk of pancreatic fistula (PF), due to the presence of two section planes of the pancreas, the soft remnant pancreas and the small main pancreatic duct (1). In a systematic review and meta-analysis of 21 studies, rate of PF was higher after CP compared to DP (5). Other surgical complications associated with CP include intrabdominal abscess and fluid collection, pancreatitis, delayed gastric emptying, and splenic vessel injury. Additionally, a systematic review by Regmi *et al.* found a higher rate of post-operative haemorrhage in CP compared to DP, as segmental resection of the pancreatic neck exposes the splenic vein-superior mesenteric vein confluence near the caudal anastomosis, as well as the splenic artery (6). A pancreatic leak may erode these surrounding blood vessels, thus inducing postoperative haemorrhage (6). However, the same paper also found a statistically significant difference in postoperative endocrine insufficiency between the central and DP cohorts, lending credence to studies that show that the tail segment is more densely populated with pancreatic islets. With female gender, higher body mass index (BMI) and resection of pancreatic volume >25% being risk factors for postoperative endocrine impairment (7), preservation of pancreatic parenchyma is critical, especially in younger patients with non-malignant disease. Therefore, the CP has an important role to play in the management of benign or borderline tumours of the pancreatic neck or body, especially with the additional benefits conferred by the robotic platform. We summarise the limited literature detailing individual experiences with RCP. The PubMed and Embase databases were searched from inception, to 10 July 2021 using the terms "central pancreatectomy" OR "middle pancreatectomy" AND "robotic". Following screening, exclusions and full text reviews, thirteen studies were identified.

Study characteristics are presented in *Table 1*. Two studies presented data from only RCP (11,12,14-18), two studies laparoscopic-assisted robotic (LAR) central pancreatomy (2,10), one study robotic after laparoscopic entry into the lesser sac (13), and three studies a combination of the above (8,9,19). Except the randomised controlled trial by Chen *et al.* (16), all studies were retrospective cohort studies or small case series.

Rate of complications associated with RCP are summarised in *Tables 2,3*. Only five studies included a cohort of patients who had undergone open central pancreatectomy (OCP) at the same centre (9,11,16,18,19). Kang *et al.* compare two LAR and three robotic CPs to 10 OCPs, and found that the robotic cohort had a longer mean operating time, less bleeding, but otherwise non-significant differences in remnant pancreas, transfusion requirement, complications, length of stay and mortality (9). Cheng *et al.* compare 7 RCP to 36 OCP, and report no statistically significant differences in operating time, blood loss, transfusion rate, fistula rate, complication rate, length of stay and mortality (11). Shi *et al.* compare 110 RCP to 60 OCP, and report significantly lower blood loss, and operating time in their RCP cohort. There was no statistically significant difference in morbidity, 30-day mortality, fistula, complications or length of stay (18). The most recent study, that of Huynh *et al.*, compares 20 minimally invasive CPs to 11 open CPs (19). In these studies, operating time was consistently longer in robotic central pancreatectomies and the shorter open CP operating time could be attributed to the experience of the surgeons with the open technique (10,13). Operating times and blood loss can be expected to reduce for RCP as surgeons gain more experience, with one learning curve study showing rapid reductions after the 44th operation performed (20).

Table 1 Study characteristics, and operative complications

Paper	Country	Year	Gender (M/F)	Age (years), mean ± SD or median (range)	Total RCP cases	OCP	Operation time (min), median (range) or mean ± SD	Bleeding (mL), median (range) or mean ± SD	Patients requiring transfusion
Giulianotti *et al.* (8)	Italy	2010	1/2	N/A	3 LAR	0	320 (270–380)	233 (100–400)	0
Kang *et al.* (9)	S. Korea	2011	0/5	45 (34–64)	5 (3 robotic + 2 LAR)	10	432.0±65.7	275.0±221.7	0
Zureikat *et al.* (2)	USA	2011	N/A	N/A	4 LAR	0	N/A	N/A	N/A for RCP
Abood *et al.* (10)	USA	2013	3/6	64 (18–75)	9 LAR	0	425 (305–506)	190 (50–350)	0
Cheng *et al.* (11)	China	2013	2/5	55 (30–62)	7 robotic	36	210 (150–300)	200 (50–400)	0
Zhan *et al.* (12)	China	2013	N/A	N/A	10 robotic	0	219.0±47.2	158.0±107.4	0
Zureikat *et al.* (13)	USA	2013	N/A	N/A	13 laparoscopic exploration + robotic after access to lesser sac	0	394±92	200	N/A
Zhang *et al.* (14)	China	2015	7/3	64.3±4.95	10 robotic	0	175.00±45.28	113.00±107.09	0
Boggi *et al.* (15)	Italy	2016	3/5	45 (27–63)	5 robotic	0	415±169	N/A	N/A
Chen *et al.* (16)	China	2017	16/34	49.6±12.4	50 robotic	50	160 (120–210)	50 (50–100)	0
Wang *et al.* (17)	China	2019	5/6	42.4±14.3	11 robotic	0	121 (105–199)	50 (20–100)	0
Shi *et al.* (18)	China	2020	24/36	53±14	110 robotic	60	162±623	88±93	N/A
Huynh *et al.* (19)	S. Korea	2021	5/15	54.2±14.2	20 minimally invasive (3 laparoscopic; 7 robotic; 9 LAR)	11	374.8±87.0	214.0±175.9	4

LAR, laparoscopic-assisted robotic surgery; N/A, not available; OCP, open central pancreatectomy; RCP, robotic central pancreatectomy; SD, standard deviation.

Benefits of the robotic platform

Although the indications for CP are strictly limited to benign or low-grade neoplasms, the RCP has an important role to play, given the protection of endocrine, exocrine and immune functions. The randomised controlled trial by Chen *et al.* found advantages associated with RCP compared to OCP—reduced length of stay, operative time, median blood loss, rate of PF, improved nutritional status and gastric emptying (16). The technical advantages offered by robotic surgery include superior three-dimensional visualization, magnification, articulation and dexterity. However, as with all new surgical technologies, there is a learning period associated with minimally invasive pancreatic surgery. Hogg *et al.* state that the learning curve of the minimally invasive pancreatoduodenectomy is reported to be between 40 and 80 procedures, and Speicher *et al.* described a three-phase approach to the laparoscopic PD that takes a minimum of 40 procedures for experienced laparoscopic surgeons (3,21). Similarly, the learning curve for the minimally invasive DP is reported by Shakir *et al.* as around 40 procedures (22). The CP is already an infrequently performed procedure, and therefore a similar learning curve would be expected.

Reconstruction type

The use of pancreaticogastrostomy (PG) versus pancreaticojejunostomy (PJ) for central pancreatectomies is controversial. Meta-analysis by Ricci *et al.* shows that PG is slightly superior to PJ in terms of Grade B/C post-operative pancreatic fistulas (POPFs) after

Table 2 Surgical features

Paper	Length of resected pancreas	Tumour size (cm), median (range) or mean ± SD	Anastomosis (PJ/PG)
Giulianotti *et al.* (8)	N/A	3 (1.5–3.5)	0/3
Kang *et al.* (9)	N/A	1.4±0.4	0/5
Zureikat *et al.* (2)	N/A	N/A	3/0
Abood *et al.* (10)	N/A	3.0 (1.9–6.0)	2/7
Cheng *et al.* (11)	N/A	3.0 (0.5–5.0)	0/7
Zhan *et al.* (12)	N/A	N/A	0/10
Zureikat *et al.* (13)	N/A	N/A	N/A
Zhang *et al.* (14)	N/A	2.55±1.52	0/10
Boggi *et al.* (15)	N/A	N/A	N/A
Chen *et al.* (16)	4.4±1.1	2.9 (2.0–3.4)	0/50
Wang *et al.* (17)	4.3±1.0	3.4±1.1	End-to-end anastomosis of pancreas
Shi *et al.* (18)	N/A	2.4±1.3	0/110
Huynh *et al.* (19)	N/A	1.5±0.5	12/8

N/A, not available; PJ, pancreaticojejunostomy; PG, pancreaticogastrostomy; SD, standard deviation.a

pancreaticoduodenectomies (23,24). In this review of the literature, PG was performed by Kang *et al.* (9) for all RCP patients, with the justification that pancreatic leak after RCP with PG can be managed safely by conservative management alone, as pancreatic juices are not exposed to bile enzyme activation that occurs after PJ, and theoretically, a lower risk of autodigestive activity. Similarly, Cheng *et al.* (11) favour the PG as it does not require bowel mobilisation and division, and thereby avoids any increase in operating time, interruption of intestinal continuity and potential leaks. Of note in this study, the rate of PF was not affected by approach (open or robotic), or reconstruction type (PG or PJ). Likewise, Shi *et al.* (18) prefer the PG, as it is difficult to mobilise the jejunum to the pancreatic remnant in robotic surgery. The same study found no statistically significant difference in rate of fistula formation. By comparison, Zuriekat *et al.* (13) and Boggi *et al.* (15) favoured the PJ, with similar complication rate. Comparatively, Wang *et al.* (17) used an innovative end-end pancreatic anastomosis, also with favourable results. Ultimately, Dumitrascu *et al.* conclude that although the evidence slightly supports PG, surgeon expertise ultimately drives the anastomosis of choice (25), as there is little evidence to support one over the other.

As demonstrated in our surgical technique video, PG was used exclusively with RCPs in our centre due to the relative technical ease of anastomosing the distal pancreas remnant to the posterior gastric wall. The gastrostomy is created posteriorly and distally, and due to the mobility of the gastric body and approximation to the resected pancreatic body, this reduces the tension on the anastomosis. Additionally, the robotic platform allows greater manoeuvrability and dissection within the confined space of the supracolic compartment, and avoids the infracolic compartment entirely. As discussed by Wakabayashi and Pessaux (26,27), since the most cranial part is at highest risk of PF, the anastomosis is carried out from the cranial edge until the level of the pancreatic duct, posteriorly to anteriorly. We then closed the caudal side, reducing any pressure on the sutured plane. We found that duct-to-mucosa anastomosis was not necessary, and instead, the connective tissue pancreatic capsule and parenchyma is sutured to all layers of the gastric wall.

Conclusions

The CP is parenchyma preserving, and hence beneficial in preserving endocrine and exocrine function. When coupled

Table 3 Complications following robotic central pancreatectomy

Paper	Complications	Post-operative bleed (number)	POPF Grade A	POPF Grade B	POPF Grade C	Complications (Clavien-Dindo)	New onset Pancreatic dysfunction	Length of stay (days), median [range] or mean ± SD	Post-op LOS (days), median [range] or mean ± SD	Mortality
Giulianotti *et al.* (8)	1	0	1	0	0	0	0 endocrine or exocrine	9 (27 for POPF)	N/A	0
Kang *et al.* (9)	1	0	0	1	0	0	0 endocrine or exocrine	14.6±7.7	N/A	0
Zureikat *et al.* (2)	4	N/A	3	0	1	0	N/A for CP	N/A	N/A	0
Abood *et al.* (10)	7	0	5	2	0	CD I/II 6 (67%), CD III/IV 1 (11%). CD Grade IV leak and sepsis requiring ICU	0 endocrine or exo-crine	10 [7–19]	N/A	0
Cheng *et al.* (11)	6	1 post-operative pancreatic haemorrhage	0	5	0	0	0 endocrine or exocrine	N/A	21 [13–33]	0
Zhan *et al.* (12)	7	1 post-operative anastomotic bleed (10%)	7	0	0	0	N/A	22.00	N/A	0
Zureikat *et al.* (13)	13	N/A for CP	2	9	1	Other unspecified CD Grade I 5 (38%); Grade II 5 (38%); Grade III 3 (23%)	N/A	8 [6–19]	N/A	0
Zhang *et al.* (14)	4	0	1	3	0	CD I/II 2 (wound infection) (20%), 1 with infection requiring endoscopic drainage CD III (10%)	1 endocrine, 0 exo-crine	19.91±8.85	N/A	0
Boggi *et al.* (15)	5	0	0	4	0	CD I 1 (20%), CD II 4 (80%)	N/A	17.5 [11.8–22.0]	N/A	0

Table 3 (*continued*)

Table 3 (*continued*)

Paper	Complications	Post-operative bleed (number)	POPF Grade A	POPF Grade B	POPF Grade C	Complications (Clavien-Dindo)	New onset Pancreatic dysfunction	Length of stay (days), median [range] or mean ± SD	Post-op LOS (days), median [range] or mean ± SD	Mortality
Chen *et al.* (16)	23 (46%)	2 (4%) intraabdominal haemorrhage; 3 (6%) gastrointestinal haemorrhage	13	8	1	4 (8%) intraabdominal abscess; 1 (2%) wound infection	N/A	15.6	14.0±4.4	0
Wang *et al.* (17)	7 (65.6%)	0	2	7	0	CD I 5 (45.5%), CD II 1 (9.1%) CD III 1 (9.1%)	0	N/A	6 [5–9]	0
Shi *et al.* (18)	57 (51.8%)	11 (10%)	0	35	3	CD grading not available. 1 (1%) bile leak; 12 (12%) abdominal infection; 1 (1%) wound infection; 1 (1%) delayed gastric emptying. 4 (4%) reoperation, 5 (5%) DSA and embolisation	3 (1.8%) new onset diabetes; 2 (2.4%) deterioration of previous diabetes; 0 exocrine dysfunc-tion	24.5±12.8	N/A	1 in 30 days
Huynh *et al.* (19)	8	N/A	0	4	0	–	1 (5%) new onset diabetes	16.7±11.0	N/A	0

CD, Clavien-Dindo; CP, central pancreatectomy; LOS, length of stay; N/A, not available; POPF, post-operative pancreatic fistula.

with the benefits of the robotic platform, the procedure is relatively safe, and reproducible. Multi-centre large volume trials are needed to further determine safety and efficacy of RCP, and to determine optimal reconstruction type.

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Footnote

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://dx.doi.org/10.21037/apc-21-7). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all 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. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee(s), and with the Helsinki Declaration (as revised in 2013). Written informed consent was obtained from the patient for publication of this article and accompanying video. A copy of the written consent is available for review by the editorial office of this journal

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