in vivo *35*: 1907-1911 (2021)
doi:10.21873/invivo.12456

Review

Robotic Total Pancreatectomy: A Narrative Review

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Abstract. *Background/Aim: Studies on robotic total pancreatectomy (RTP) have been limited regardless of the increasing evidence on robotic pancreatoduodenectomy. The aim of this study was to review the current status of RTP in terms of surgical techniques and outcomes. Materials and Methods: A literature search using PubMed was conducted to investigate surgical techniques and outcomes of RTP. Results: A total of eight case series with 56 patients were included. The indications for RTP consisted of benign or pre-malignant tumors in 43 patients and malignant tumors in 13 patients. Surgical techniques included the "dividing technique" and "en-bloc technique". Regarding surgical outcomes, the rate of conversion to open total pancreatectomy was 3.6% and the incidence of major complications was 10.7%. Conclusion: Although evidence for RTP is still lacking, RTP is feasible for selected patients when performed in specialized centers. Further studies are essential to investigate the effectiveness of RTP compared to open total pancreatectomy.*

Since the recent development of minimally invasive surgery, the evidence of minimally invasive pancreatectomy has been growing (1, 2). However, total pancreatectomy (TP) has often been performed using an open approach due to the technical difficulties of a minimally invasive approach. Therefore, evidence of robotic total pancreatectomy (RTP) has been limited regardless of increasing evidence of robotic pancreatoduodenectomy (3). Moreover, no reviews on RTP have been published. Since the indication of TP has been expanded for diffuse pancreatic diseases including pancreatic ductal adenocarcinoma, intraductal papillary mucinous neoplasm, chronic pancreatitis, and pancreatic neuroendocrine tumor, the current status of RTP should be investigated. The aim of this review was to summarize surgical techniques and outcomes in patients undergoing RTP.

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Key Words: Total pancreatectomy, robot, review.

Materials and Methods

The present study is reported in accordance with the Preferred Reporting Items for Systematic Reviewers and Meta-Analyses (PRISMA) guidelines (4). A literature search of the PubMed was performed on 12th of February 2021, using the keywords of robotic and total pancreatectomy. The search was limited to articles reporting on outcomes of RTP in English. After screening titles and abstracts, full-text articles were subsequently reviewed to extract the data on RTP. Records without abstracts and conference abstracts were excluded. In multiple reports with overlapping inclusion periods from the same institute, only the report with the higher number of patients was included.

Results

Overall, a literature search identified 108 articles, as depicted in Figure 1. Finally, eight case series regarding RTP were included (5-12). The characteristics of the included articles are summarized in Table I. All included studies were single-center case series from the United States (n=5), Italy (n=1), China (n=1), and the Netherlands (n=1). Regarding indications for RTP, there were 16 patients with benign tumors including chronic pancreatitis (n=15) and serous cystadenoma (n=1), 27 patients with pre-malignant tumors including intraductal papillary mucinous neoplasm (n=20) and pancreatic neuroendocrine tumor (n=7), and 13 patients with malignant tumors including pancreatic ductal adenocarcinoma (n=8),

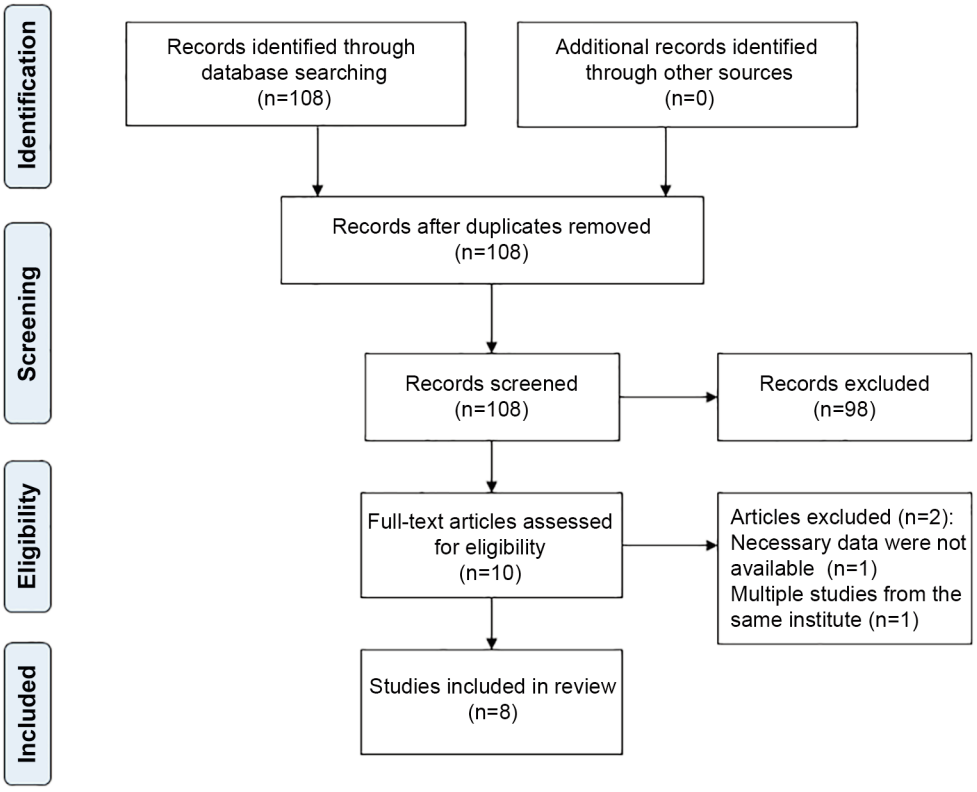

Figure 1. *PRISMA 2009 flow diagram.*

intraductal papillary mucinous carcinoma (n=3), and renal cell carcinoma metastasis (n=2).

Surgical technique of robotic total pancreatectomy. Several surgical approaches of RTP have been reported (Table I). Briefly surgical technique can be divided into "dividing technique" and "*en-bloc* technique".

In the dividing technique (5, 11), the pancreas is transected at the level of the superior mesenteric vein resulting in two specimens; the pancreatic head and the pancreatic body and tail. Thereafter, a distal pancreatectomy (DP) followed by pancreatoduodenectomy (PD) (5), or PD followed by DP (11) are performed. However, this approach is only possible if the pancreatic neck is not involved with the tumor. In addition, this approach has the potential risk of tumor spillage.

In the *en-bloc* technique, the traditional technique of RTP starts with the DP part. Firstly, the lower and upper border of the pancreas are dissected to mobilize the tail of the pancreas and spleen. Following splenic vessel dissection and division, full mobilization of the *en-bloc* pancreatic body, tail and spleen are performed. Splenic vessel preservation technique (*i.e.* Warschaw or Kimura technique) can be applied in spleen-preserving TP. In the *en-bloc* approach, the neck of the pancreas is not transected. Subsequently, PD, including the Kocher maneuver, dissection of the hepatoduodenal ligament, and the uncinate dissection, is performed. Finally, biliary and gastrointestinal reconstructions are achieved.

On the other hand, a novel technique starting with PD (the pancreatic head-first approach) followed by DP and reconstructions has been recently reported (12). In this technique, the first step with PD includes an extended Kocher's maneuver, dissection of the hepatoduodenal ligament and the superior mesenteric vein, and the detachment of the uncinate process along the superior mesenteric artery in order to mobilize the pancreatic head and duodenum completely. Again, the neck is not transected. The second step involves DP with the transection of the splenic artery and vein, and the mobilization of the pancreatic body from medial towards the pancreatic tail, followed by the dissection around the spleen. The final step is the biliary and gastrointestinal reconstruction.

Outcomes of robotic total pancreatectomy. Postoperative outcomes of case series are summarized in Table II. The mean operative time was 517 min (range=300-712 min) and the estimated blood loss was 363 ml (range=100-650 ml). Conversion rate to open TP was 3.6% (2 cases out of 56).

Table I. *Characteristics of the reported cases subjected to robotic total pancreatectomy.*

Author	Year	Country	Study type	No. of patients	Indications	Surgical technique
Giulianotti *et al*. (5)	2011	United States	Case series	5	CP (n=1) SC (n=1) IPMN (n=1) PNET (n=1) PDAC (n=1)	Dividing technique: DP followed by PD *En-bloc* technique: DP followed by PD
Galvani *et al*. (6)	2014	United States	Case series	6	CP (n=6)	*En-bloc* technique: DP followed by PD Gastrointestinal reconstruction with modified Braun anastomosis IAT
Boggi *et al*. (7)	2015	Italy	Case-match study	11	CP (n=1) IPMN (n=5) IPMC (n=3) PDAC (n=2)	*En-bloc* technique: DP followed by PD Biliary and gastrointestinal reconstruction
Zureikat *et al*. (8)	2015	United States	Case series	10	CP (n=3) IPMN (n=6) PDAC (n=1)	*En-bloc* technique: Laparoscopic Kocher maneuver Robotic dissection of the hepatoduodenal ligament DP followed by PD with or without IAT Biliary and gastrointestinal reconstruction
Konstantinidis *et al*. (9)	2018	United States	Case report	1	IPMN (n=1)	*En-bloc* technique: DP followed by PD Biliary and gastrointestinal reconstruction
de Mesquita Neto *et al*. (10)	2018	United States	Case series	7	CP (n=1) IPMN (n=4) PNET (n=2)	*En-bloc* technique: DP followed by PD Biliary and gastrointestinal reconstruction
Weng *et al*. (11)	2020	China	PSM	15	CP (n=3) IPMN (n=3) PNET (n=3) PDAC (n=4) RCC (n=2)	Dividing technique: PD followed by DP *En-bloc* technique: Kocher maneuver, and DP followed by PD Biliary and gastrointestinal reconstruction
Takagi *et al*. (12)	2021	Netherlands	Case report	1	PNET (n=1)	*En-bloc* technique: PD-first, followed by DP Biliary and gastrointestinal reconstruction

CP: Chronic pancreatitis; SC: serous cystadenoma; IPMN: intraductal papillary mucinous neoplasm; IPMC: intraductal papillary mucinous carcinoma; PNET: pancreatic neuroendocrine tumor; PDAC: pancreatic ductal adenocarcinoma; RCC: renal cell carcinoma metastasis; DP: distal pancreatectomy; PD: pancreatoduodenectomy; IAT: islet-cell autotransplantation; PSM: propensity score matching.

The overall incidences of reoperation and major complications were 5.4% (3 out of 56) and 10.7% (6 out of 56), respectively. The mean postoperative hospital stay was 13 days (range=7-27 days).

Two studies compared outcomes of RTP to open TP. Boggi *et al*. (7) performed a case-matched study comparing RTP (n=11) with open TP (n=11). Operative time was significantly longer in RTP (600 min *vs*. 469 min, p=0.014), however, blood loss was significantly decreased (220 ml *vs*. 705 ml, p=0.004). Postoperative outcomes and recovery measures did not differ significantly between the groups, showing the feasibility of RTP in selected patients. In another study by Weng *et al*. (11), a propensity score matching between RTP (n=15) and open TP (n=15) demonstrated significantly decreased operative time (300 min *vs*. 360 min, p=0.03), and high *en-bloc* resection rate (73% *vs*. 40%, p=0.14) in RTP. Both RTP and open TP groups had comparable postoperative outcomes (major complications: 6.7% *vs*. 26.7%, p=0.33; mortality: 0% *vs*. 6.7%, p=1.0) and quality of life on exocrine and endocrine insufficiency.

Discussion

This review is the first to highlight surgical techniques and outcomes in RTP, summarizing the current literature on RTP. To date, only eight case series have been reported on the feasibility of RTP. The use of a minimally invasive approach for TP could be associated with better postoperative outcomes such as decreased blood loss and shorter hospital stay. However, the majority of the available data on the potential benefits of RTP is based on small single center studies. Therefore, it remains unclear whether RTP decreases the complication rates and provides significant benefits justifying the additional costs of the robotic approach. To overcome these issues, further studies with larger volumes are needed.

Table II. *Outcomes of robotic total pancreatectomy.*

Author	No. of patients	Operative time (min)	Blood loss (ml)	Conversion	Reoperation	Major morbidity	Mortality	Hospital stay (days)	Comparison with other procedure (numbers)
Giulianotti *et al.* (5)	5	480 (300-560)	300 (50-650)	0	0	0	0	7 (5-10)	NA
Galvani *et al.* (6)	6	712 (612-835)	630 (500-800)	0	0	0	0	12 (11-14)	NA
Boggi *et al.* (7)	11	600 (400-800)	220 (100-450)	0	1 (9%)	2 (18%)	0	27 (12-88)	RTP (11) *vs.* OTP (11)
Zureikat *et al.* (8)	10	560 (461-592)	650 (400-1,000)	1	1 (10%)	2 (20%)	0	10 (7-10)	NA
Konstantinidis *et al.* (9)	1	NA	NA	0	0	0	0	9	NCDB review: RTP (73), LTP (455) *vs.* OTP (3348)
de Mesquita Neto *et al.* (10)	7	480 (330-660)	240 (50-400)	1	1	1	0	10 (7-14)	NA
Weng *et al.* (11)	15	300 (250-360)	400 (200-700)	0	0	1 (7%)	0	18	RTP (15) *vs.* OTP (78)
Takagi *et al.* (12)	1	490	100	0	0	0	0	10	NA

NA: Not assessed; RTP: robotic total pancreatectomy; LTP: laparoscopic total pancreatectomy; OTP: open total pancreatectomy; NCDB: National Cancer Database.

The outcomes of RTP from eight case series involving 56 patients were acceptable, with a conversion rate to open procedure of 3.6% and a major complication rate of 10.7%. Furthermore, a study by Konstantinidis *et al.* (9) demonstrated the outcomes of RTP (n=73) compared to laparoscopic (n=455) and open TP (n=3348) between 2010 and 2014 using the National Cancer Database (NCDB) in the United States. The results showed that minimally invasive TP was associated with shorter hospital stay and reduced mortality compared to open TP. Clinicopathological factors including negative margin rates and retrieved lymph nodes were found to be similar between the groups. Moreover, the median overall survival for pancreatic ductal adenocarcinoma was similar between robotic, laparoscopic, and open TP (22.5 *vs.* 22.4 *vs.* 20.0 months, p=0.22). Although a randomized controlled trial comparing robotic, laparoscopic, and open TP appears infeasible, high-level evidence supporting the benefits of RTP should be investigated in large international multicenter studies.

The Miami international evidence-based guidelines on minimally invasive pancreas resection have been recently published (1), however there have been no recommendations on performing minimally invasive TP. Based on our findings, the feasibility of RTP has been demonstrated, however, the safety should be confirmed in larger series.

With respect to technical aspects, RTP is a complex and challenging procedure, requiring advanced skills and experiences with both pancreatic and robotic surgery. However, TP is the combination of PD and DP. Therefore, RTP should be performed after achieving extensive experience with robotic PD and DP. It has been reported that high-volume centers have improved postoperative outcomes following minimally invasive pancreas resection (13, 14), Therefore, RTP should be performed in selected high-volume centers.

With respect to surgical techniques of RTP, the *en-bloc* technique has the potential benefit of reducing the risk of tumor spillage in patients with malignant diseases. In the *en-bloc* technique, the potential advantages using the pancreatic head-first approach have been suggested (12), however no comparative studies have been reported so far regarding the surgical techniques in RTP. In contrast, due to the limited space in the intraabdominal cavity, the dividing technique might be easier compared to the management of the large specimen consisting of the whole pancreas and the spleen in the *en-bloc* approach. Accordingly, surgical techniques should be selected according to the surgeons' experience and patients' diseases.

There are a few limitations to this study. The included studies are all case series with small sample size from single centers. Furthermore, well designed studies with or without randomization are lacking. Surgeon experience, training, and available resources should be considered to determine which approach can be adopted. Prospective national registration should be employed to monitor the outcomes as well as to improve the quality of evidence on this topic.

Conclusion

The present review represents the current status of RTP in terms of surgical techniques and outcomes. RTP in selected

patients can be an appropriate alternative to open TP. Although the evidence of RTP remains limited, the feasibility has been demonstrated with improved postoperative outcomes compared to open TP. Further large studies should be conducted to prove the safety and superiority of RTP.

Conflicts of Interest

The Authors declare that they have no conflicts of interest regarding this study.

Authors' Contributions

K.T. contributed to the study conception and design, the acquisition of data, the development of the protocol, and the drafting of the manuscript. B.G.K. contributed to the development of the protocol and the critical revision of the final draft. All Authors have approved the final version.

Acknowledgements

Financial support was received from Japan Society for the Promotion of Science (JSPS KAKENHI Grant Number JP 21K16447).

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Received March 10, 2021
Revised April 12, 2021
Accepted April 13, 2021