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Comparison of 3 Minimally Invasive Methods Versus Open Distal Pancreatectomy: A Systematic Review and Network Meta-Analysis

Yunxiao Lyu, MD, Yunxiao Cheng, MD, Bin Wang, MD, SiCong Zhao, MD, and Liang Chen, MD

Background: The efficacy and safety of open distal pancreatectomy (DP), laparoscopic DP, robot-assisted laparoscopic DP, and robotic DP have not been established. The authors aimed to comprehensively compare these 4 surgical methods using a network meta-analysis.

Materials and Methods: The authors systematically searched MEDLINE, Scopus, Web of Science, the Cochrane Central Register of Controlled Trials, and ClinicalTrials.gov for studies that evaluated at least 2 of the following pancreatectomy techniques: robot-assisted DP, laparoscopic DP, open DP, and robotic DP. The surface under the cumulative ranking curve (SUCRA) was applied to show the probability that each method would be the best for each outcome.

Results: Altogether, 46 trials with 8377 patients were included in this network meta-analysis. Robotic DP showed the highest probability of having the least estimated blood loss (SUCRA, 90.9%), the lowest incidences of postoperative pancreatic fistula (SUCRA, 94.5%), clinically related postoperative pancreatic fistula (SUCRA, 94.6%), postoperative bleeding (SUCRA, 75.3%), reoperation (SUCRA, 96.4%), overall complications (SUCRA, 86.9%), and major complications (SUCRA, 99.3%), and the lowest mortality (SUCRA, 83.4%). Robotic DP also proved to be the best approach regarding the attainment of R0 resection (SUCRA, 75.4%) and the number of lymph nodes harvested (SUCRA, 64.1%).

Conclusion: Robotic DP seems to offer clinical and oncological advantages compared with other DP methods for addressing diseases of the pancreatic body and tail, although it may require a longer operation time and learning curve. The present results require confirmation in future head-to-head randomized controlled trials.

Key Words: distal pancreatectomy, robot-assisted, robotic, laparoscopic, network meta-analysis

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From the Department of Hepatobiliary Surgery, Affiliated Dongyang Hospital of Wenzhou Medical University, Dongyang, Zhejiang, People's Republic of China.
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Reprints: Yunxiao Lyu, MD, Department of Hepatobiliary Surgery, Affiliated Dongyang Hospital of Wenzhou Medical University, Dongyang, Zhejiang 322100, People's Republic of China (e-mail: lvyunxiao1986@gmail.com).
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Distal pancreatectomy (DP) has been widely used to treat benign and malignant tumors of the pancreatic body and tail. Minimally invasive DP (MIDP) has been widely reported,[1–4] with 3 approaches currently in use: laparoscopic DP (LDP), robot-assisted LDP (RADP), and robotic DP (RDP). The latest guidelines, published in 2020, recommend MIDP over open DP (ODP) for benign and low-grade malignant tumors.[5] A recent multicenter randomized controlled trial (RCT) comparing MIDP with ODP showed that MIDP has the advantages of shorter hospital stay, less blood loss, and fewer overall complications (OCs).[6] However, we believe that more evidence is needed to confirm that MIDP is preferable to ODP and should be used in the clinical setting. Furthermore, other previous studies, including many meta-analyses, focused on MIDP but did not distinguish RADP, RDP, and LDP as separate entities.[7–9] Thus, the safety and efficacy of these individual MIDP methods remain controversial. One meta-analysis that included 17 studies revealed that RADP resulted in fewer OCs than LDP or ODP.[10] Conversely, Kamarajah et al[8] showed that the OC rate did not significantly differ between RDP and LDP. However, few studies have focused on the differences between RADP and RDP. We hypothesized that the type of DP may play an important role in the efficacy and safety of this surgery. Therefore, we conducted a systematic, aggregate network meta-analysis to assess the value of each of the 4 DP methods (3 minimally invasive and 1 open).

MATERIALS AND METHODS

Study Design

The protocol we used for our data search was derived from the Cochrane Handbook for Systematic Reviews of Interventions.[11] We conducted a comprehensive search of MEDLINE, Scopus, Web of Science, the Cochrane Central Register of Controlled Trials, and ClinicalTrials.gov for relevant studies published between 1990 and 2019. This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement. The following keywords were used in several logical combinations: distal pancreatectomy, distal pancreatectomies, robotic, robot-assisted, open, laparoscopy, and laparoscopic. The search was limited to RCTs performed with human subjects for which the full-text articles were available, with the publication language restricted to English. We also searched the reference lists of the initially retrieved articles for potentially relevant papers.

IRB approval and informed consent were not needed for this study.

Inclusion and Exclusion Criteria

The inclusion criterion was that the study compared at least 2 of RADP, LDP, ODP, and RDP. ODP, LDP, and

RADP were defined as reported previously.[12] RDP was defined as completely robotic surgery without laparoscopic assistance, as previously reported.[13] Studies that compared total pancreatectomy or pancreaticoduodenectomy were excluded from the present study. We also excluded articles that on-human studies, review articles, letters, abstracts, case reports, and articles that did not report the outcomes of interest that were assessed in the present study.

Outcome Measures

The outcomes analyzed in our study were categorized as intraoperative outcomes, postoperative outcomes, and oncological outcomes. The intraoperative outcomes were: operation time (OT), estimated blood loss (EBL), and spleen preservation (SP). The postoperative outcomes were the presence of postoperative pancreatic fistula (POPF) and/or clinically related POPF (CR-POPF), postoperative bleeding (POBL), reoperation, OCs, major complications (MCs), and mortality. The oncological outcomes were the achievement of R0 margins and the number of lymph nodes harvested (LNH). POPF were classified in accordance with the criteria of the International Study Group of Pancreatic Fistula, with grades B and C regarded as indicating the presence of CR-POPF.[14] An MC was defined as grades III and IV in accordance with the Clavien-Dindo grading system.[15]

Data Extraction and Quality Assessment

Two authors independently conducted comprehensive literature searches to identify articles in multiple electronic databases. Microsoft Excel (Microsoft Corporation, Redmond, WA) was used to identify duplicate studies, which were then removed. The following data were recorded on a standardized form: first author's name, year of publication, study setting, sample size, and surgical procedure. Disagreements in data abstraction were resolved by consensus, and the methodological quality of the included trials was assessed in accordance with the Newcastle-Ottawa scale.

Statistical Analysis

Data were analyzed using STATA version 13.0 software (Stata Corp, College Station, TX) in a frequentist network meta-analysis. Continuous variables were analyzed using the weighted mean difference and its 95% credible interval. Dichotomous variables were analyzed on the basis of odds ratios with 95% confidence intervals. The percent surface under the cumulative ranking curve (SUCRA) and the mean ranks were calculated for each intervention. The SUCRA index ranges between 0 and 100, with higher values indicating better efficacy.[16] Consistency or inconsistency testing was not performed because of the absence of a closed-loop in the network meta-analysis.[17] Publication bias of the literature was evaluated using funnel plots.

RESULTS

Study Selection

The initial electronic literature search retrieved 1808 articles, of which 527 were removed after identification as duplicates. Another 1013 trials were excluded for various reasons, and 240 full-text articles were excluded because they had no relevance to our study. A final total of 46 studies met the eligibility criteria and were included in the present analysis.[12,13,18–61] A detailed flowchart of the selection process is shown in Figure 1. The characteristics of the included studies are summarized in Table 1. Among the 46 included studies, 4 were 3-armed trials, whereas 42 were 2-armed trials. The sample size ranged from 14 to 1126 patients.

Intraoperative Outcomes

The network geometry of the intraoperative outcomes is shown in Figure 2, and the contribution plots are shown in eFigure 1 in the Supplementary Material (Supplemental Digital Content 1, http://links.lww.com/SLE/A252). ODP showed the greatest probability of having the shortest OT (SUCRA, 63.5%), followed by LDP (SUCRA, 63.0%), RADP (SUCRA, 40.4%), and RDP (SUCRA, 33.2%; Table 2). RDP showed the greatest probability of having the least EBL (SUCRA, 90.9%), followed by RADP (SUCRA, 55.8%), LDP (SUCRA, 51.5%), and ODP (SUCRA, 1.9%; Table 2). RADP showed the greatest probability of having the most SPs (SUCRA, 84.1%), followed by RDP (SUCRA, 61.6%), LDP (SUCRA, 41.9%), and ODP (SUCRA, 14.6%; Table 2). The mixed head-to-head comparisons of intraoperative outcomes are shown in eFigure 2 in the Supplementary Material (Supplemental Digital Content 1, http://links.lww.com/SLE/A252).

Postoperative Outcomes

The network geometry of postoperative outcomes is shown in Figure 2, and the contribution plots are shown in eFigure 1 in the Supplementary Material (Supplemental Digital Content 1, http://links.lww.com/SLE/A252). POPF data were provided in 34 studies (4 three-armed studies and 30 two-armed studies); RDP showed the greatest probability of having the lowest incidence of POPF (SUCRA, 94.5%), followed by ODP (SUCRA, 51.3%), RADP (SUCRA, 31.4%), and LDP (SUCRA, 22.8%; Table 2). CR-POPF data were provided in 30 trials; the SUCRA values of RADP, LDP, ODP, and RDP were 31.4%, 22.7%, 52.3%, and 94.6%, respectively (Table 2). POBL data were provided in 17 trials; RDP showed the greatest probability of having the lowest incidence of POBL (SUCRA, 65.3%), followed by RADP (SUCRA, 54.6%), LDP (SUCRA, 43.4%), and ODP (SUCRA, 36.8%; Table 2). Reoperation data were provided in 23 studies; the SUCRA values for RADP, LDP, ODP, and RDP were 31.8%, 61.3%, 10.5%, and 96.4%, respectively (Table 2). OCs were reported in 30 studies (1 three-armed study and 29 two-armed studies); RDP had the greatest probability of having the lowest incidence of OCs (SUCRA, 86.9%), followed by RADP (SUCRA, 45.8%), LDP (SUCRA, 44.2%), and ODP (SUCRA, 23.1%; Table 2). MCs were least likely to occur in RDP (SUCRA, 99.3%), followed by LDP (SUCRA, 57%), ODP (SUCRA, 42.0%), and RADP (SUCRA, 0.9%; Table 2). Mortality data were provided in 35 studies; the SUCRA values for RADP, LDP, ODP, and RDP were 39.2%, 57.8%, 19.6%, and 83.4%, respectively (Table 2). The mixed head-to-head comparisons of intraoperative outcomes are shown in eFigure 2 in the Supplementary Material (Supplemental Digital Content 1, http://links.lww.com/SLE/A252).

Oncological Outcomes

The network geometry of oncological outcomes is shown in Figure 2, and the contribution plots are shown in eFigure 1 in the Supplementary Material (Supplemental Digital Content 1, http://links.lww.com/SLE/A252). The R0 margin data were provided in 28 studies (2 three-armed studies and 26 two-armed studies); RDP tended to be the best procedure for achieving R0 margins (SUCRA, 75.4%),

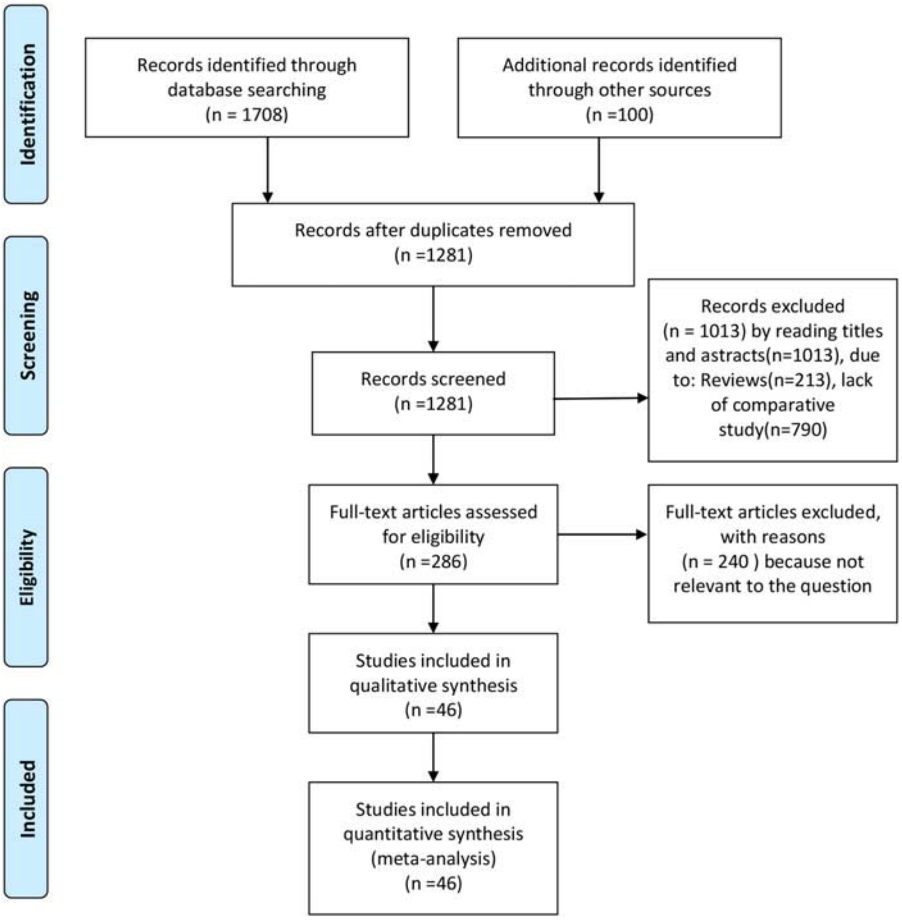

FIGURE 1. Flow diagram of the published articles evaluated for inclusion in this meta-analysis.

followed by RADP (SUCRA, 59.4%), LDP (SUCRA, 33.2%), and ODP (SUCRA, 32%; Table 2). LNH data were provided in 14 studies (3 three-armed studies and 11 two-armed studies); RDP tended to be the best procedure for LNH (SUCRA, 63.8%), followed by RADP (SUCRA, 58.3%), ODP (SUCRA, 54.8%), and LDP (SUCRA, 23.1%; Table 2). The mixed head-to-head comparisons of intraoperative outcomes are shown in eFigure 1 in the Supplementary Material (Supplemental Digital Content 1, http://links.lww.com/SLE/A252).

Inconsistency, Heterogeneity, and Publication Bias

The inconsistency and heterogeneity for the assessed procedures are shown in Table 3. None of the outcomes had significant local inconsistency within the networks. Heterogeneity was low ($\tau < 0.1$) for POPF, CR-POPF, POBL, OC, MC, mortality, and R0 resection. Heterogeneity was high for OT ($\tau > 1$), SP ($\tau = 0.52$, 0.44), and LNH ($\tau > 1$). The comparison-adjusted funnel plots suggested that there was no significant publication bias.

DISCUSSION

Several studies, including meta-analyses, have compared MIDP with ODP. The 4 DP approaches are ODP, LDP, RADP, and RDP. We believe that the present study is the first network meta-analysis to compare the efficacy and safety of these 4 approaches. The present systematic review and network meta-analysis of 46 studies with 8377 patients showed that RDP was comparable with both other MIDPs and ODP in terms of intraoperative and postoperative outcomes. Regarding the oncological outcomes, RDP showed the greatest probability of achieving R0 resection and optimal LNH. However, the present findings require confirmation in further studies, especially head-to-head RCTs and long-term oncological studies.

EBL was one of the factors evaluated to assess the efficacy of the various DP approaches. Our study showed that RDP had the greatest probability of having the least EBL, followed by RADP and LDP. Most other studies reported that LDP is associated with less EBL than ODP.[6,62] However, LDP has limitations, such as 2-dimensional imaging and only a limited area for manipulation. Theoretically, the 3-dimensional (3D) visualization and bionic structure of the robotic surgical field could improve this complex dissection. Compared with traditional LDP, there is less EBL during robotic surgery comprising RADP or RDP. The present head-to-head meta-analysis showed that RDP was associated with less EBL than LDP or RADP.

SP was another factor used to evaluate the efficacy of the various DP methods. SP plays an important role in the

TABLE 1. Characteristic of Included Studies

Source	Country	Study Design	Procedure	Sample Size	Age (y)	Sex (F/M)	BMI (kg/m²)	NOS
Adam et al[18]	USA	R	RADP	61	65 ± 14	32/29	NA	8
			LDP	474	64 ± 13	255/219		
Alfieri et al[19]	Italy	R	RADP	96	NA	50/46	NA	7
			LDP	85		42/43		
Bauman et al[55]	USA	R	LDP	33	66 ± 2	16/17	26.2 ± 0.8	7
			DPO	46	66 ± 2	28/18	27.8 ± 0.9	
Benizri et al[12]	France	R	RADP	11	50 ± 21	8/3	26 ± 6	9
			LDP	23	52 ± 15	13/10	27 ± 5	
Boggi et al[20]	Italy	P	RADP	11	61.8 (50-74)	5/6	24.8 (18.4-35.0)	8
			ODP	11	68.4 (49-78)	4/7	25.0 (17.9-30.8)	
Braga et al[21]	Italy	P	LDP	100	61.4 ± 13.5	56/44	NA	7
			ODP	100	61.0 ± 13.8	56/44		
Butturini et al[22]	Italy	P	RADP	22	54(26-77)	16/6	25	8
			LDP	21	55(20-71)	14/7	24	
Chen et al[24]	China	R	RADP	69	56 ± 13	46/23	25 ± 3	9
			LDP	50	57 ± 15	33/17	25 ± 3	
Chen et al[23]	China	R	LDP	334	60	196/138	22	7
			ODP	48	74.5	21/27	22	
Daouadi et al[25]	USA	R	RADP	30	59 ± 13	21/9	28 ± 5	7
			LDP	94	59 ± 16	61/33	29 ± 7	
Duran et al[26]	Spain	R	LDP	18	58 ± 10	8/8	NA	7
			ODP	13	63.8 ± 10.3	7/6		
			RDP	16	61 ± 12	7/9		
Eckhardt et al[27]	Germany	R	RADP	12	49 (29-76)	9/3	23 (20-34)	8
			LDP	29	59 (17-85)	18/11	27 (19-36)	
Eom et al[28]	Korea	R	LDP	31	46.7 ± 16.7	NA	22.2 ± 2.2	8
			ODP	62	47.5 ± 14.9		23.0 ± 3.4	
Goh et al[29]	Singapore	R	RADP	8	57 (21-68)	6/2	28 (22-31)	9
			LDP	31	56 (25-78)	14/17	24 (19-36)	
Han et al[30]	Korea	R	LDP	42	53 (30-75)	21/21	24.64 (18.82-31.53)	7
			ODP	52	54 (36-75)	18/34	23.99 (18.97-31.20)	
Hong et al[31]	Saudi Arabia	R	RADP	46	51.2 ± 13.8	32/14	24.9 ± 4.1	7
			LDP	182	60.2 ± 13	88/94	24.6 ± 3.2	
Hu et al[32]	China	R	LDP/ODP	11	53.1 ± 13.2	4/7	23.9 ± 4.2	8
				23	49.1 ± 9.5	10/13	25.6 ± 4.0	
Huang et al[33]	China	R	LDP	48	47.5 ± 17.3	22/26	23.7 ± 1.9	7
			ODP	40	51.4 ± 20.3	29/11	24.1 ± 2.2	
Ielpo et al[34]	Spain	P	LDP	26	61 (41-79)	16/10	25 (18-32)	7
			RDP	28	60 (35-73)	15/13	24 (19-32)	
Ito et al[61]	Japan	R	LDP	10	42	NA	NA	7
			RDP	4	52.7			
Jarufe et al[56]	Chile	R	LDP	57	49 (13-82)	44/13	NA	7
			ODP	36	53 (14-74)	25/11		
Kang et al[35]	Korea	R	RADP	20	45 ± 16	12/8	24 ± 3	8
			LDP	25	57 ± 14	12/13	23 ± 3	
Khaled et al[57]	UK	R	LDP	22	57 (34-78)	14/8	26.5 (21.5-70.2)	8
			ODP	22	59.9 (32-78)	14/8	28.3 (24-36.6)	
Kooby et al[36]	USA	R	LDP	23	64.6 ± 12.3	11/12	28.5 ± 5.7	7
			ODP	189	65.9 ± 11.1	109/80	26.2 ± 6.0	
Lai et al[58]	China	R	LDP	18	63 ± 18	14/4	26 ± 3	8
			RDP	17	61 ± 10	6/11	24 ± 2	
Lee et al[37]	USA	R	RADP	37	58 ± 11	27/10	29	8
			LDP	131	58 ± 15	74/57	28	
			ODP	637	63 ± 13.5	351/286		
Liu et al[13]	China	R	LDP	102	50 ± 15	55/47	NA	8
			RDP	102	48 ± 16	68/34		
Lyman et al[38]	USA	R	RADP	108	53 ± 16.1	62/46	29.3 ± 6.5	8
			LDP	139	59.5 ± 15.5	6475	29 ± 8.5	
Marino et al[39]	Japan	R	RADP	35	59.3 (40-73)	15/20	NA	7
			LDP	35	58.5 (34-69)	16/19		
Matsumoto et al[40]	Japan	P	LDP	32	63 ± 14	23/9	22.5 ± 3.6	7
			ODP	35	58 ± 17	20/15	22.9 ± 3.9	
Ocuin et al[41]	USA	R	ODP	11	63.5 ± 15.0	5/6	28.1 (24.5-30.3)	7
			RDP	19	62.2 ± 9.6	11/8	26.0 (23.6-28.4)	
Qu et al[42]	China	R	LDP	35	58 ± 11	23/22	24 ± 4	8
			RDP	35	58 ± 11	23/22	24 ± 3	
Raoof et al[43]	USA	NCSC	LDP	563	NA	261/302	NA	9
			ODP	563		259/304		

TABLE 1. (*continued*)

Source	Country	Study Design	Procedure	Sample Size	Age (y)	Sex (F/M)	BMI (kg/m^2)	NOS
Raoof et al[44]	USA	NCS	RADP	99	NA	54/45	NA	8
			LDP	605		283/322		
Rehman et al[45]	UK	R	LDP	8	64.2	NA	NA	8
			ODP	14	64			
Rodriguez et al[46]	France	R	LDP	25	62.5 (27-83)	13/12	27.3 (20-41)	7
			ODP	43	65 (38-86)	21/22	24.7 (17-34)	
			RDP	21	53 (27-79)	15/6	25 (18-33)	
Sharpe et al[47]	USA	NCS	LDP	144	67.7 ± 10.1	NA	NA	7
			ODP	625	65.6 ± 10.5			
Shin et al[48]	Korea	R	LDP	70	61 ± 7.8	23/47	24.1 ± 2.1	8
			ODP	80	65 ± 6	32/48	23.1 ± 2.2	
Soreide et al[49]	Norway	NCS	LDP	327	66 (55-72)	158/169	NA	8
			ODP	227	66 (55-72)	126/101		
Souche et al[50]	France	P	RADP	23	66 (44-83)	14/9	25 (20-34)	7
			LDP	15	57 (34-72)	12/3	23 (19-31)	
Stauffer et al[51]	Italy	R	LDP	44	72 ± 5.8	8/26	28.3 ± 7.7	7
			ODP	28	67.3 ± 6.8	12/16	26.1 ± 4.3	
Vijan et al[59]	USA	R	LDP	100	59.0 ± 17.3	60/40	27.4 ± 5.2	8
			ODP	100	58.6 ± 15.2	50/50	27.9 ± 5.0	
Waters et al[52]	USA	R	LDP	18	59	9/9	NA	7
			ODP	22	59	12/10		
			RDP	17	64	11/6		
Zhang et al[54]	China	R	LDP	17	60 ± 7.75	6/11	23.4 ± 4.7	7
			ODP	34	64 ± 9	15/19	23.7 ± 2.4	
Zhang et al[53]	China	R	LDP	22	55.2 ± 13.1	13/9	23.9 ± 2.7	8
			ODP	76	59.8 ± 9.0	46/30	23.7 ± 3.3	
Zhang et al[60]	China	R	LDP	31	49 ± 12	19/12	NA	7
			RDP	43	48 ± 11	23/20		

BMI indicates body mass index; LDP, laparoscopic distal pancreatectomy; NA, not available; NCS, nationwide cohort study; ODP, open distal pancreatectomy; P, prospective study; R, retrospective study; RADP, robotic-assisted distal pancreatectomy; RDP, robotic distal pancreatectomy.

human immune system.[63] MIDP reportedly increases SP compared with ODP. A recent meta-analysis showed that RADP and LDP are associated with a higher SP rate than ODP, although the SP rate does not significantly differ between RADP and LDP.[10] In the present study, RADP and RDP had higher SP rates than either LDP or ODP. The higher SP rate in robotic surgery maybe because of the 3D magnified surgical field. The mixed head-to-head analysis showed that the SP rate did not significantly differ between RADP and RDP. Surgeons prefer to perform MIDP for less invasive, small tumors, and SP is physiologically desirable in patients with benign or low-grade malignancy. However, there is still no consensus on whether the spleen should be preserved. The numbers of patients in the RDP groups were small, and the indication for SP in the presence of various diseases remains controversial. Furthermore, SP is influenced by many factors, including tumor size and surgical expertise.

The incidence of postoperative OCs did not significantly differ between the 4 DP approaches, although RDP tended to have the lowest OC rate, followed by RADP, LDP, and ODP. This finding is consistent with most previous studies.[6,7] RDP was associated with fewer MCs than RADP or LDP. Niu et al[64] reported that the MC rate does not significantly differ between RADP and LDP. To date, few studies have compared RADP with RDP. In addition, the definition of complications was variable in the included studies, which may have introduced bias. The complication rate of the various DP approaches requires further investigation in head-to-head and scaled RCTs.

POPF is the most common postoperative complication associated with DP. The present study showed that RDP seems to be the best approach for avoiding POPF and CR-POPF, although the subject remains controversial. Alfieri et al[19] showed that the incidences of POPF and CR-POPF do not significantly differ between RADP and LDP. Similar results have been reported regarding the minimally invasive treatment of neuroendocrine tumors.[30] However, the texture of the pancreatic remnant and the type of pancreatic remnant closure may influence the development of a POPF or CR-POPF. Previous studies have shown that the risk of POPF formation is increased when the pancreas has a soft texture. However, the texture of the pancreas is a subjective judgment, and there is currently no unified objective standard. The included studies did not report adequate details about the texture of the pancreas. More research is needed to determine whether robotic surgery reduces the incidence of POPF.

Regarding the oncological outcomes, our study showed that RDP fared well compared with other procedures. Several previous studies, including a meta-analysis, have suggested that MIDP produces oncological results comparable with those achieved with ODP.[65,66] MIDP commonly includes RADP, LDP, and RDP. Our study compared these 3 approaches regarding both the R0 status and LNH. A propensity score-matched study involving multiple European centers showed that MIDP is associated with a higher R0 resection rate and a lower number of LNH.[65] However, the required standard of lymphadenectomy in DP is debatable. Although Slidell et al[67] demonstrated that at least 12 lymph nodes need removal in DP,

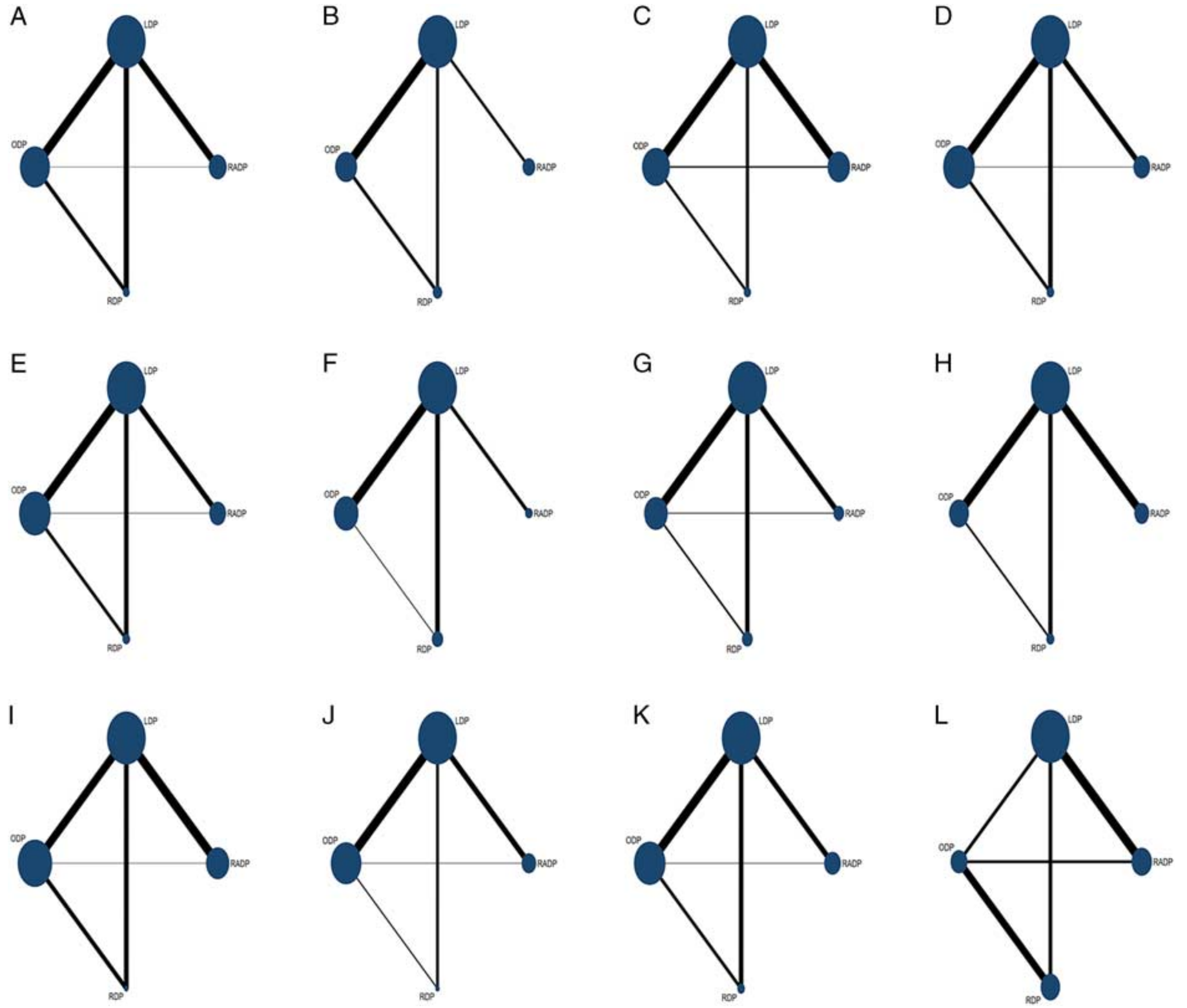

FIGURE 2. Network geometry of the included studies. A, Operation time (OT). B, Estimated blood loss (EBL). C, Spleen preservation (SP). D, Postoperative pancreatic fistula (POPF). E, Clinically related POPF (CR-POPF). F, Postoperative bleeding (POBL). G, Reoperation. H, Overall complications (OCs). I, Major complications (MCs). J, Mortality. K, R0 resection. L, Number of lymph nodes harvested (LNH). LAP indicates laparoscopic distal pancreatectomy; ODP, open distal pancreatectomy; RADP, robot-assisted laparoscopic pancreatectomy; RDP, robotic distal pancreatectomy.

most of the studies included in the present analysis reported that the mean number of LNH was >12. Unlike previous reports, our study first showed that RDP may be the best approach in terms of oncological outcomes, although these results must be interpreted with caution because the oncological outcomes may be influenced by several factors. The judgment of an R0 pathologic/clinical outcome depends on the experience of the pathologist and the criteria for R0. In addition, the number of LNH may be related to the nature of the tumor and the scope of the surgery. The International Study Group of Pancreatic Fistula suggests that standard lymph node dissection range and numbers are necessary for tumors located in the tail of the pancreas.[68] Theoretically, however, the 3D visual surgical field in RDP may improve the accuracy of judging R0 margins and LNH.

There was high heterogeneity between included studies regarding OT, SP, and LNH. The variation in OT among studies may be related to the method used to calculate the OT, the experience of the surgeon, and the degree of tumor extension. The SP and LNH depend on the surgeon's experience and the tumor characteristics, among other factors. Furthermore, the sample sizes of the included studies were relatively small, which may contribute to the heterogeneity.

The present study has some limitations. First, the sample sizes of some of the included studies were small and some of the studies were retrospective. Second, the definitions of included outcomes (such as POPF or CR-POPF) varied between studies. Third, although the outcome of surgery may be affected by many factors, such as the texture of the pancreas and the patient's body mass index, these data were not fully provided in the included studies. Finally, there were few head-to-head and RCT studies.

Despite these limitations, the present study showed that RDP seems to offer clinical and oncological advantages compared with other DP methods for addressing diseases of

TABLE 2. SUCRA Values and Mean Rank of Outcome Measures

	SUCRA (%)				Mean Rank			
Outcome Measures	**RADP**	**LDP**	**ODP**	**RDP**	**RADP**	**LDP**	**ODP**	**RDP**
Intraoperative outcomes								
OT	40.4	63	63.5	33.2	2.8	2.1	2.1	3.0
EBL	48.7	50.4	4.7	90.6	2.5	2.5	3.9	1.1
SP	84.1	41.9	14.6	59.4	1.5	2.7	3.6	2.2
Postoperative outcomes								
POPF	31.4	22.8	51.3	94.5	3.1	3.3	2.5	1.2
CR-POPF	31.4	22.7	52.3	94.6	3.1	3.3	2.5	1.2
POBL	54.6	43.4	36.8	65.3	2.4	2.7	2.9	2.0
Reoperation	31.8	61.3	10.5	96.4	3.0	2.2	3.7	1.1
OC	45.8	44.2	23.1	86.9	2.6	2.7	3.3	1.4
MC	0.9	57	42.9	99.3	4.0	2.3	2.7	1.0
Mortality	39.2	57.8	19.6	83.4	2.8	2.3	3.4	1.5
Oncological outcomes								
R0	59.4	33.2	32	75.4	2.2	3.0	3.0	1.7
LNH	58.3	23.1	54.8	63.8	2.2	3.3	2.4	2.1

CR-POPF indicates clinically related postoperative pancreatic fistula; EBL, estimated blood loss; LDP, laparoscopic distal pancreatectomy; LNH, lymph node harvested; MC, major complication; OC, overall complication; ODP, open distal pancreatectomy; OT, operation time; POBL, postoperative bleeding; POPF, postoperative pancreatic fistula; RADP, robotic-assisted distal pancreatectomy; RDP, robotic distal pancreatectomy; SP, spleen preservation; SUCRA, surface under the cumulative ranking curves.

the pancreatic body and tail, although it may require a longer OT and learning curve. These results require confirmation in a future head-to-head RCT.

TABLE 3. Loop Inconsistency and Heterogeneity

	Inconsistency		
Outcome Measures	**Loop**	**RoR (95% CI)**	**Heterogeneity, τ**
Intraoperative outcomes			
OT	B-C-D	25.23 (1.00-82.24)	> 1
	A-B-C	4.95 (1.00-31.92)	> 1
EBL	B-C-D	4.65 (1.00-42.35)	> 1
SP	B-C-D	2.36 (1.00-111.88)	0.51
	A-B-C	12.78 (1.00-70.56)	0.40
Postoperative outcomes			
POPF	A-B-C	1.82 (1.00-6.43)	< 0.1
	B-C-D	1.17 (1.00-2.90)	< 0.1
CR-POPF	A-B-C	1.823 (1.00-6.43)	< 0.1
	B-C-D	1.175 (1.00-2.90)	< 0.1
POBL	B-C-D	1.179 (1.00-19.86)	< 0.1
OC	B-C-D	1.645 (1.00-5.86)	< 0.1
MC	A-B-C	1.92 (1.00-4.96)	< 0.1
OC	B-C-D	1.35 (1.00-17.96)	< 0.1
Mortality	B-C-D	3.22 (1.00-37.99)	< 0.1
	A-B-C	2.163 (1.00-50.30)	< 0.1
R0	A-B-C	1.82 (1.00-6.43)	< 0.1
	B-C-D	1.17 (1.00-2.90)	< 0.1
Oncological outcomes			
LNH	B-C-D	20.52 (1.00-125.19)	> 1
	A-B-C	11.73 (1.00-45.28)	> 1

A indicates robotic-assisted distal pancreatectomy; B, laparoscopic distal pancreatectomy; C, open distal pancreatectomy; CI, confidence interval; CR-POPF, clinically related postoperative pancreatic fistula; D, robotic distal pancreatectomy; EBL, estimated blood loss; IT, intraoperative transfusion; LNH, lymph node harvested; MC, major complication; OC, overall complication; OT, operation time; POBL, postoperative bleeding; POPF, postoperative pancreatic fistula; RoR, logarithm of the ratio of 2 odds ratios; SSI, surgical site infection.

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