Chen *et al. BMC Surgery* (2025) 25:212
https://doi.org/10.1186/s12893-025-02934-5

BMC Surgery

SYSTEMATIC REVIEW **Open Access**

A comparison of postoperative outcomes between robotic-assisted and laparoscopic-assisted total gastrectomy: a comprehensive meta-analysis and systematic review

Jianhua Chen[2,4†], Fei Wang[1†], Yong Wang[2†], Jie Zhou[1], Yapeng Yang[2], Ziming Zhao[2], Rongfan Wu[2], Liuhua Wang[2,3,4] and Jun Ren[2,3,4*]

Abstract

Background The application of robot-assisted technology in gastric cancer surgery is gradually gaining attention from surgeons. In this meta-analysis, our main objective was to assess whether robot-assisted techniques are more advantageous than laparoscopic-assisted technology in total gastrectomy.

Methods We searched Pubmed, Embase, Web of Science, and Cochrane Library databases for clinical studies published before October 2023 comparing robotic-assisted total gastrectomy (RATG) and laparoscopic-assisted total gastrectomy (LATG) for gastric cancer. Non-clinical studies, data unavailability, or fewer than 50 included cases were excluded. The Newcastle-Ottawa Scale was used to assess the risk of bias by determining the quality of the observational studies. Statistical meta-analysis and drawing were performed using the Software Review Manager version 5.3 and Stata version 16.0. $P < 0.05$ was considered significant.

Results Nine studies that included 1,864 patients with gastric cancer were included, published between 2012 and 2023. The results of the analysis showed that RATG has advantages in the following aspects: intraoperative blood loss was 17.69 ml lower in the RATG group than in the LATG group (WMD: -17.69,*95% CI*:-20.90 ~ -14.49; $P < 0.05$); In terms of the number of resected lymph nodes, the RATG group had 2.65 more than the LATG group (WMD: 2.65,*95% CI*:0.88 ~ -4.42); $P < 0.05$); the time to start liquid and postoperative hospital stays were 0.62 and 0.90 days shorter in the RATG group than in the LATG group, respectively (WMD: -0.62,*95%CI*: -1.06 ~ -0.19; $P < 0.05$), (WMD: -0.90,*95%CI*: -1.43 ~ -0.37; $P < 0.05$)); the incidence of major complications and pancreas fistula in the RATG group was 0.59% and 0.17% lower than in the LATG group, respectively (OR: 0.59,*95% CI*: 0.38 ~ 0.93; $P < 0.05$), (OR: 0.17,95% *CI*: 0.03 ~ 0.94; $P < 0.05$). However, the analysis showed that the operative time in the RATG group was 30.96 min longer than in the LATG group (WMD: 30.96,*95% CI*: 21.24 ~ 40.69; $P < 0.05$).

[†]Jianhua Chen, Fei Wang and Yong Wang equally contributed to this work and should be acknowledged with first authorship.

*Correspondence:
Jun Ren
freezingfall@163.com

Full list of author information is available at the end of the article

Conclusions Based on the results of this meta-analysis, we concluded that robotic-assisted technology may be a worthwhile technique to apply in the surgical treatment of total gastrectomy. However, this meta-analysis has the limitations that the included studies were all non-randomized controlled trials and published in Asian countries, and more high-quality randomized controlled trials are needed for further validation in the future.

The registered name and registration number The study protocol for this meta-analysis is registered on the PROSPERO website under registration number CRD42024500512.

Keywords Gastric cancer, Robotic-assisted total gastrectomy, Laparoscopic-assisted total gastrectomy, Surgical outcomes, Meta-analysis

Introduction

As the fifth most prevalent malignant tumor, gastric cancer (GC) is also the fourth leading cause of cancer-related death in the world [1, 2]. Globally, there were more than 1 million new cases of stomach cancer in 2020 and 769,000 deaths due to stomach cancer [1]. Although GC is steadily declining globally, it is worth noting that the incidence of GC is increasing in young and middle-aged populations (age < 50 years) [1]. Therefore, GC remains a serious threat to human health. Radical gastrectomy remains the gold standard for treating resectable GC [3–6]. In recent years, minimally invasive techniques have developed rapidly in surgery. With the application of minimally invasive techniques, total gastrectomy have shown shorter hospital stays, lower incisional complication rates, and faster postoperative recovery for patients [7]. The laparoscopic technique is one of the first minimally invasive techniques widely used in various surgical procedures, among which laparoscopic gastrectomy (LG) is well-recognized by gastrointestinal surgeons.

However, with the widespread application of LG technology, its drawbacks have been gradually exposed, such as a two-dimensional field of view, limitation of instrumental movement, amplification of hand tremor, and extended learning curve, which puts more pressure on the surgeons than the open gastrectomy (OG) [8–13]. Furthermore, the above limitations have restricted the widespread use of D2 spleen-preserving laparoscopic-assisted total gastrectomy (LATG) [14, 15].

Robotic surgery, an emerging technology, has ushered in a new era of minimally invasive surgery. Robotic surgical systems are considered to overcome the technical shortcomings of traditional laparoscopic surgery and are widely used in general surgery and other surgical fields [16].

The safety and efficacy of robotic gastrectomy (RG) in early-stage GC patients have been gradually recognized [17–19]. Several studies [20–26] have reported surgical outcomes in RG and LG. However, no studies have systematically analyzed surgical outcomes in patients undergoing robotic-assisted total gastrectomy (RATG) and LATG. Therefore, the primary endpoint of this study was to compare which minimally invasive technique (RATG or LATG) is more advantageous in terms of surgical characteristics, postoperative recovery and postoperative complications. The secondary endpoint was to compare which minimally invasive technique had better postoperative quality of life.

Materials and methods

This study was carried out according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) and AMSTAR (Assessing the methodological quality of systematic reviews) Guidelines [27, 28]. Because this study was a meta-analysis, Institutional Review Board (IRB) approval and patient consent were not required. The study protocol for this meta-analysis is registered on the PROSPERO website under registration number CRD42024500512.

Search strategy

We searched the Pubmed, Embase, Web of Science, and Cochrane Library databases for clinical studies published before October 2023 comparing RATG and LATG. We searched the literature using the "MeSH terms OR free-text terms" method, and the same formula was used to search across four databases. The search formula used in four databases was in Additional file 1.

Inclusion and exclusion criteria

The included studies must meet all the following criteria: (1) population: Adults (age ≥ 18 years) diagnosed with GC by postoperative pathologic biopsy; (2) intervention: The study reported postoperative outcomes of RATG versus LATG for GC; (3) outcomes: Postoperative outcomes reported in the study at least one of the following clinical data: operative time, intraoperative blood loss, retrieved lymph nodes, time to start liquid, postoperative hospital stays, postoperative complications, operative mortality, unplanned reoperation; The original data provides odds ratios (OR) values and 95% confidence intervals (95%*CI*) or the OR values and 95%*CI* can be calculated from the data; (4) study: the included studies should meet the criteria of being randomized controlled or non-randomized controlled trials published in English; If the same team or authors have published multiple related articles, we enrolled the latest or the more extensive scale number studies.

Studies that met the following criteria were excluded: (1) patients with esophagogastric junction cancer or residual GC; (2) the study data could not be extracted or were not available; (3) the number of cases was less than 50 in studies.

Study selection and data extraction

One reviewer (J.Z) imported literature from four database searches into EndNote X9 (Clarivate Analytics, Philadelphia, USA). The two reviewers (Y.P.Y and Z.M.Z) were independently and sequentially screened strictly by reading the title, abstract, and full text. Two reviewers discussed and resolved the issue in case of disagreements, with a third person if necessary (R.F.W). Clinical data from each of the included studies was extracted and transformed by two reviewers (Y.P.Y and Z.M.Z), including study author, date and country of publication, study design, number of study cases, age, sex ratio, body mass index (BMI), tumor diameter, scope of lymphadenectomy, operative time, intraoperative blood loss, number of retrieved lymph nodes, proximal margin, time to start liquid, postoperative hospital stays, overall complications, major complications (Clavien-Dindo classification ≥ IIIa) [29], etc. According to the Japanese gastric cancer treatment guidelines 2021 (6th edition) [30], D1 + lymph node dissection includes Nos. 1–7, 8a, 9, 11p; D2 lymph node dissection includes Nos. 1–7, 8a, 9, 11p, 11d, 12a. It needs to be clarified that we did not contact the authors of the included studies for missing data.

Quality assessment

We evaluated the quality of the research using the Newcastle-Ottawa scale (NOS) (http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp). The NOS quality assessment criteria for a case-control study include Selection, Comparability, and Exposure, and the quality assessment criteria of the NOS for a cohort study include Selection, Comparability, and Outcome. It should be noted that for the "Was follow-up long enough for outcomes to occur" and "Adequacy of follow-up of cohorts" components of the "outcome" aspect, we required a follow-up time of ≥ 1 years and a follow-up failure rate ≤ 25% to receive 1 star, respectively. According to the NOS, two reviewers independently scored the research quality of each study. The NOS ranges from 0 to 9 stars, and ≥ six stars could be considered reliable for the quality of the study. Two reviewers (Y.P.Y and Z.M.Z) discussed and resolved the issue in case of disagreements, with a third person if necessary (R.F.W).

Statistical analysis

The software of RevMan 5.3 (The Cochrane Collaboration, Oxford, England) and Stata 16.0 (StataCorp LP, Texas, United States) were used to perform statistical meta-analysis and drawing. This statistical analysis used the OR value to assess the count data and weighted mean difference (WMD) for continuous variables. The effect size was calculated with a 95%*CI* for each meta-data set. Heterogeneity was assessed utilizing the I-squared (I^2) tests. If the I^2 statistic was greater than or equal to 50%, we considered that there was high heterogeneity in the results. We use a fixed-effects model in the presence of low heterogeneity (< 50%) as well as a random-effects model in the case of high heterogeneity (> 50%). The Stata 16.0 software was used to perform subgroup analyses, sensitivity analyses, and publication bias analyses for this study. Sensitivity analysis was performed by sequentially removing each study. We have chosen an outcome that includes all studies for publication bias analysis. The funnel plot was utilized to show and assess the publication of bias, and the Begg's and Egger tests were utilized to evaluate the degree of bias. When the P-value < 0.05, the difference in the analyzed results was statistically significant.

Results

Study selection

Based on the above-mentioned search strategies, 1534 related studies were searched from the four databases, including 479 in PubMed, 477 in Embase, 63 in the Cochrane Library, and 515 in Web of Science. After rigorous selection and careful discussion by two reviewers, nine studies [31–39] were finally selected. Of the nine included studies, one was a case-control study, and the remaining eight were cohort studies. The screening flow diagram is shown in Fig. 1.

Study characteristics and quality assessment

The nine studies published between 2012 and 2023, came from three countries: China, Japan, and Korea, which included one prospective study and the remaining eight were retrospective. Our study included 1864 participants with GC, 706 of whom had undergone RATG, and 1158 with LATG. General information about the participants in this meta-analysis is summarized in Table 1. We assessed the quality of research for each study according to the NOS. The details of the quality evaluation in the included studies are presented in Table 2.

Meta analysis

We performed the statistical meta-analysis and graphing of the clinical data. The results of all the analyses are summarized in Table 3.

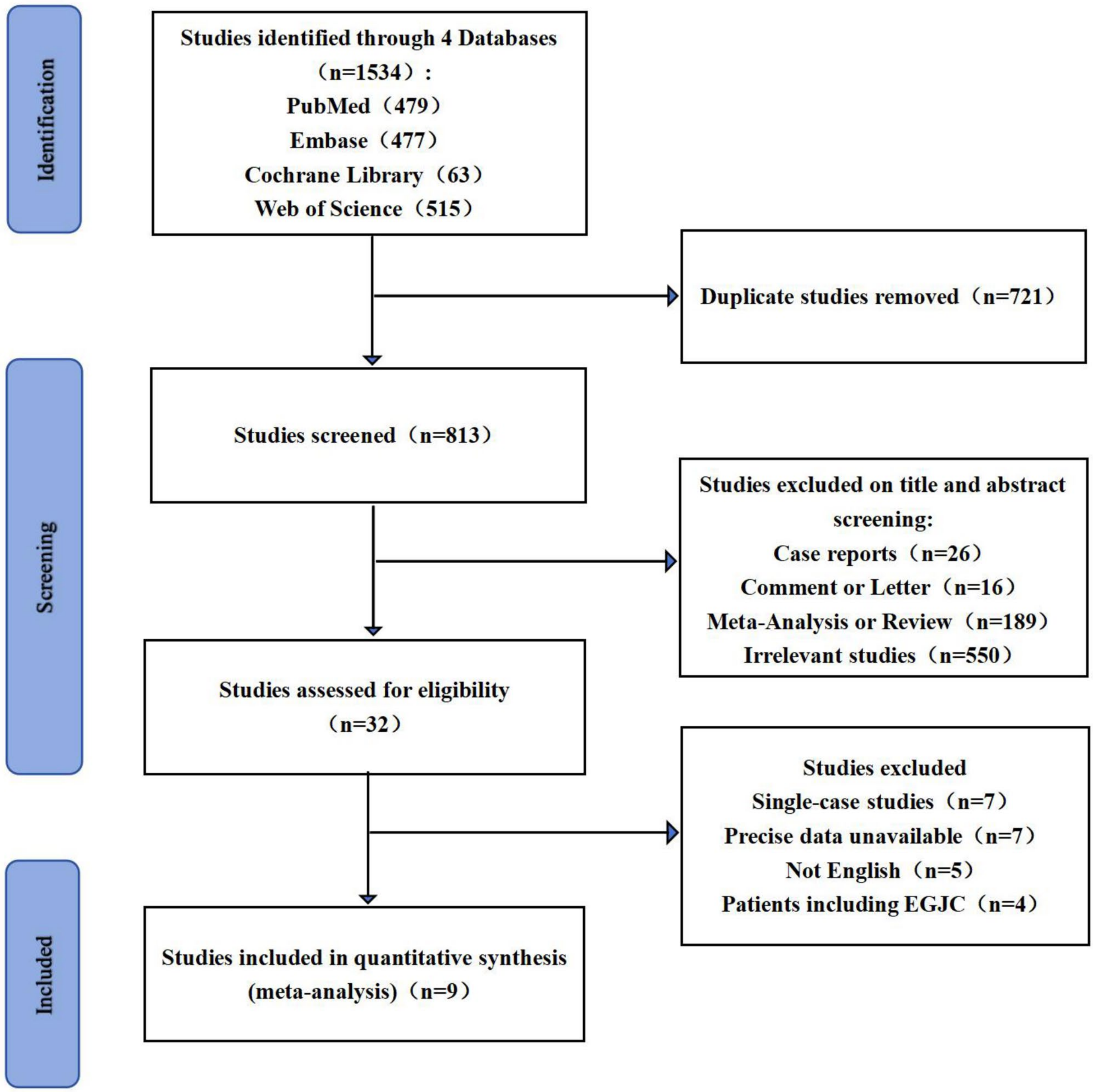


Fig. 1 PRISMA diagram showing the meta-analysis comparing the outcomes of robotic-assisted total gastrectomy and laparoscopic-assisted total gastrectomy; EGJC, esophagogastric junction cancer

Surgical outcomes

Operative time

All nine included studies reported information on operative time, and a total of 1864 patients (RATG:706, LATG:1158) were included. Due to the significant heterogeneity among the studies ($I^2 = 78\%$; $P < 0.05$), the result was analyzed using a random effects model. The results demonstrated that the operative time in the RATG group was 30.96 min longer than in the LATG group (WMD: 30.96,95% *CI*:21.24 ~ 40.69;P<0.05) (Fig. 2a).

Intraoperative blood loss

Eight studies provided results in intraoperative blood loss, and a total of 1763 patients (RATG:670, LATG:1093) were included. We analyzed the results using a fixed-effects model. The analysis of the results showed intraoperative blood loss was 17.69 ml lower in the RATG group than in the LATG group (WMD: -17.69,95% *CI*:-20.90~-14.49;P<0.05) (Fig. 2b).

Table 1 Characteristics and quality scores of included studies

Author	Year	Country	Study design	Study period	Group	Cases *n*	Age Years	Gender (male/female)	BMI (Kg/m$^{2)}$	Tumor size (cm)	Lymph-adenectomy	NOS Score
Chen et al.	2022	China	OCS (P)	2018.03-2020.02	RTAG	48	61.3 ± 9.3^a	38/10	22.3 ± 2.7^a	4.4 ± 2.6^a	D2	6
				2015.01-2018.12	LTAG	96	61.6 ± 7.6^a	79/17	22.3 ± 3.2^a	4.5 ± 2.1^a	D2	
Hikage et al.	2022	Japan	OCS (R)	2013.10-2020.12	RTAG	36	$72\ (43–84)^b$	26/10	$23.1\ (18.1–30.1)^b$	NA	D1+/D2	9
				2013.10-2020.12	LTAG	58	$71\ (36–86)^b$	46/12	$22.8\ (16.2–35.5)^b$	NA	D1+/D2	
Jia et al.	2023	China	OCS (R)	2014.10-2021-10	RTAG	147	62.92 ± 10.00^a	118/29	24.97 ± 3.70^a	5.07 ± 2.69^a	D2	8
				2014.10-2021-10	LTAG	371	62.52 ± 9.43^a	294/77	24.54 ± 3.35^a	5.03 ± 2.80^a	D2	
Roh et al.	2021	Korea	OCS (R)	2009.01-2018.12	RTAG	74	53.8 ± 11.6^a	42/32	23.6 ± 2.9^a	3.5 ± 1.7^a	D1+/D2	9
				2009.01-2018.12	LTAG	74	54.6 ± 12.7^a	42/32	23.8 ± 3.4^a	3.5 ± 2.6^a	D1+/D2	
Shibasaki et al.	2022	Japan	OCS (R)	2009.01-2021.06	RTAG	100	$69\ (60–75)^c$	69/31	$23.0\ (20.3–25.3)^c$	$6.0\ (2.7–7.3)^c$	D1+/D2	8
				2009.01-2021.06	LTAG	100	$68\ (61–75)^c$	67/33	$23.1\ (21.1–25.3)^c$	$5.0\ (3.0\text{-}7.5)^c$	D1+/D2	
Son et al.	2014	Korea	OCS (R)	2003.05-2010.12	RTAG	51	55.3 ± 12.2^a	23/28	22.7 ± 2.9^a	3.04 ± 1.33^a	D2	9
				2003.05-2010.12	LTAG	58	58.8 ± 12.2^a	36/22	23.2 ± 3.3^a	3.17 ± 1.95^a	D2	
Wang et al.	2022	China	OCS (R)	2016.07-2020.12	RTAG	115	60.4 ± 9.4^a	91/24	22.5 ± 3.0^a	4.41 ± 2.38^a	D2	8
				2016.07-2020.12	LTAG	230	60.3 ± 10.4^a	179/51	22.4 ± 3.0^a	4.35 ± 2.50^a	D2	
Ye et al.	2019	China	OCS (R)	2015.06-2018.10	RATG	99	58.7 ± 6.7^a	58/41	$23.9\ (17.3–28.6)^b$	NA	D2	7
				2015.06-2018.10	LATG	106	59.0 ± 7.3^a	55/51	$23.9\ (19.9–28.3)^b$	NA	D2	
Yoon et al.	2012	Korea	OCS(R)	2009.02-2011.05	RATG	36	53.9 ± 11.7^a	18/18	23.2 ± 2.5^a	NA	D1+/D2	8
				2009.02-2011.05	LATG	65	56.9 ± 12.3^a	31/34	23.6 ± 3.4^a	NA	D1+/D2	

OCS; observational clinical study; P, prospective study; R, retrospective study; RATG, robotic-assisted total gastrectomy; LATG, laparoscopy-assisted total gastrectomy; [a] Mean ± Standard deviation; [b] Median (range); [c] median (interquartile range); NA, Not available; D1 + lymph node dissection: Nos. 1–7, 8a, 9, 11p; D2 lymph node dissection: Nos. 1–7, 8a, 9, 11p, 11d, 12a; NOS, Newcastle-Ottawa Scale

Table 2 Results of quality assessment using the Newcastle-Ottawa scale for included studies

study	Selection				Comparability	Exposure/Outcome			Total scores
	a	b	c	d	e	f	g	h	
Chen et al. (2022) *	★	☆	☆	★	★★	★	☆	★	6
Hikage et al. (2022) *	★	★	★	★	★★	★	★	★	9
Jia et al. (2023) *	★	★	★	★	★★	★	☆	★	8
Roh et al. (2021) *	★	★	★	★	★★	★	★	★	9
Shibasaki et al. (2022) *	★	★	★	★	★★	★	☆	★	8
Son et al. (2014) *	★	★	★	★	★★	★	★	★	9
Wang et al. (2022) *	★	★	★	★	★★	★	☆	★	8
Ye et al. (2019) *	★	★	☆	★	★★	★	☆	★	7
Yoon et al. (2012) **	★	☆	★	★	★★	★	★	★	8

*, Study quality of case-control study: a, Is the case definition adequate?; b, Representativeness of the cases; c, Selection of Control; d, Definition of Controls; e, Comparability of cases and controls on the basis of the design or analysis; f, Ascertainment of exposure; g, Same method of ascertainment for cases and controls; h, Non-Response Rate; **, Study quality of cohort study: a, Representativeness of the exposed cohort; b, Selection of the non exposed cohort; c, Ascertainment of exposure to implants; d, Demonstration that outcome of interest was not present at start of study; e, Comparability of cohorts on the basis of the design or analysis f, Assessment of outcome; g, Was follow up long enough for outcomes to occur; h, Adequacy of follow up of cohorts; ★, 1 score; ☆, 0 score

Table 3 Meta analysis of clinical outcomes between LATG and RATG

Outcomes	No.studies	No.patients		Heterogeneity		WMD/OR [95%CI]	*P*
		RATG	LATG	I^2 (%)	*P*		
Surgical outcomes							
Operative time (min)*	9	706	1158	78	< 0.05	30.96 [21.24, 40.69]	< 0.01
Intraoperative blood loss (ml)*	8	670	1093	15	> 0.05	−17.69 [−20.90,−14.49]	< 0.01
Oncological outcomes							
Retrieved lymph nodes*	8	655	1100	50	= 0.05	2.65 [0.88, 4.42]	< 0.01
Proximal margin	3	161	197	0	> 0.05	-0.08 [-0.54, 0.38]	0.74
Postoperative recovery							
Time to start liquid (days)*	4	361	755	86	< 0.05	−0.62 [−1.06,−0.19]	< 0.01
Postoperative hospital stays (days)*	7	634	1035	0	> 0.05	−0.90 [−1.43,−0.37]	< 0.01
Postoperative complications							
Overall complications	7	570	1000	0	> 0.05	0.92 [0.70, 1.22]	0.58
Major complications*	8	607	1043	18	> 0.05	0.59 [0.38, 0.93]	0.02
Pancreas fistula*	8	632	1084	0	> 0.05	0.17 [0.03, 0.94]	0.04
Wound problem	7	570	1000	0	> 0.05	1.05 [0.53, 2.11]	0.89
Intra-abdominal abscess	6	434	655	0	> 0.05	0.43 [0.13, 1.41]	0.16
Anastomotic leakage	9	706	1158	0	> 0.05	0.82 [0.43, 1.56]	0.54
Intestinal obstruction	9	706	1158	0	> 0.05	0.92 [0.48, 1.75]	0.79
Intra-abdominal bleeding	6	535	929	0	> 0.05	0.67 [0.26, 1.76]	0.42
Operative mortality	7	571	994	0	> 0.05	3.24 [0.33, 31.57]	0.31
Unplanned reoperation	6	497	920	0	> 0.05	1.05 [0.40, 2.74]	0.92

WMD, weighted mean difference; OR, odds ratio; CI, confidence interval; I^2, I-squared tests; RATG, robotic-assisted total gastrectomy; LATG, laparoscopy-assisted total gastrectomy; time to start liquid, postoperative interval to start liquid diet; *, $p < 0.05$ was considered statistically significant

Oncological outcomes

Retrieved lymph nodes

Eight articles showed the results on the number of lymph node resections, including 655 and 1100 cases in the RATG and LATG groups, separately. In terms of the number of resected lymph nodes, the RATG group had 2.65 more than the LATG group (WMD: 2.65,95% *CI*:0.88 ~ 4.42;*P*<0.05) (Fig. 3a).

Proximal margin

Three articles showed the results of the proximal margin, including 161 cases and 197 cases in the RATG and LATG groups, separately. The outcome of the proximal margin showed no significant differences between the RATG and LATG groups (WMD: -0.08,95% *CI*:-0.54 ~ 0.38;*P*>0.05) (Fig. 3b).

Postoperative recovery

Time to start the liquid

Regarding the time to start the liquid, four studies reported data, and 1116 patients (RATG: 361, LATG: 755) were included. The result was analyzed using a random-effects model ($I^2 = 86\%$; $P < 0.05$). The results indicated that the time to start liquid and postoperative

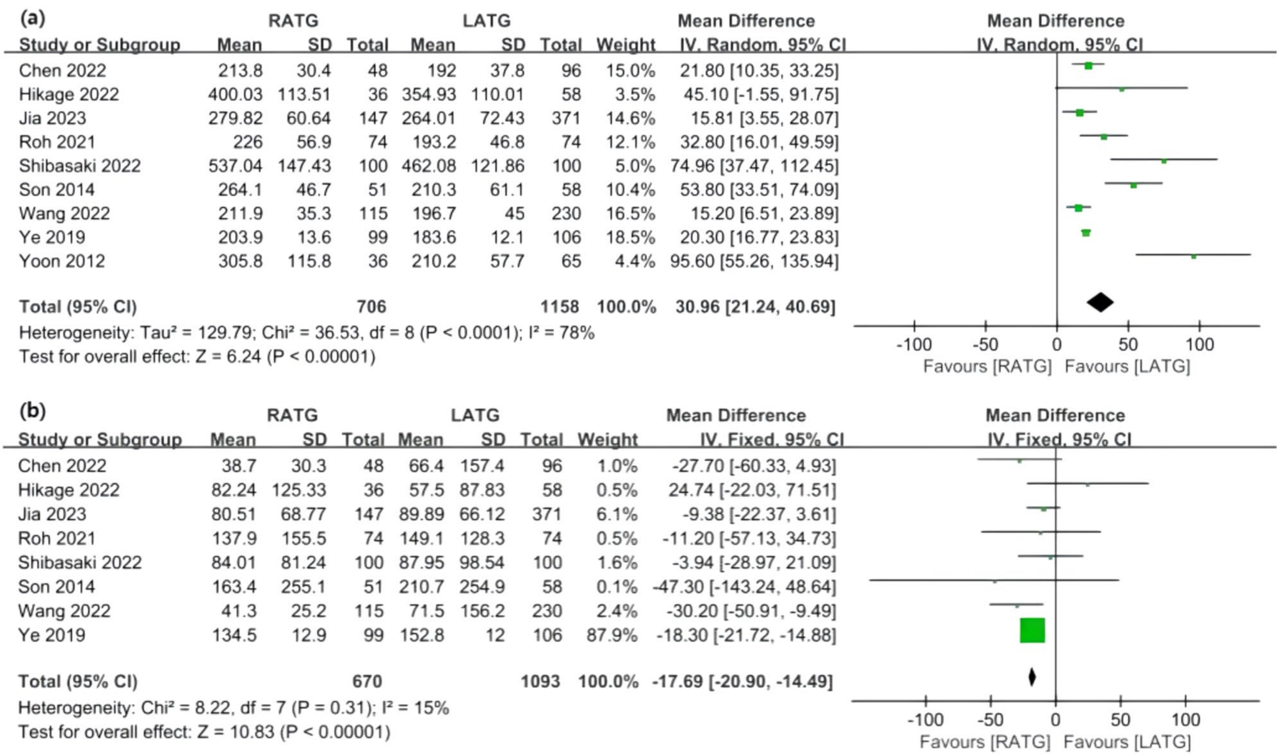


Fig. 2 Forest plot of the included studies for Surgical outcomes: (**a**) operative time; (**b**) intraoperative blood loss

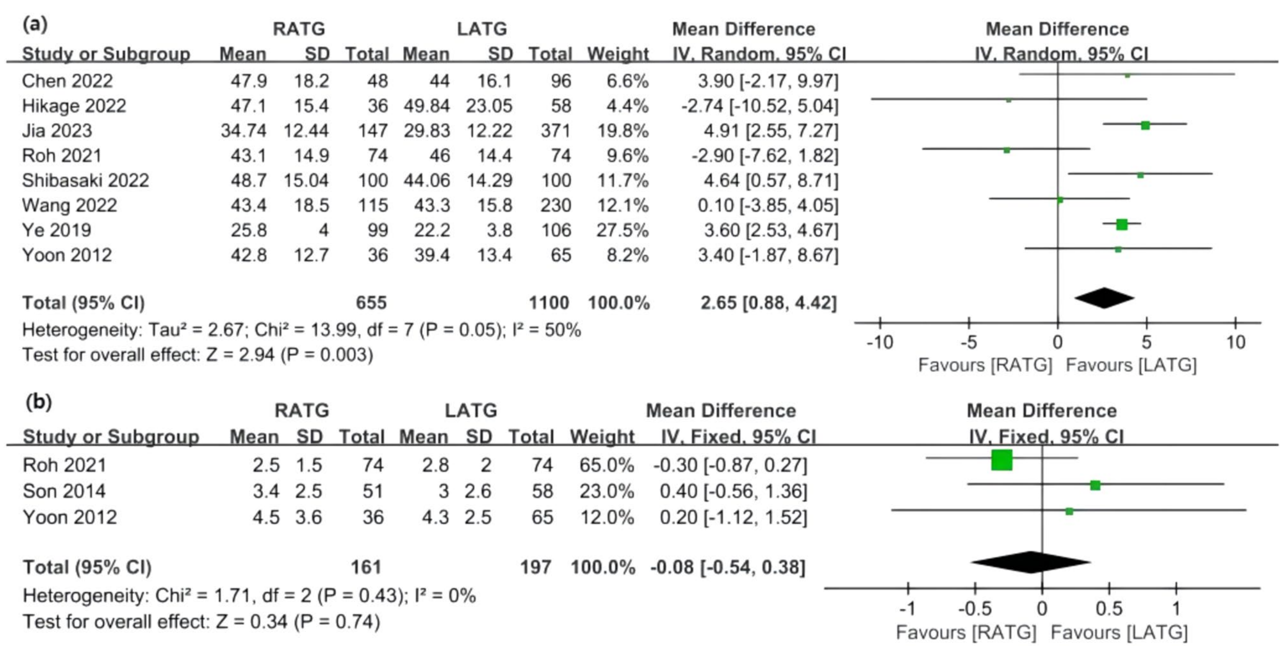


Fig. 3 Forest plot of the included studies for Oncological outcomes: (**a**) retrieved lymph nodes; (**b**) proximal margin

hospital stays were 0.62 days shorter in the RATG group than in the LATG group (WMD: -0.62,95% *CI*:-1.06~-0.19;*P*<0.05) (Fig. 4a).

Postoperative hospital stays

Seven studies presented outcomes of postoperative hospital stays, and a total of 1669 patients (RATG: 634, LATG: 1035) were included. The postoperative hospital stays were 0.90 days shorter in the RATG group than in the LATG group (WMD: -0.90,95% *CI*:-1.43~-0.37;*P*<0.05) (Fig. 4b).

Postoperative complications

Overall complications

Seven studies provided precise data on overall complications and a total of 1570 patients (RATG: 570, LATG: 1000) were included. There was no significant difference in the occurrence of overall complications between the two groups (OR: 0.92,95% *CI*:0.70 ~ 1.22;*P* > 0.05) (Fig. 5a).

Major complications

The occurrence of major complications was demonstrated in eight studies (RATG: 607, LATG: 1043). The analysis presented that the occurrence of major complications in the RATG group was 0.59% lower than in the LATG group (OR: 0.59,95% *CI*:0.38 ~ 0.93;*P*<0.05) (Fig. 5b).

Pancreas fistula

Eight articles reported the results of the pancreatic fistula, separately including 632 and 1084 cases in the RATG and LATG groups. The analyzed result was statistically different between the two groups, and the incidence of pancreas fistula in the RATG group was 0.17% lower than in the LATG group (OR: 0.17,95% *CI*:0.03 ~ 0.94;*P*<0.05) (Fig. 5c).

Other postoperative complications

The results of other postoperative complication rates showed no significant differences between the two groups, including wound problem (Fig. 5d), intra-abdominal abscess (Fig. 5e), anastomotic leakage (Fig. 5f), intestinal obstruction (Fig. 5g), intra-abdominal bleeding (Fig. 5h), operative mortality (Fig. 5i) and unplanned reoperation (Fig. 5j).

Subgroup analyses

Operative time

Country-specific subgroup analyses of the operative time were conducted (Fig. 6), The studies of China and Japan demonstrated significantly longer operative times in the RATG than LATG, which showed low heterogeneity ($I^2 = 0.0\%$, $I^2 = 0.0\%$). Similarly, the same results were shown in the Korean study.The operative times were also significantly longer in the RATG group than in the LATG group, but showed high heterogeneity ($I^2 = 77.1\%$).

Retrieved lymph nodes

Country-specific and lymphadenectomy-specific subgroup analyses of the retrieved lymph nodes were conducted (Fig. 7a and b), The studies of China have shown RATG to be significantly superior to LATG in retrieved lymph nodes ($I^2 = 28.6\%$). There was no significant difference between RATG and LATG in the studies of Japan and Korea ($I^2 = 63.2\%$, $I^2 = 67.1\%$). The studies of D2 lymphadenectomy have shown RATG to be significantly superior to LATG ($I^2 = 28.6\%$). There was no significant difference between RATG and LATG in the studies of

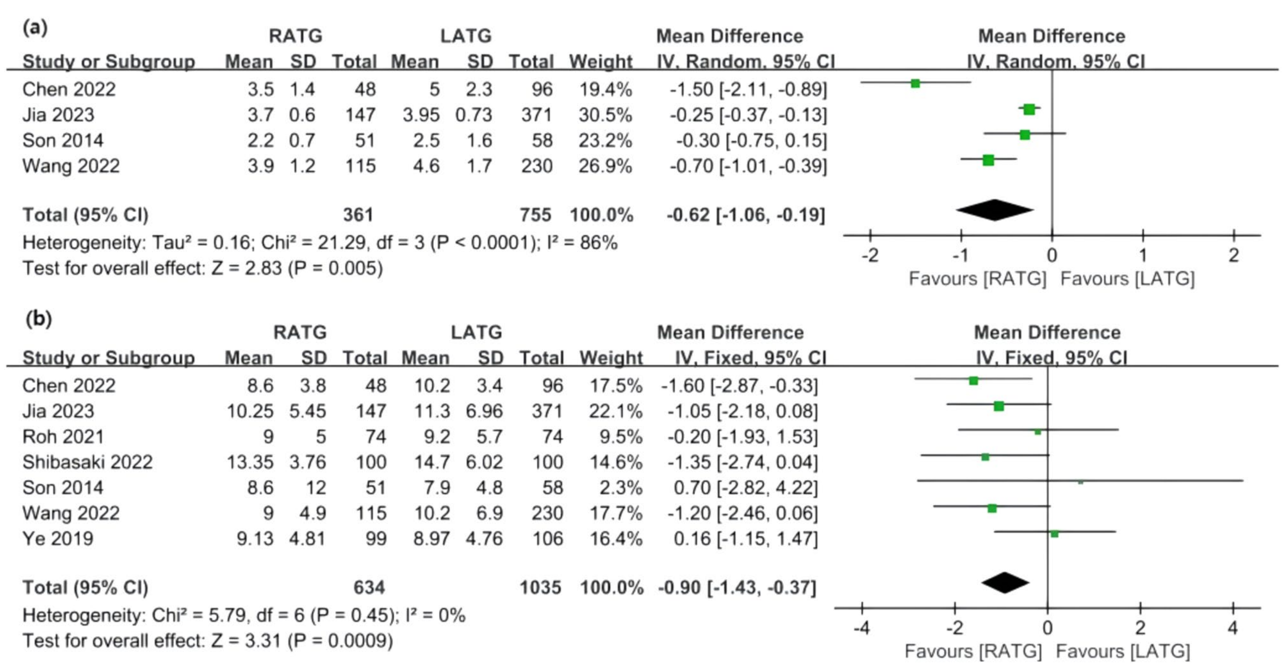


Fig. 4 Forest plot of the included studies for Postoperative recovery: (**a**) time to start liquid; (**b**) postoperative hospital stays

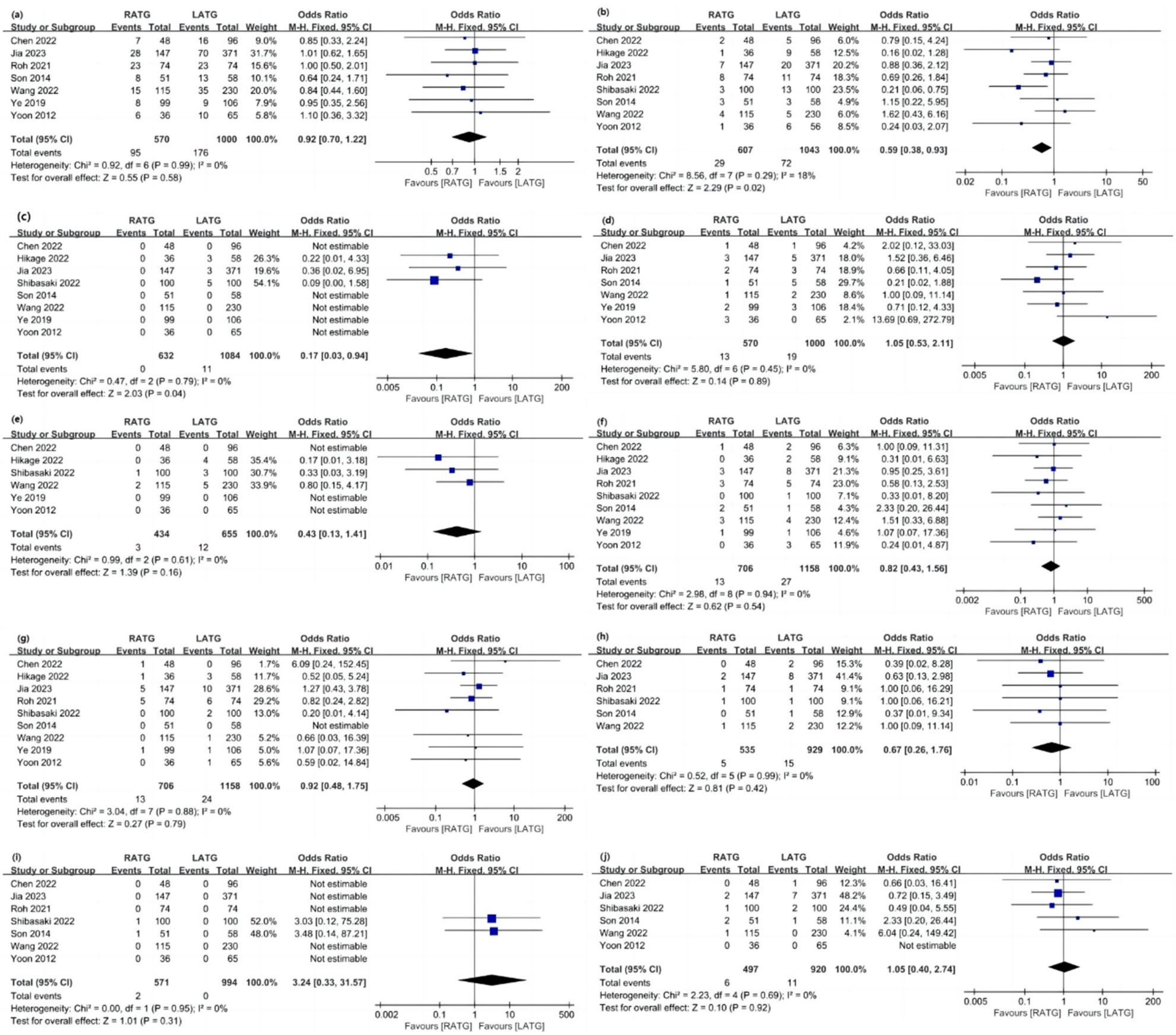


Fig. 5 Forest plot of the included studies for Postoperative complications: (**a**) overall complications; (**b**) major complications; (**c**) pancreas fistula; (**d**) wound problem; (**e**) intra-abdominal abscess; (**f**) anastomotic leakage; (**g**) intestinal obstruction; (**h**) intra-abdominal bleeding; (**i**) operative mortality; (**j**) unplanned reoperation

D1+/D2 lymphadenectomy ($I^2 = 58.7\%$). Our analysis for sources of high heterogeneity revealed that when the ROh studies were excluded the results showed that RATG was significantly superior to LATG in retrieved lymph nodes, and the results showed low heterogeneity. We read the full study and found that the number of lymph node resections was significantly different between pre-propensity score matching and post-propensity score matching, which may be related to the high heterogeneity of the results of the retrieved lymph nodes.

Time to start liquid

Country-specific subgroup analyses of the time to start liquid were conducted (Fig. 8). The studies of China have shown RATG to be significantly shorter than LATG in time to start liquid ($I^2 = 90.6\%$). We found that each study did not detail the criteria by which the first postoperative liquid diet could be given, which may be the source of high heterogeneity.

Major complications

Country-specific subgroup analyses of the major complications were conducted (Fig. 9). There was no significant difference between RATG and LATG in the studies of China and Japan ($I^2 = 0\%$, $I^2 = 0\%$). However, the studies of Korea have shown RATG to be significantly less than LATG in the incidence of major complications($I^2 = 0\%$).

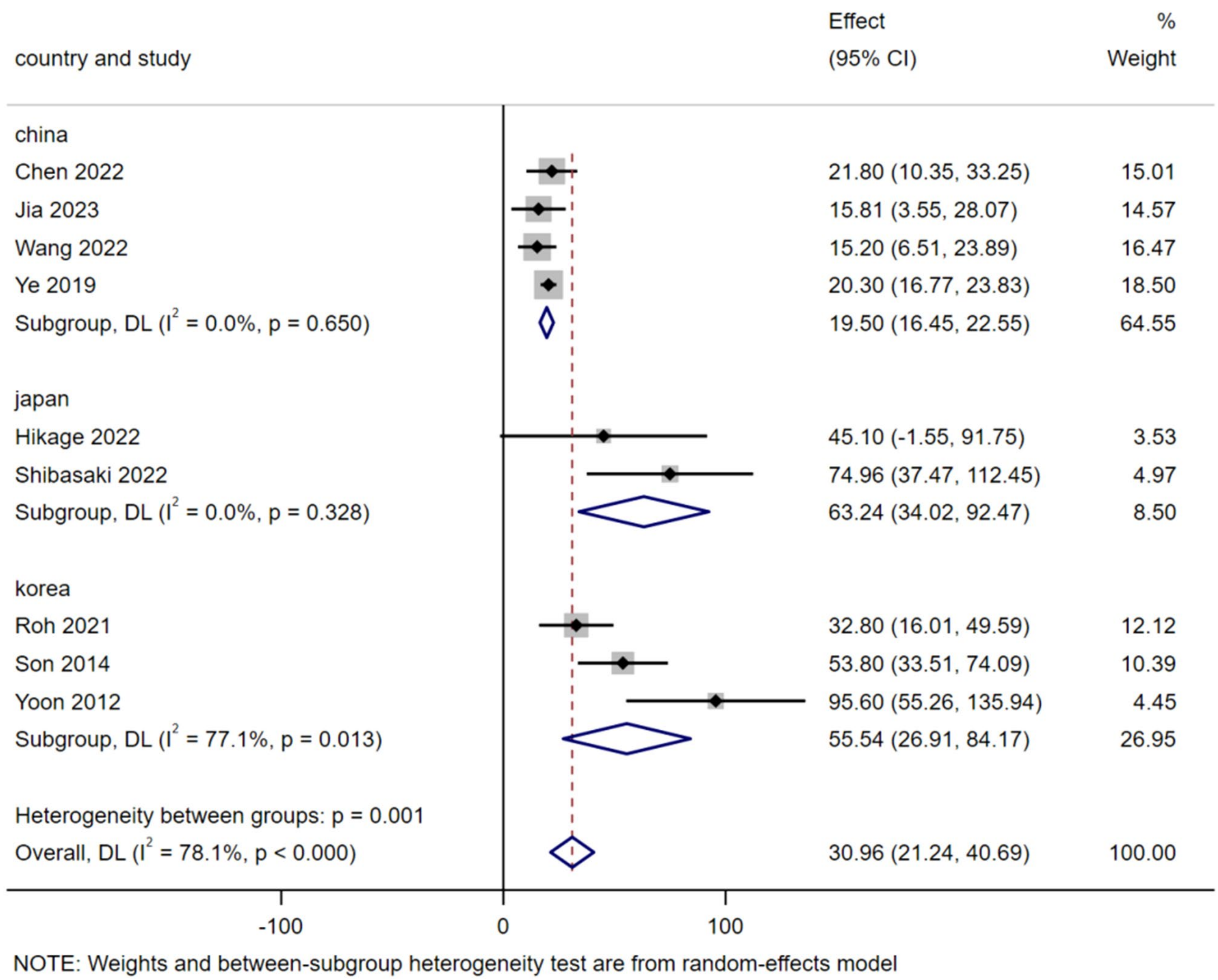
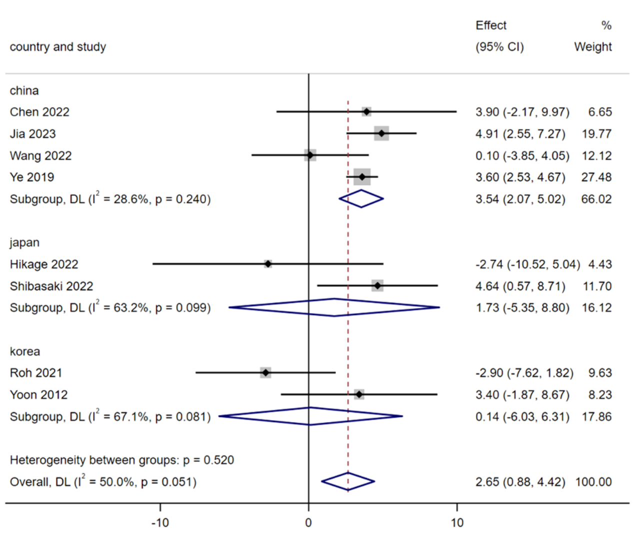


Fig. 6 Country-specific subgroup analyses of the operative time



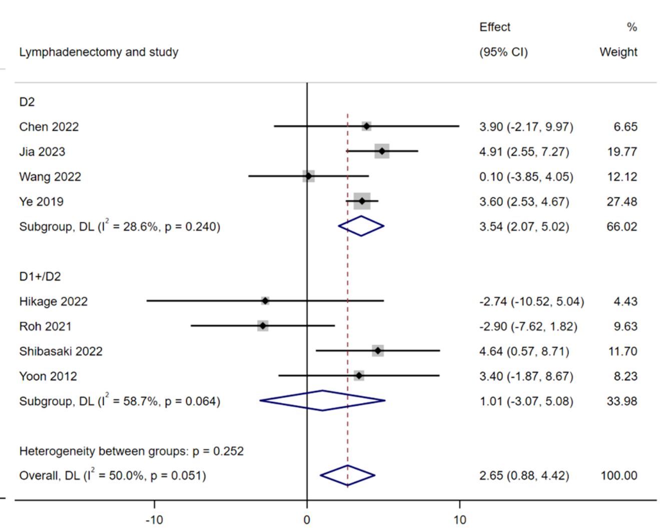


Fig. 7 (**a**) Country-specific subgroup analyses of the retrieved lymph nodes. (**b**) Lymphadenectomy-specific subgroup analyses of the retrieved lymph nodes

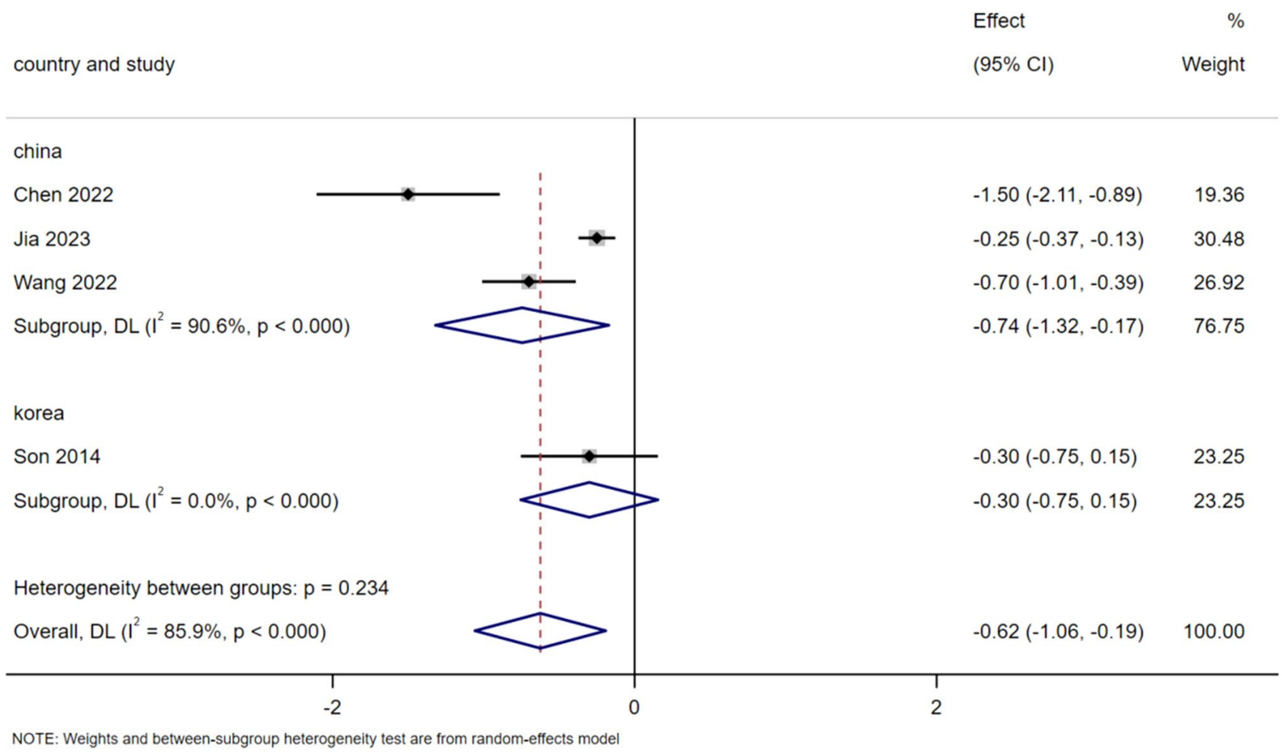


Fig. 8 Country-specific subgroup analyses of the time to start liquid

Sensitivity analysis

We performed sensitivity analyses for each outcome indicator using a one-by-one exclusion method. After analysis, we found that the statistical significance changed in the retrieved lymph nodes and major complications, indicating a lack of stability in the original results. The sensitivity analyses of the remaining outcome indicators did not show significant differences from the original results, which demonstrated the stability of the initial results, such as the operative time (Figure S1) and the time to start the liquid (Figure S2).

When we excluded studies by Jia et al. and Ye et al., respectively, the recalculations indicated that the lymph nodes retrieved did not show any notable differences between the RATG and LATG group (WMD: 2.00,95% *CI*:-0.15 ~ 4.15;*P*=0.07, I^2 = 50%); (WMD:2.09, 95% *CI*:-0.43 ~ 4.61; *P*:0.10, I^2:55%) (Fig. 10a), which was inconsistent with our original result (WMD:2.65, 95% *CI*:0.88 ~ 4.42; *P*<0.05, I^2:50%). Combined with the results of the previous subgroup analyses, we did not incorporate the results after the sensitivity analyses because we considered that the instability of the original result could have originated from surgical treatment by different surgeons.

After excluding studies by Hikage et al. and Shibasaki et al., respectively, the analyses demonstrated that there was no notable difference in the occurrence of major complications between the two groups (OR: 0.66, 95% *CI*:0.41 ~ 1.04;*P*=0.07, I^2:9%); (OR:0.71, 95% *CI*:0.44 ~ 1.16; *P*:0.17, I^2 = 0%) (Fig. 10b). The original result contradicted this observation (OR:0.59, 95% *CI*:0.38 ~ 0.93; *P*<0.05, I^2:18%). The previous subgroup analysis indicated that the instability of this outcome may be related to different countries. Furthermore, there was no remarkable heterogeneity in the initial outcome, and we decided not to exclude these two studies.

Publication bias

By observing the funnel plot of the anastomotic leakage (Fig. 11) and using Begg and Egger tests (Begg's test: *P* = 0.251; Egger's test: *P* = 0.323), we found no significant publication bias in this analysis.

Discussion

With the rapid development of minimally invasive surgery (MIS), robotic-assisted techniques have been gradually applied in gastric cancer surgery. The performance of robotic surgery in TG, the most challenging procedure in GC surgery, has attracted considerable attention [40]. However, we have yet to find a systematic meta-analysis of the postoperative outcomes of RATG and LATG. This meta-analysis aimed to investigate whether RATG is a valuable option for patients with GC.

Operative time is one of the most critical surgical factors when comparing two minimally invasive techniques, as it is an essential factor in assessing the quality and

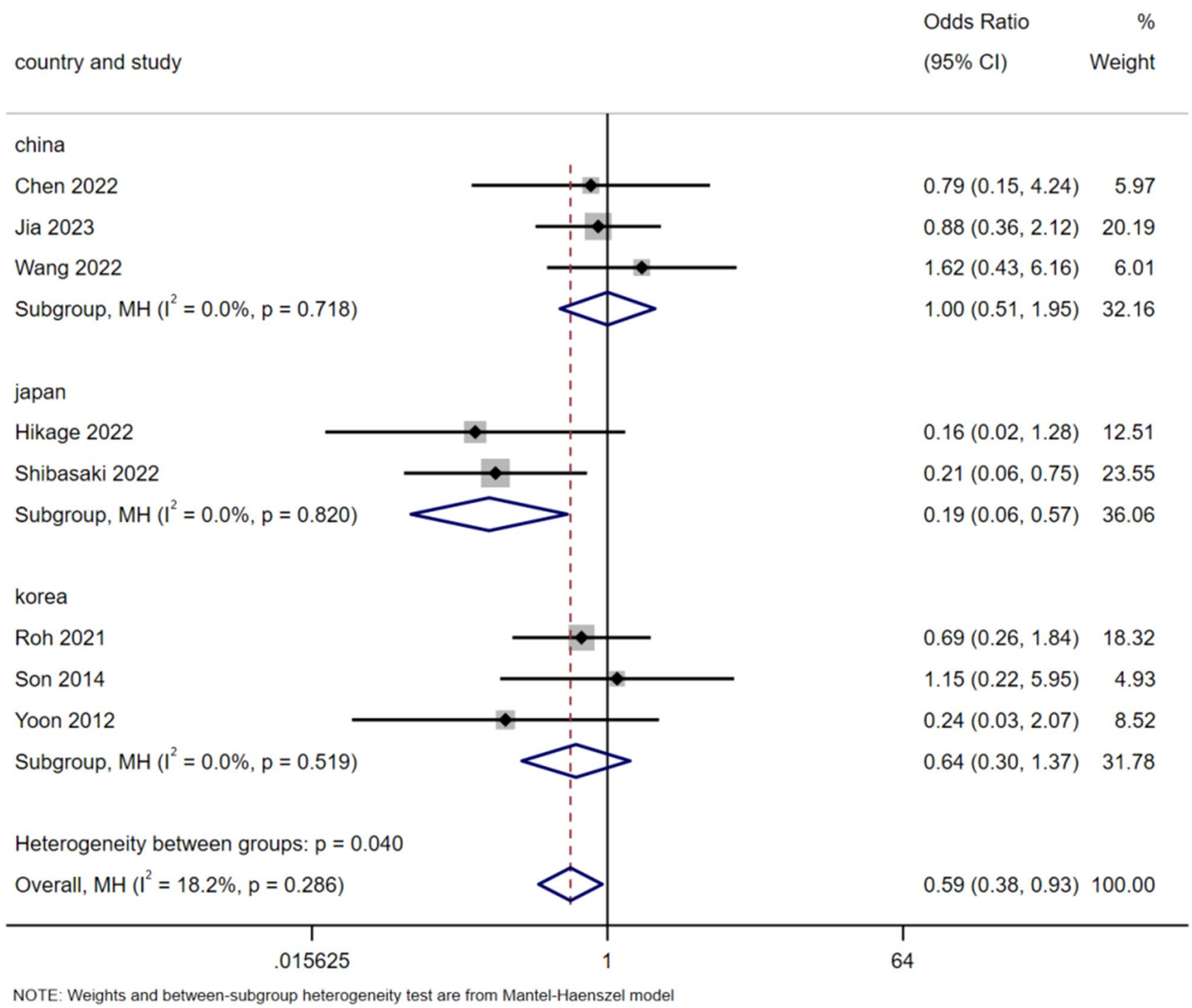


Fig. 9 Country-specific subgroup analyses of the Major complications

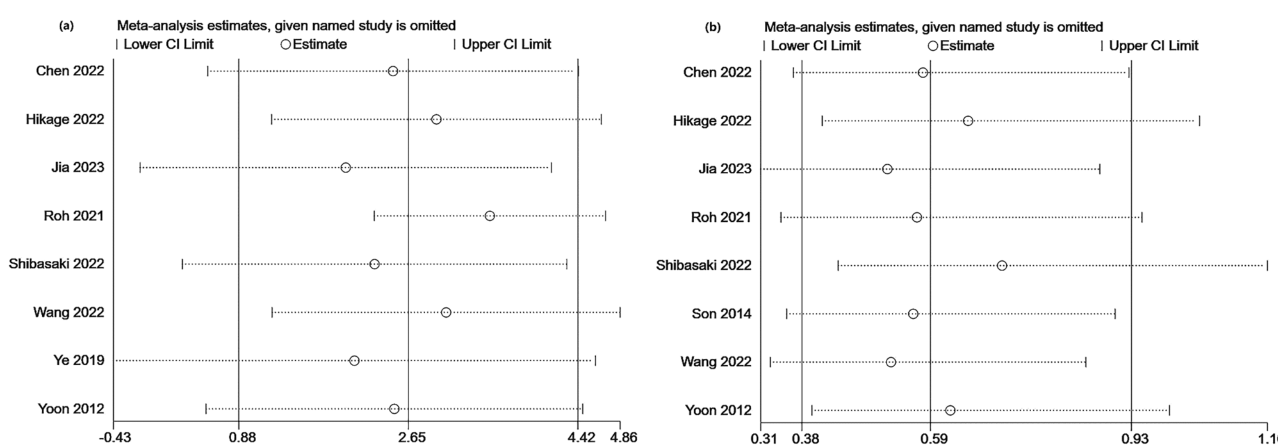


Fig. 10 (**a**) sensitivity analysis for the retrieved lymph nodes using a one-by-one exclusion method; (**b**) sensitivity analysis for the major complications using a one-by-one exclusion method

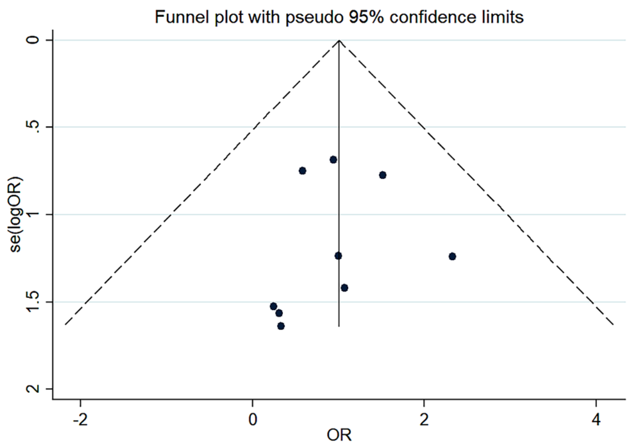


Fig. 11 Funnel plot of the anastomotic leakage

accessibility of the procedure [41, 42]. Some studies [41, 43–46] have suggested that the longer time for robotic surgery is mainly related to two aspects: (1) the need for additional robotic arm docking and equipment commissioning before the formal operation of robotic surgery. (2) the inexperience of surgeons in using robotic surgical systems. Related studies by Jia et al. and Chen et al. [39, 47] demonstrated no meaningful difference between RATG and LATG regarding the robot/laparoscopy time (the actual time of entry into the abdominal cavity for operative procedures). In addition, the relevant literature reports that robotic surgery time can be reduced by improving surgical experience after a sufficient learning curve [19, 42, 48, 49]. Notably, for experienced surgeons who have performed LG, the learning curve for RG was shorter than LG [18, 50–52]. Thus, the standardization of early commissioning operations and the increased surgeon experience may contribute to similar results for both technical approaches [53, 54].

Surgical blood loss is also one of the most significant surgical indicators in assessing the outcomes of radical gastrectomy. Less intraoperative bleeding is associated with a better short-term clinical course [55, 56], and more importantly, reduces the chance of postoperative blood transfusion in patients. According to the relevant literature, perioperative blood transfusion increases the risk of cancer recurrence and is negatively associated with long-term survival after radical gastrectomy [57–60]. Compared to laparoscopic procedures, robotic surgery has the advantages of tremor filtering, high definition 3D image, high degree of freedom and comfortable remote console [21, 51, 52, 61–66], which are more favorable for manipulation by the surgeons, such as separation and ligation of blood vessels and tissues. Especially for TG, a marathon surgery that requires precise vascular ionization and lymph node dissection, these advantages of robotic manipulation are crucial.

It is worth highlighting that lymph node dissection is crucial in radical gastrectomy. The condition of lymph node dissection and surgical margin are frequently used as an indicator to assess oncological safety [43]. Related studies have reported that independent risk factors for early relapse in patients with radical gastrectomy include lymphovascular infiltration [67], lymph node metastasis and tumor stage. Standard lymph node dissection not only improves the precision of the patient's pathological stage and provides the clinical basis for further treatment, but also reduces the incidence of cancer recurrence and metastasis [68]. The use of conventional laparoscopic forceps to expose and manipulate deep vessels and areas can be particularly difficult, especially when performing lymph node dissection around the hepatic, splenic hilar, and splenic arteries [61]. Conversely, operators can more easily expose and dissect lymph nodes with the assistance of the robotic system, even in particularly narrow and complex areas [69]. Surgical margins are strongly associated with postoperative survival and local recurrence rates [70]. This study demonstrated that the condition of the proximal margin was not significant between the RATG and LATG groups. Due to insufficient data, the results of the positive margin and the distal cut-off margin were not included in this study. In general, RATG had a similar margin profile and adequate lymph node dissection outcome compared to LATG.

Rapid postoperative recovery is known to be a significant advantage of MIS. This meta-analysis demonstrated that the RATG group had a shorter time to first postoperative fluid intake and postoperative hospitalization than the LATG group. The flexible stability of the robotic arm avoids excessive pulling on the intestinal tract, thus benefiting the recovery of bowel function [64]. Early food intake also speeds up patient recovery and shortens postoperative hospitalization.

The occurrence of postoperative complications is an invaluable indicator for evaluating the short-term prognosis and the safety and feasibility of the procedure [48, 70]. The main complications are the most demanding in terms of clinical care, cost, prognosis, and quality of life, and place additional burdens on clinical treatment and patients [61]. Therefore, the incidence of major complications allows an accurate assessment of surgical outcomes and reduces subjectivity. Pancreatic fistulas have been associated with parenchymal manoeuvers when performing lymph node dissection [3]. The high degree of freedom and stability of the robotic arm minimizes pulling on the pancreas during lymph node dissection or other operations, thus reducing substantial injury [42, 50, 53]. Furthermore, there were no significant differences in the rates of surgical mortality and unplanned reoperation between the RATG and LATG groups. Based on these outcomes, we consider RATG to be safe and acceptable.

The high cost is a crucial issue that prevents the widespread use of robotics in gastric cancer surgery. Several studies have revealed that RG costs are significantly higher than LG [42, 61, 71, 72]. Studies also show that the advantages of robotic surgery can compensate for its higher cost, such as fewer postoperative complications and length of hospitalization [73, 74]. However, the higher cost of the robotic system was deemed insufficient by the researchers involved to justify the theoretical advantages of the technology [75]. If robotic surgery leads to a better prognosis for patients with gastric cancer, then we believe its high cost is acceptable. Due to the low number of included studies reporting on the cost aspect of surgery, we were unable to perform a meta-analysis on this aspect. Therefore, future studies are needed to prove whether the high cost of GC therapy is consistent with the potential strength of RATG.

This study is the first meta-analysis to compare RATG with LATG in terms of efficacy, safety, and feasibility. However, some of the limitations of this study must be considered when utilizing its outcomes: (1) all included studies were retrospective, except for one prospective study. The absence of high-quality randomized controlled trials (RCT) may lead to publication bias; (2) all included studies were published by Asian countries, and the applicability and generalizability of these results are limited, thus the results of these analyses must be treated with caution; (3) due to the few number of included studies, data on some variables could not be meta-analyzed, such as distal margins, drain amylase levels, and nutritional status; (4) most of the included studies did not perform survival analyses or had a short follow-up period, and long-term postoperative prognosis needs to be further analyzed, such as postoperative quality of life, 5-year recurrence rate and survival rate; (5) there was significant heterogeneity in the analyzed outcome in terms of operative time, retrieved lymph nodes, and time to start liquid, and the outcome of sensitivity analyses suggested a lack of stability in the outcome of retrieved lymph nodes and major complications. Therefore, we need to refer to these results with caution.

Conclusion

RATG showed better outcomes in terms of intraoperative bleeding, lymph node dissection, postoperative recovery, and relevant surgical complications. Although the long duration and high cost of surgery remain a concern, RATG may be a promising and valuable technique for the treatment of GC. Due to certain limitations of this meta-analysis, the systematic meta-analysis of multiple high-quality, multicenter RCTs is still needed to validate the advantages of RATG in future studies.

Abbreviations

GC	Gastric Cancer
LG	Laparoscopic Gastrectomy
OG	Open Gastrectomy
LATG	Laparoscopic-Assisted Total Gastrectomy
RG	Robotic Gastrectomy
RATG	Robotic-Assisted Total Gastrectomy
PRISMA	Preferred Reporting Items for Systematic Review and Meta-Analysis
IRB	Institutional Review Board
BMI	Body Mass index
NOS	Newcastle-Ottawa Scale
MIS	Minimally Invasive Surgery
RCT	Randomized Controlled Trials
OR	Odds Ratios
WMD	Weighted Mean Difference
CI	Confidence Interval
I^2	I-squared
X^2	Chisquared

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12893-025-02934-5.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Acknowledgements

We would like to thank the researchers and study participants for their contributions.

Author contributions

J.H.C, Y.W and J.R were involved in the conception and design; J.Z, Z.M.Z, R.F.W, Y.W and Y.P.Y were involved in the selection of the study and the collection of data; J.H.C, F.W, L.H.W and J.R were involved in the analysis and interpretation of data; J.H.C, F.W, Y.W and J.R were involved in the drafting and revision of articles and submitted the final manuscript; All authors approved the final version to be published.

Funding

Social development project of Yangzhou, Yangzhou, China (YZ2023086) and Social development project of Ili Kazak Autonomous Prefecture, Ili, China (YJC2023A33).

Data availability

All data generated or analysed during this study are included in this published article.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Competing interests

The authors declare no competing interests.

Author details

[1]Department of Clinical Medical College, The Yangzhou School of Clinical Medicine, Dalian Medical University, Yangzhou, People's Republic of China

[2]Department of General Surgery, Northern Jiangsu People's Hospital Affiliated to Yangzhou University, 98 Nantong West Road, Yangzhou 225001, People's Republic of China
[3]Yangzhou Key Laboratory of Basic and Clinical Transformation of Digestive and Metabolic Diseases, Yangzhou, People's Republic of China
[4]General Surgery Institute of Yangzhou, Northern Jiangsu People's Hospital, Yangzhou, People's Republic of China

Received: 11 October 2024 / Accepted: 24 April 2025
Published online: 15 May 2025

References

1. Sung H, Ferlay J, Siegel RL, et al. Global Cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin May. 2021;71(3):209–49. https://doi.org/10.3322/caac.21660.
2. Zhao EH, Ling TL, Cao H. Current status of surgical treatment of gastric cancer in the era of minimally invasive surgery in China: opportunity and challenge. Int J Surg Apr. 2016;28:45–50. https://doi.org/10.1016/j.ijsu.2016.02.027.
3. Suda K, Man IM, Ishida Y, Kawamura Y, Satoh S, Uyama I. Potential advantages of robotic radical gastrectomy for gastric adenocarcinoma in comparison with conventional laparoscopic approach: a single institutional retrospective comparative cohort study. Surg Endosc Mar. 2015;29(3):673–85. https://doi.org/10.1007/s00464-014-3718-0.
4. Uyama I, Suda K, Satoh S. Laparoscopic surgery for advanced gastric cancer: current status and future perspectives. J Gastric Cancer Mar. 2013;13(1):19–25. https://doi.org/10.5230/jgc.2013.13.1.19.
5. Wong MCS, Huang J, Chan PSF, et al. Global incidence and mortality of gastric cancer, 1980–2018. JAMA Netw Open Jul. 2021;1(7):e2118457. https://doi.org/10.1001/jamanetworkopen.2021.18457.
6. Yasunaga H, Horiguchi H, Kuwabara K, et al. Outcomes after laparoscopic or open distal gastrectomy for early-stage gastric cancer: a propensity-matched analysis. Ann Surg Apr. 2013;257(4):640–6. https://doi.org/10.1097/SLA.0b013e31826fd541.
7. Maegawa FB, Patel AD, Patel SG, et al. Robotic versus laparoscopic gastrectomy for adenocarcinoma in the US: a propensity score-matching analysis of 11,173 patients on oncological adequacy. Surg Endosc Dec. 2023;37(12):9643–50. https://doi.org/10.1007/s00464-023-10519-7.
8. Baik SH, Kwon HY, Kim JS, et al. Robotic versus laparoscopic low anterior resection of rectal cancer: short-term outcome of a prospective comparative study. Ann Surg Oncol Jun. 2009;16(6):1480–7. https://doi.org/10.1245/s10434-009-0435-3.
9. Kim MC, Heo GU, Jung GJ. Robotic gastrectomy for gastric cancer: surgical techniques and clinical merits. Surg Endosc Mar. 2010;24(3):610–5. https://doi.org/10.1007/s00464-009-0618-9.
10. El-Sedfy A, Brar SS, Coburn NG. Current role of minimally invasive approaches in the treatment of early gastric cancer. World J Gastroenterol Apr. 2014;14(14):3880–8. https://doi.org/10.3748/wjg.v20.i14.3880.
11. Kim MC, Jung GJ, Kim HH. Learning curve of laparoscopy-assisted distal gastrectomy with systemic lymphadenectomy for early gastric cancer. World J Gastroenterol Dec. 2005;21(47):7508–11. https://doi.org/10.3748/wjg.v11.i47.7508.
12. Jin SH, Kim DY, Kim H, et al. Multidimensional learning curve in laparoscopy-assisted gastrectomy for early gastric cancer. Surg Endosc Jan. 2007;21(1):28–33. https://doi.org/10.1007/s00464-005-0634-3.
13. Kang SY, Lee SY, Kim CY, Yang DH. Comparison of learning curves and clinical outcomes between Laparoscopy-assisted distal gastrectomy and open distal gastrectomy. J Gastric Cancer Dec. 2010;10(4):247–53. https://doi.org/10.5230/jgc.2010.10.4.247.
14. Pan JH, Zhou H, Zhao XX, Ding H, Qin L, Pan YL. Long-term oncological outcomes in robotic gastrectomy versus laparoscopic gastrectomy for gastric cancer: a meta-analysis. Surg Endosc Oct. 2017;31(10):4244–51. https://doi.org/10.1007/s00464-017-5891-4.
15. Zhou D, Quan Z, Wang J, Zhao M, Yang Y, Mar. 2014;24(3):139–50. doi:https://doi.org/10.1089/lap.2013.0481.
16. Liu G, Shen W, Chen L, Wei B. [Robotic versus laparoscopic gastrectomy for gastric cancer: a meta-analysis]. Zhonghua Wei Chang Wai Ke Za Zhi Mar. 2016;19(3):328–33.
17. Song J, Oh SJ, Kang WH, Hyung WJ, Choi SH, Noh SH. Robot-assisted gastrectomy with lymph node dissection for gastric cancer: lessons learned from an initial 100 consecutive procedures. Ann Surg Jun. 2009;249(6):927–32. https://doi.org/10.1097/01.sla.0000351688.64999.73.
18. Kang BH, Xuan Y, Hur H, Ahn CW, Cho YK, Han SU. Comparison of surgical outcomes between robotic and laparoscopic gastrectomy for gastric cancer: the learning curve of robotic surgery. J Gastric Cancer Sep. 2012;12(3):156–63. https://doi.org/10.5230/jgc.2012.12.3.156.
19. Pugliese R, Maggioni D, Sansonna F, et al. Subtotal gastrectomy with D2 dissection by minimally invasive surgery for distal adenocarcinoma of the stomach: results and 5-year survival. Surg Endosc Oct. 2010;24(10):2594–602. https://doi.org/10.1007/s00464-010-1014-1.
20. Park JM, Kim HI, Han SU, et al. Who May benefit from robotic gastrectomy? A subgroup analysis of multicenter prospective comparative study data on robotic versus laparoscopic gastrectomy. Eur J Surg Oncol Dec. 2016;42(12):1944–9. https://doi.org/10.1016/j.ejso.2016.07.012.
21. Wang WJ, Li HT, Yu JP, et al. Severity and incidence of complications assessed by the Clavien-Dindo classification following robotic and laparoscopic gastrectomy for advanced gastric cancer: a retrospective and propensity score-matched study. Surg Endosc Oct. 2019;33(10):3341–54. https://doi.org/10.1007/s00464-018-06624-7.
22. Lee J, Kim YM, Woo Y, Obama K, Noh SH, Hyung WJ. Robotic distal subtotal gastrectomy with D2 lymphadenectomy for gastric cancer patients with high body mass index: comparison with conventional laparoscopic distal subtotal gastrectomy with D2 lymphadenectomy. Surg Endosc Nov. 2015;29(11):3251–60. https://doi.org/10.1007/s00464-015-4069-1.
23. Shin HJ, Son SY, Wang B, Roh CK, Hur H, Han SU. Long-term comparison of robotic and laparoscopic gastrectomy for gastric cancer: A propensity Score-weighted analysis of 2084 consecutive patients. Ann Surg Jul. 2021;1(1):128–37. https://doi.org/10.1097/sla.0000000000003845.
24. Bobo Z, Xin W, Jiang L, et al. Robotic gastrectomy versus laparoscopic gastrectomy for gastric cancer: meta-analysis and trial sequential analysis of prospective observational studies. Surg Endosc Apr. 2019;33(4):1033–48. https://doi.org/10.1007/s00464-018-06648-z.
25. Hoshino N, Murakami K, Hida K, et al. Robotic versus laparoscopic surgery for gastric cancer: an overview of systematic reviews with quality assessment of current evidence. Updates Surg Sep. 2020;72(3):573–82. https://doi.org/10.1007/s13304-020-00793-8.
26. Loureiro P, Barbosa JP, Vale JF, Barbosa J. Laparoscopic versus robotic gastric Cancer surgery: Short-Term Outcomes-Systematic review and Meta-Analysis of 25,521 patients. J Laparoendoscopic Adv Surg Techniques Part Aug. 2023;33(8):782–800. https://doi.org/10.1089/lap.2023.0136.
27. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ Mar. 2021;29:372:n71. https://doi.org/10.1136/bmj.n71.
28. Shea BJ, Reeves BC, Wells G, et al. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. BMJ Sep. 2017;21:358:j4008. https://doi.org/10.1136/bmj.j4008.
29. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg Aug. 2004;240(2):205–13. https://doi.org/10.1097/01.sla.0000133083.54934.ae.
30. Japanese Gastric Cancer A. Japanese Gastric Cancer Treatment Guidelines. 2021 (6th edition). *Gastric Cancer*. Jan 2023;26(1):1–25. https://doi.org/10.1007/s10120-022-01331-8
31. Yoon HM, Kim Y-W, Lee JH et al. May. Robot-assisted total gastrectomy is comparable with laparoscopically assisted total gastrectomy for early gastric cancer. Article. *Surgical Endoscopy and Other Interventional Techniques*. 2012;26(5):1377–1381. https://doi.org/10.1007/s00464-011-2043-0
32. Son T, Lee JH, Kim YM, Kim HI, Noh SH, Hyung WJ. Robotic spleen-preserving total gastrectomy for gastric cancer: comparison with conventional laparoscopic procedure. Article. Surg Endosc. 2014;28(9):2606–15. https://doi.org/10.1007/s00464-014-3511-0.
33. Ye S-p, Shi J, Liu D-n, et al. Robotic-assisted versus conventional laparoscopic-assisted total gastrectomy with D2 lymphadenectomy for advanced gastric cancer: short-term outcomes at a mono-institution. Article. Bmc Surg Jul. 2019;9:1986. https://doi.org/10.1186/s12893-019-0549-x.
34. Roh CK, Lee S, Son S-Y, Hur H, Han S-U. Textbook outcome and survival of robotic versus laparoscopic total gastrectomy for gastric cancer: a propensity score matched cohort study. Article. Sci Rep Jul. 2021;28(1):15394. https://doi.org/10.1038/s41598-021-95017-3.
35. Chen Q-Y, Zhong Q, Liu Z-Y, et al. Surgical outcomes, technical performance, and surgery burden of robotic total gastrectomy for locally advanced gastric

Cancer A prospective study. Article. Annals Surg Nov. 2022;276(5):E434–43. https://doi.org/10.1097/sla.0000000000004764.
36. Hikage M, Fujiya K, Kamiya S, Tanizawa Y, Bando E, Terashima M. Comparisons of surgical outcomes between robotic and laparoscopic total gastrectomy in patients with clinical stage I/IIA gastric cancer. Surg Endosc Jul. 2022;36(7):5257–66. https://doi.org/10.1007/s00464-021-08903-2.
37. Shibasaki S, Nakauchi M, Serizawa A, et al. Clinical advantage of standardized robotic total gastrectomy for gastric cancer: a single-center retrospective cohort study using propensity-score matching analysis. Gastric Cancer Jul. 2022;25(4):804–16. https://doi.org/10.1007/s10120-022-01288-8.
38. Wang Z-K, Lin J-X, Wang F-H, et al. Robotic spleen-preserving total gastrectomy shows better short-term advantages: a comparative study with laparoscopic surgery. Article. Surg Endoscopy Other Interventional Techniques Nov. 2022;36(11):8639–50. https://doi.org/10.1007/s00464-022-09352-1.
39. Jia Z, Cao S, Meng C, et al. Intraoperative performance and outcomes of robotic and laparoscopic total gastrectomy for gastric cancer: A high-volume center retrospective propensity score matching study. Cancer Med. May 2023;12(9):10485–98. https://doi.org/10.1002/cam4.5785.
40. Terashima M, Tokunaga M, Tanizawa Y, et al. Robotic surgery for gastric cancer. Gastric Cancer Jul. 2015;18(3):449–57. https://doi.org/10.1007/s10120-015-0501-4.
41. Zhang Z, Zhang X, Liu Y, et al. Meta-analysis of the efficacy of Da Vinci robotic or laparoscopic distal subtotal gastrectomy in patients with gastric cancer. Med Aug. 2021;27(34):e27012. https://doi.org/10.1097/md.0000000000027012.
42. Alhossaini RM, Altamran AA, Seo WJ, Hyung WJ. Robotic gastrectomy for gastric cancer: current evidence. Ann Gastroenterol Surg Jun. 2017;1(2):82–9. https://doi.org/10.1002/ags3.12020.
43. Gong S, Li X, Tian H, et al. Clinical efficacy and safety of robotic distal gastrectomy for gastric cancer: a systematic review and meta-analysis. Surg Endosc. May 2022;36(5):2734–48. https://doi.org/10.1007/s00464-021-08994-x.
44. Chuan L, Yan S, Pei-Wu Y. Meta-analysis of the short-term outcomes of robotic-assisted compared to laparoscopic gastrectomy. Minim Invasive Therapy Allied Technologies: MITAT: Official J Soc Minim Invasive Therapy Jun. 2015;24(3):127–34. https://doi.org/10.3109/13645706.2014.985685.
45. deSouza AL, Prasad LM, Park JJ, Marecik SJ, Blumetti J, Abcarian H. Robotic assistance in right hemicolectomy: is there a role? Dis Colon Rectum Jul. 2010;53(7):1000–6. https://doi.org/10.1007/DCR.0b013e3181d32096.
46. Kim MS, Kim WJ, Hyung WJ, et al. Comprehensive learning curve of robotic surgery: discovery from a multicenter prospective trial of robotic gastrectomy. Ann Surg May. 2021;1(5):949–56. https://doi.org/10.1097/sla.0000000000003583.
47. Chen QY, Zhong Q, Liu ZY, et al. Surgical outcomes, technical performance, and surgery burden of robotic total gastrectomy for locally advanced gastric cancer: A prospective study. Ann Surg Nov. 2022;1(5):e434–43. https://doi.org/10.1097/sla.0000000000004764.
48. Chen K, Pan Y, Zhang B, Maher H, Wang XF, Cai XJ. Robotic versus laparoscopic gastrectomy for gastric cancer: a systematic review and updated meta-analysis. BMC Surg Aug. 2017;24(1):93. https://doi.org/10.1186/s12893-017-0290-2.
49. Hyun MH, Lee CH, Kim HJ, Tong Y, Park SS. Systematic review and meta-analysis of robotic surgery compared with conventional laparoscopic and open resections for gastric carcinoma. Br J Surg Nov. 2013;100(12):1566–78. https://doi.org/10.1002/bjs.9242.
50. Uyama I, Kanaya S, Ishida Y, Inaba K, Suda K, Satoh S. Novel integrated robotic approach for suprapancreatic D2 nodal dissection for treating gastric cancer: technique and initial experience. World J Surg Feb. 2012;36(2):331–7. https://doi.org/10.1007/s00268-011-1352-8.
51. Huang KH, Lan YT, Fang WL, et al. Initial experience of robotic gastrectomy and comparison with open and laparoscopic gastrectomy for gastric cancer. J Gastrointest Surg Jul. 2012;16(7):1303–10. https://doi.org/10.1007/s11605-012-1874-x.
52. Eom BW, Yoon HM, Ryu KW, et al. Comparison of surgical performance and short-term clinical outcomes between laparoscopic and robotic surgery in distal gastric cancer. Eur J Surg Oncol Jan. 2012;38(1):57–63. https://doi.org/10.1016/j.ejso.2011.09.006.
53. Isobe T, Murakami N, Minami T, et al. Robotic versus laparoscopic distal gastrectomy in patients with gastric cancer: a propensity score-matched analysis. BMC Surg Apr. 2021;21(1):203. https://doi.org/10.1186/s12893-021-01212-4.
54. Nishi M, Shimada M, Yoshikawa K, et al. Propensity Score-Matched analysis of the Short- and Long-Term outcomes of robotic versus laparoscopic gastrectomy for gastric Cancer. Ann Surg Oncol Jun. 2022;29(6):3887–95. https://doi.org/10.1245/s10434-021-11203-7.
55. van Boxel GI, Ruurda JP, van Hillegersberg R. Robotic-assisted gastrectomy for gastric cancer: a European perspective. Gastric Cancer Sep. 2019;22(5):909–19. https://doi.org/10.1007/s10120-019-00979-z.
56. Coratti A, Annecchiarico M, Di Marino M, Gentile E, Coratti F, Giulianotti PC. Robot-assisted gastrectomy for gastric cancer: current status and technical considerations. World J Surg Dec. 2013;37(12):2771–81. https://doi.org/10.1007/s00268-013-2100-z.
57. Kamei T, Kitayama J, Yamashita H, Nagawa H. Intraoperative blood loss is a critical risk factor for peritoneal recurrence after curative resection of advanced gastric cancer. World J Surg Jun. 2009;33(6):1240–6. https://doi.org/10.1007/s00268-009-9979-4.
58. Linder BJ, Frank I, Cheville JC, et al. The impact of perioperative blood transfusion on cancer recurrence and survival following radical cystectomy. Eur Urol May. 2013;63(5):839–45. https://doi.org/10.1016/j.eururo.2013.01.004.
59. Liang YX, Guo HH, Deng JY, et al. Impact of intraoperative blood loss on survival after curative resection for gastric cancer. World J Gastroenterol Sep. 2013;7(33):5542–50. https://doi.org/10.3748/wjg.v19.i33.5542.
60. Arita T, Ichikawa D, Konishi H, et al. Increase in peritoneal recurrence induced by intraoperative hemorrhage in gastrectomy. Ann Surg Oncol Mar. 2015;22(3):758–64. https://doi.org/10.1245/s10434-014-4060-4.
61. Guerrini GP, Esposito G, Magistri P, et al. Robotic versus laparoscopic gastrectomy for gastric cancer: the largest meta-analysis. Int J Surg Oct. 2020;82:210–28. https://doi.org/10.1016/j.ijsu.2020.07.053.
62. Junfeng Z, Yan S, Bo T, et al. Robotic gastrectomy versus laparoscopic gastrectomy for gastric cancer: comparison of surgical performance and short-term outcomes. Surg Endosc Jun. 2014;28(6):1779–87. https://doi.org/10.1007/s00464-013-3385-6.
63. Yoon HM, Kim YW, Lee JH, et al. Robot-assisted total gastrectomy is comparable with laparoscopically assisted total gastrectomy for early gastric cancer. Surg Endosc May. 2012;26(5):1377–81. https://doi.org/10.1007/s00464-011-2043-0.
64. Kim KM, An JY, Kim HI, Cheong JH, Hyung WJ, Noh SH. Major early complications following open, laparoscopic and robotic gastrectomy. Br J Surg Dec. 2012;99(12):1681–7. https://doi.org/10.1002/bjs.8924.
65. Wang JB, Liu ZY, Chen QY, et al. Short-term efficacy of robotic and laparoscopic spleen-preserving Splenic hilar lymphadenectomy via Huang's three-step maneuver for advanced upper gastric cancer: results from a propensity score-matched study. World J Gastroenterol Oct. 2019;7(37):5641–54. https://doi.org/10.3748/wjg.v25.i37.5641.
66. Yang SY, Roh KH, Kim YN, et al. Surgical outcomes after open, laparoscopic, and robotic gastrectomy for gastric Cancer. Ann Surg Oncol Jul. 2017;24(7):1770–7. https://doi.org/10.1245/s10434-017-5851-1.
67. Xu J, Shen L, Shui Y, et al. Patterns of recurrence after curative D2 resection for gastric cancer: implications for postoperative radiotherapy. Cancer Med Jul. 2020;9(13):4724–35. https://doi.org/10.1002/cam4.3085.
68. Coburn NG. Lymph nodes and gastric cancer. J Surg Oncol Mar. 2009;15(4):199–206. https://doi.org/10.1002/jso.21224.
69. Kim YW, Reim D, Park JY, et al. Role of robot-assisted distal gastrectomy compared to laparoscopy-assisted distal gastrectomy in suprapancreatic nodal dissection for gastric cancer. Surg Endosc Apr. 2016;30(4):1547–52. https://doi.org/10.1007/s00464-015-4372-x.
70. Shen WS, Xi HQ, Chen L, Wei B. A meta-analysis of robotic versus laparoscopic gastrectomy for gastric cancer. Surg Endosc Oct. 2014;28(10):2795–802. https://doi.org/10.1007/s00464-014-3547-1.
71. Kim HI, Han SU, Yang HK, et al. Multicenter prospective comparative study of robotic versus laparoscopic gastrectomy for gastric adenocarcinoma. Ann Surg Jan. 2016;263(1):103–9. https://doi.org/10.1097/SLA.0000000000001249.
72. Marano L, Fusario D, Savelli V, Marrelli D, Roviello F. Robotic versus laparoscopic gastrectomy for gastric cancer: an umbrella review of systematic reviews and meta-analyses. Updates Surg Oct. 2021;73(5):1673–89. https://doi.org/10.1007/s13304-021-01059-7.
73. Wang Y, Zhang L, Yang Y, Lu S, Chen H. Progress of gastric Cancer surgery in the era of precision medicine. Int J Biol Sci. 2021;17(4):1041–9. https://doi.org/10.7150/ijbs.56735.
74. Tian Y, Cao S, Kong Y, et al. Short- and long-term comparison of robotic and laparoscopic gastrectomy for gastric cancer by the same surgical team: a

propensity score matching analysis. Surg Endosc. Jan 2022;36(1):185–95. https://doi.org/10.1007/s00464-020-08253-5.
75. Park JS, Choi GS, Park SY, Kim HJ, Ryuk JP. Randomized clinical trial of robot-assisted versus standard laparoscopic right colectomy. Br J Surg Sep. 2012;99(9):1219–26. https://doi.org/10.1002/bjs.8841.

Publisher's note