Robotic Versus Laparoscopic Gastrectomy for Gastric Cancer: A Mega Meta-Analysis

Shantanu Baral1,2, Mubeen Hussein Arawker1,3, Qiannan Sun2,4, Mingrui Jiang1,2, Liuhua Wang2,4, Yong Wang2,4, Muhammad Ali1,2,3 and Daorong Wang1,2,3,4*

1Clinical Medical College, Yangzhou University, Yangzhou China, 2Department of Gastrointestinal Surgery, Northern Jiangsu People’s Hospital, Yangzhou China, 3General Surgery Institute of Yangzhou, Yangzhou University, Yangzhou China, 4Yangzhou Key Laboratory of Basic and Clinical Transformation of Digestive and Metabolic Diseases, Yangzhou China

Background: Laparoscopic gastrectomy and robotic gastrectomy are the most widely adopted treatment of choice for gastric cancer. To systematically assess the safety and effectiveness of robotic gastrectomy for gastric cancer, we carried out a systematic review and meta-analysis on short-term and long-term outcomes of robotic gastrectomy.

Methods: In order to find relevant studies on the efficacy and safety of robotic gastrectomy (RG) and laparoscopic gastrectomy (LG) in the treatment of gastric cancer, numerous medical databases including PubMed, Medline, Cochrane Library, Embase, Google Scholar, and China Journal Full-text Database (CNKI) were consulted, and Chinese and English studies on the efficacy and safety of RG and LG in the treatment of gastric cancer published from 2012 to 2022 were screened according to inclusion and exclusion criteria, and a meta-analysis was conducted using RevMan 5.4 software.

Results: The meta-analysis included 48 literatures, with 20,151 gastric cancer patients, including 6,175 in the RG group and 13,976 in the LG group, respectively. Results of our meta-analysis showed that RG group had prolonged operative time (WMD = 35.72, 95% CI = 28.59–42.86, P < 0.05) (RG: mean ± SD = 258.69 min ± 32.98; LG: mean ± SD = 221.85 min ± 31.18), reduced blood loss (WMD = −21.93, 95% CI = −28.94 to −14.91, P < 0.05) (RG: mean ± SD = 105.22 ml ± 62.79; LG: mean ± SD = 127.34 ml ± 79.62), higher number of harvested lymph nodes (WMD = 2.81, 95% CI = 1.99–3.63, P < 0.05) (RG: mean ± SD = 35.88 ± 4.14; LG: mean ± SD = 32.73 ± 4.67), time to first postoperative food intake shortened (WMD = −0.20, 95% CI = −0.29 to −0.10, P < 0.05) (RG: mean ± SD = 4.5 d ± 1.94; LG: mean ± SD = 4.7 d ± 1.54), and lower length of postoperative hospital stay (WMD = −0.54, 95% CI = −0.83 to −0.24, P < 0.05) (RG: mean ± SD = 8.91 d ± 6.13; LG: mean ± SD = 9.61 d ± 7.74) in comparison to the LG group. While the other variables, for example, time to first postoperative flapus, postoperative complications, proximal and distal mar gin, R0 resection rate, mortality rate, conversion rate, and 3-year overall survival rate were all found to be statistically similar at P > 0.05.
**INTRODUCTION**

Gastric cancer is the most common malignant tumor of the digestive tract in far-eastern countries. The global incidence of gastric cancer has declined steadily in recent years, but Asia still has the highest incidence of gastric cancer (1). Due to the lack of early diagnosis methods, most patients are already in the middle and late stages of the disease at the time of their diagnosis. The best method of treatment is currently surgery. The surgical method has evolved from traditional open surgery to laparoscopic surgery (2). Since the mid-1980s, laparoscopic techniques have received increasing recognition for their minimally invasive advantages in treating gastric cancer (3), and laparoscopic gastrectomy (LG) has become the standard treatment for early gastric cancer. Nonetheless, laparoscopic techniques have some limitations and shortcomings, including inflexible operation of surgical instruments, two-dimensional imaging display interface, and a limited range of operation. In recent years, robotic technologies have made tremendous progress in overcoming the technological limitations of traditional laparoscopy. Robot-assisted surgical procedure has visual direction from the bottom to the top and not the other way around as in traditional open surgery, which makes it more advantageous to expose the dirty surface tissue. Although several scholars have conducted meta-analyses of such studies, all of them focused on assessing its immediate efficacy without considering its long-term effectiveness, such as its 3-year survival rate, and some of the results differed from study to study. As the robotic surgery system continues to advance, both its technology and efficacy are continually improving, and the research reports associated with it continue to be updated. In addition, the robotic system was only recently applied to some patients undergoing gastric cancer surgery, and its status in the treatment of gastric cancer has not been conclusively established or included in guidelines. To evaluate the short and long-term efficacy and safety of the robotic surgery system in the clinical treatment of gastric cancer, this study conducted a meta-analysis of published clinical comparative studies (3–31) on RG and LG.

**MATERIALS & METHODS**

**Search Strategy**

In order to search PubMed, Medline, Cochrane Library, Embase, Google Scholar, and China Journal Full-text Database (CNKI) and other databases according to clinical comparison studies of RG and LG, the search strings "Robotic OR da Vinci OR Robot-Assisted", “Gastrectomy”, “Gastric ”, “Cancer OR Carcinoma OR Tumor OR Neoplasm”, “Laparoscopic OR Laparoscopic-Assisted “ and “Robotic”, Searches were limited to the period 2012–2021, with the “related search” feature being utilized further to exclude omissions.

**Literature Inclusion and Exclusion Criteria**

Inclusion criteria: (1) published randomized or non-randomized controlled trials comparing RG with LG; (2) patients diagnosed with gastric cancer who have undergone their first surgical procedure; (3) provide clear criteria for the selection of study cases and methods for grouping; (4) provide evidence of clinical efficacy comparison between RG and LG; (5) include data studies of superior quality and detail; (6) describe the raw data, including continuous variables such as mean and standard deviation, and count information such as the number of events and the number of samples. For dichotomous variables, the combined odds ratio (OR) and 95% confidence interval (CI) should be provided, as well as a regression coefficient that can be converted to the combined OR and 95% CI and standard error. Exclusion criteria: (1) comparisons of non-LG and RG cases; (2) study cases containing other benign gastrointestinal diseases; (3) study cases involving only undergone palliative major gastrectomy, tumor reduction, or short-circuit surgery; (4) study cases involving emergency surgery; (5) no reliable comparisons could be drawn from the literature; (6) duplicate published studies; (7) no controlled studies conducted simultaneously; and (8) no clear grouping tendency in terms of the extent of lymph node dissection or stage of the disease.

**Data Extraction**

Extractions are made by two investigators independently, and if a dispute occurs, it is resolved through mutual discussion or by a third party. The following data types can be identified: (1) General information, including the names of the authors, the dates of literature publication, the type of study, the sample size, the tumor site and its size, and the TNM stage; (2) outcome indicators, such as operative time and blood loss, lymph node dissection, transit rate, distal margin length, R0 resection rate, postoperative hospital stay, immediate postoperative gas and food intake, complication rate, 3-year survival rate, and morbidity and mortality rate.

**Evaluation of the Quality of the Literature**

We used the MINORS scoring criteria (32) to assess the quality of the clinical trials (score 0: no description, score 1: inadequate description, and score 2: adequate description). A modified set of MINORS scoring criteria containing 12 items, which yields

**Conclusions:** In the treatment of gastric cancer, robotic gastrectomy is a safe and effective procedure that has both short- and long-term effects. To properly evaluate the advantages of robotic surgery in gastric cancer, more randomised controlled studies with rigorous research methodologies are needed.

**Keywords:** robotic, laparoscopic, gastrectomy, gastric cancer, meta-analysis
TABLE 1 | Basic characteristics of the literatures included in the meta-analysis.

| Author          | Year | Country | Study period   | Study design | Sample size | Surgical extension | Level of LND | MINORS |
|-----------------|------|---------|----------------|--------------|-------------|--------------------|--------------|--------|
|                  |      |         |                | RG           | LG          |                    |              |        |
| Eom (4)         | 2012 | Korea   | 2009–2010      | OCS (P)      | 30          | 62                 | D            | D1, D2 | 22     |
| Kang (5)        | 2012 | Korea   | 2008–2011      | OCS (P)      | 100         | 282                | D, T         | D1, D2 | 22     |
| Yoon (6)        | 2012 | Korea   | 2009–2011      | OCS (R)      | 36          | 65                 | T            | D1, D2 | 23     |
| Uyama (7)       | 2012 | Japan   | 2009–2010      | OCS (P)      | 25          | 225                | D            | D2     | 21     |
| Kim KM (8)      | 2012 | Korea   | 2008–2011      | OCS (R)      | 100         | 282                | D, T         | D1, D2 | 23     |
| Zeng (9)        | 2012 | Korea   | 2009–2011      | OCS (P)      | 97          | 70                 | D, P, T      | D2     | 18     |
| Hyun (11)       | 2013 | Korea   | 2009–2010      | OCS (P)      | 38          | 83                 | D, T         | D1, D2 | 22     |
| Kang (12)       | 2013 | Korea   | 2003–2009      | OCS (P)      | 172         | 481                | D, T         | D1, D2 | 22     |
| Noshiro (13)    | 2014 | Japan   | 2010–2012      | OCS (P)      | 21          | 160                | D            | D1, D2 | 22     |
| Huang (14)      | 2014 | Taiwan  | 2008–2014      | OCS (P)      | 72          | 73                 | D, T         | D1, D2 | 22     |
| Son T (15)      | 2014 | Korea   | 2003–2010      | OCS (P)      | 51          | 58                 | T            | D2     | 22     |
| Zhou (3)        | 2014 | China   | 2010–2013      | OCS (R)      | 120         | 394                | D, P, T      | D1, D2 | 23     |
| Liu J (16)      | 2014 | China   | 2012–2013      | OCS (R)      | 100         | 100                | D, P, T      | D2     | 19     |
| Han (17)        | 2015 | Korea   | 2008–2013      | OCS (R)      | 68          | 68                 | PPG          | D1     | 23     |
| Seo (18)        | 2015 | Korea   | 2004–2009      | OCS (P)      | 40          | 40                 | D            | D1, D2 | 20     |
| Park (19)       | 2015 | Korea   | 2009–2011      | OCS (P)      | 145         | 612                | D, T         | D1     | 19     |
| Lee (20)        | 2015 | Korea   | 2003–2010      | OCS (P)      | 133         | 267                | D            | D2     | 21     |
| Suda (21)       | 2015 | Japan   | 2009–2012      | OCS (R)      | 88          | 438                | D, T         | D1, D2 | 22     |
| Shen (22)       | 2015 | China   | 2011–2014      | OCS (R)      | 93          | 330                | D, T         | D1, D2 | 21     |
| Li P (23)       | 2015 | China   | 2011–2014      | OCS (P)      | 126         | 124                | T            | D2     | 21     |
| Cianchi (24)    | 2016 | Italy   | 2008–2015      | OCS (P)      | 30          | 41                 | D            | D1, D2 | 21     |
| Kim HI (25)     | 2016 | Korea   | 2011–2012      | OCS (P)      | 185         | 185                | D, T         | D1, D2 | 23     |
| Nakachi (26)    | 2016 | Japan   | 2009–2012      | OCS (R)      | 84          | 437                | D, T         | D1, D2 | 23     |
| Hong (27)       | 2016 | Korea   | 2008–2015      | OCS (P)      | 232         | 232                | D            | D1, D2 | 22     |
| Kim YW (28)     | 2016 | Korea   | 2009–2011      | OCS (P)      | 87          | 288                | D            | D1, D2 | 20     |
| Xue (29)        | 2016 | China   | 2012–2014      | OCS (R)      | 35          | 35                 | D            | D2     | 20     |
| Parisi (30)     | 2017 | Italy   | 2015–2016      | OCS (P)      | 151         | 151                | D, T         | D2     | 21     |
| Yang (31)       | 2017 | Korea   | 2009–2015      | OCS (P)      | 173         | 511                | D, T         | D1, D2 | 21     |
| Li GT (33)      | 2017 | China   | 2011–2014      | OCS (R)      | 15          | 15                 | T            | D2     | 20     |
| Teng (34)       | 2017 | China   | 2016–2017      | OCS (R)      | 41          | 58                 | D            | D1, D2 | 20     |
| Hu (35)         | 2017 | China   | 2014–2016      | OCS (R)      | 39          | 39                 | D            | D2     | 21     |
| Lan (36)        | 2017 | China   | 2014–2016      | OCS (R)      | 196         | 673                | D, P, T      | NA     | 20     |
| Liu HB (37)     | 2018 | China   | 2017          | OCS (R)      | 100         | 135                | D, T         | D1, D2 | 21     |
| Lu (38)         | 2018 | China   | 2016–2017      | OCS (P)      | 101         | 303                | D, T         | D1, D2 | 20     |
| Obama (39)      | 2018 | Korea   | 2005–2009      | OCS (P)      | 315         | 525                | D, T         | D1, D2 | 23     |
| Zhang K (40)    | 2018 | China   | 2011–2013      | OCS (P)      | 27          | 62                 | D, P, T      | D1     | 23     |
| Li ZY (41)      | 2018 | China   | 2013–2017      | OCS (P)      | 112         | 112                | D, T         | D2     | 23     |
| Li SY (42)      | 2018 | China   | 2015–2017      | OCS (R)      | 50          | 56                 | D            | D2     | 21     |
| Wang WJ (43)    | 2019 | China   | 2016–2018      | OCS (P)      | 251         | 276                | D, T         | D2     | 23     |
| Gao (44)        | 2019 | China   | 2011–2014      | OCS (P)      | 163         | 339                | D, P, T      | D1, D2 | 21     |
| Ahoossaini (45) | 2020 | Korea   | 2015–2017      | OCS (R)      | 25          | 30                 | T            | NA     | 23     |
| Ye SP (46)      | 2020 | Korea   | 2014–2019      | OCS (P)      | 285         | 285                | D            | D2     | 23     |
| Shibasaki (47)  | 2020 | Japan   | 2009–2019      | OCS (P)      | 359         | 1042               | D, P, T      | D1, D2 | 22     |
| Kong (48)       | 2020 | China   | 2014–2017      | OCS (R)      | 294         | 750                | D, P, T      | D1, D2 | 23     |

(continued)
scores ranging from 0 to 24 was used to evaluate the quality of the literature included in this study (Supplementary file Appendix 1).

### Statistical Analysis

We performed the meta-analysis using RevMan 5.4 software, using odds ratio (OR) values for measurement data and weighted mean differences (WMD) for efficacy analysis for count data. The 95% confidence interval (CI) for the effect sizes was calculated. It was checked for heterogeneity between the studies using the $\chi^2$ test and $I^2$ values, and in case of heterogeneity ($I^2 > 50\%$, $P < 0.05$), a random-effects model was applied; if there was no heterogeneity ($I^2 < 50\%$, $P \geq 0.05$), a fixed-effects model was applied. The differences were considered statistically significant at $P < 0.05$.

### RESULTS

#### Search Results

A preliminary search retrieved a total of 5,440 articles published from 2012 to 2021. After reviewing all titles and abstracts, 76 complete articles were found, 28 of which were rejected because they did not meet the inclusion criterion. Supplementary Figure 1 illustrates the search process. Ultimately, 20,151 patients data from 48 retrospective studies were included in the present study, with 6,175 in the RG group and 13,976 in the LG group (3–30). Table 1 presents the basic characteristics of the included literature and MINORS scale for quality assessment, while Table 2 provides the patients’ characteristics of the included literature. Supplementary Figure 2 depicts MINORS scores bar graph for the observational studies included in our systematic review.

#### Meta-Analysis Results

Operation time was reported in 45 publications, with homogeneity test $I^2 = 97\%$, $P < 0.05$. Using a random effect model analysis showed that the RG group had a significantly longer operation time than the LG group ($WMD = 35.72$, 95% CI = 28.59–42.86, $P < 0.05$) (Figure 1). The mean ± SD values are 258.69 min ± 32.98 and 221.85 min ± 31.18, for the RG and LG groups, respectively.

Intraoperative bleeding was reported in 43 publications with homogeneity test $I^2 = 93\%$, $P < 0.05$, and analysis using a random effects model showed that intraoperative bleeding was significantly less in the RG group than in the LG group ($WMD = −21.93$, 95% CI = −28.94 to −14.91, $P < 0.05$) (Figure 2). The mean ± SD values are 105.22 ml ± 62.79 and 127.34 ml ± 79.62, for the RG and LG groups, respectively.

Number of lymph node dissection 46 publications reported the number of lymph node dissections with homogeneity test $I^2 = 87\%$, $P < 0.05$, and analysis using a random effects model showed that the number of lymph node dissections was higher in the RG group than in the LG group ($WMD = 2.81$, 95% CI = 1.99–3.63, $P < 0.05$) using random effects model analysis (Figure 3). The mean ± SD values are 35.88 ± 4.14 and 32.73 ± 4.67, for the RG and LG groups, respectively.

Time to first postoperative flatus 26 publications reported time to first postoperative flatus with homogeneity test $I^2 = 97\%$, $P < 0.05$, and analysis using a random effects model showed not statistically significant in time to first postoperative flatus between the two groups ($WMD = −0.20$, 95% CI = −0.42 to 0.02, $P > 0.05$) (Figure 4). The mean ± SD values are 5.02 d ± 1.24 and 5.25 d ± 2.54, for the RG and LG groups, respectively.

Time to first postoperative food intake 26 publications reported time to first postoperative food intake with homogeneity test $I^2 = 53\%$, $P < 0.05$, and analysis using a random effects model showed that time to first postoperative food intake was significantly shorter in the RG group than in the LG group ($WMD = −0.20$, 95% CI = −0.39 to −0.01, $P < 0.05$) (Figure 5). The mean ± SD values are 4.55 d ± 1.94 and 4.76 ± 1.54, for the RG and LG groups, respectively.

Postoperative length of hospital stay 46 publications reported postoperative length of stay, homogeneity test $I^2 = 80\%$, $P < 0.05$, and a random effects model analysis showed significantly lower length of hospital stay in the RG group than in the LG group ($WMD = −0.54$, 95% CI = −0.83 to −0.24, $P < 0.05$) (Figure 6). The mean ± SD values are 8.91 d ± 6.13 and 9.61 d ± 7.74, for the RG and LG groups, respectively.

Postoperative Complication rates 47 publications reported complication rates with homogeneity test $I^2 = 22\%$, $P > 0.05$, and a random effects model analysis showed no statistically significant difference in complication rates between the two groups ($OR = 0.88$, 95% CI = 0.78–1.00, $P < 0.05$) (Figure 7). The average complication rate was 15.68 in RG group and 16.59 in LG group.

Proximal margin distance 16 publications reported proximal margin distance with homogeneity test $I^2 = 57\%$, $P < 0.05$, and analysis using a random effects model analysis showed no...
TABLE 2 | Patients’ characteristics of the included literature.

| Author     | Year | Gender (M/F) | Age | BMI (kg/m²) | TNM Stage |
|------------|------|--------------|-----|-------------|-----------|
| Eom (4)    | 2012 | 21/9         | 52.8 ± 11.5 | 24.2 ± 4.5 | I, II, III |
| Kang (5)   | 2012 | 191/91       | 53.2 ± 12.03| 23.7 ± 3.2 | I, II, III |
| Yoon (6)   | 2012 | 31/34        | 53.9 ± 11.7 | 23.2 ± 2.5 | I, II, III |
| Uyama (7)  | 2012 | 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |
| Kim LG (8) | 2012 | 63/37        | 54.2 ± 12.5 | 23.6 ± 3.1 | I, II, III |
| Huang (9)  | 2012 | 191/91       | 53.2 ± 12.03| 23.7 ± 3.2 | I, II, III |
| Zhang (10) | 2012 | 31/34        | 53.9 ± 11.7 | 23.2 ± 2.5 | I, II, III |
| Hyun (11)  | 2013 | 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |
| Kim HI (12)| 2014 | 294/187      | 55.2 ± 11.7 | 23.6 ± 3.1 | I, II, III |
| Huang (13)| 2014 | 249/181      | 55.2 ± 11.7 | 23.6 ± 3.1 | I, II, III |
| Uyama (14)| 2014 | 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |
| Kim HI (15)| 2014| 294/187      | 55.2 ± 11.7 | 23.6 ± 3.1 | I, II, III |
| Huang (16)| 2014 | 31/34        | 53.9 ± 11.7 | 23.2 ± 2.5 | I, II, III |
| Hyun (17)  | 2014 | 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |
| Kim HI (18)| 2014| 294/187      | 55.2 ± 11.7 | 23.6 ± 3.1 | I, II, III |
| Huang (19)| 2014 | 31/34        | 53.9 ± 11.7 | 23.2 ± 2.5 | I, II, III |
| Hyun (20)  | 2014 | 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |
| Lee (21)   | 2015 | 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |
| Suda (22)  | 2015 | 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |
| Shen (23)  | 2015 | 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |
| Li P (24)  | 2015 | 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |
| Cianchi (25)| 2015| 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |
| Kim HI (26)| 2016| 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |
| Suda (27)  | 2016 | 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |
| Shen (28)  | 2016 | 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |
| Li P (29)  | 2016 | 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |
| Cianchi (30)| 2016| 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |
| Kim HI (31)| 2017| 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |
| Suda (32)  | 2017 | 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |
| Shen (33)  | 2017 | 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |
| Li P (34)  | 2017 | 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |
| Cianchi (35)| 2017| 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |
| Kim HI (36)| 2018| 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |
| Suda (37)  | 2018 | 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |
| Shen (38)  | 2018 | 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |
| Li P (39)  | 2018 | 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |
| Cianchi (40)| 2018| 156/69       | 61.6 ± 11.0 | 22.6 ± 3.1 | I, II, III |

(continued)
TABLE 2 | Continued

| Author | Year | Gender (M/F) | Age | BMI (kg/m^2) | TNM Stage |
|--------|------|--------------|-----|--------------|-----------|
|        |      | RG | LG | RG | LG | RG | LG |
| Shin   | 2021| 264/157 | 1088/575 | 53 ± 12 | 60 ± 12 | 23.87 ± 3.13 | 23.89 ± 3.22 | I, II, III |
| Hikage | 2021| 219/126 | 595/240 | 67 ± 16 | 69 ± 16.5 | 22.3 ± 4.05 | 22.7 ± 5.5 | I, II, III |
| Li ZY  | 2021| 22/7 | 31/10 | 60.3 ± 12.6 | 58.2 ± 9.8 | 19.4 ± 2.2 | 20.4 ± 2.5 | I, II, III |

NA, not available; M, male; F, female; RG, robotic gastrectomy; LG, laparoscopic gastrectomy.

FIGURE 1

Comparison of operation time between RG and LG group.
A statistically significant difference in proximal margin distance between the two groups (WMD = −0.02, 95% CI = −0.23 to 0.19, \(P > 0.05\)) (Supplementary Figure 3). The mean ± SD values are 4.05 cm ± 1.15 and 4.05 cm ± 0.94, for the RG and LG groups, respectively.

Distal margin distance 16 publications reported distal margin distance with homogeneity test \(I^2 = 71\%, P < 0.05\), and a random effects model analysis showed not statistically significant in distal margin distance between the two groups (WMD = 0.18, 95% CI = −0.71 to 0.48, \(P > 0.05\)) (Supplementary Figure 4). The mean ± SD values are 5.98 cm ± 1.56 and 5.66 cm ± 1.89, for the RG and LG groups, respectively.

R_0_ resection rates 48 publications reported \(R_0\) resection rates with homogeneity test \(I^2 = 17\%, P < 0.05\), and analysis using a fixed effect model showed no statistically significant difference in \(R_0\) resection rates between the two groups (OR = 1.74, 95% CI = 0.70–4.28, \(P > 0.05\)) (Supplementary Figure 5). The average \(R_0\) resection rate was 128.52 in RG group and 290.81 in LG group.

Tumor size 22 publications reported tumor size with homogeneity test \(I^2 = 95\%, P < 0.05\), and analysis using a random effects model analysis showed no statistically significant difference in tumor size between the two groups (WMD = −0.19, 95% CI = −0.52 to 0.14, \(P > 0.05\)) (Supplementary Figure 6). The mean ± SD values are 3.27 cm ± 0.82 and 3.31 cm ± 0.76, for the RG and LG groups, respectively.

Mortality rate 20 publications reported mortality rate with homogeneity test \(I^2 = 0\%, P > 0.05\), and analysis using a fixed effect model showed no statistically significant difference in mortality rate between the two groups (OR = 0.71, 95% CI = 0.42–1.23, \(P > 0.05\)) (Supplementary Figure 7). The average mortality rate was 12.31 in RG group and 11.75 in LG group.
mortality rate between the two groups ($OR = 1.16$, 95% CI $= 0.76$–$1.76$, $P > 0.05$) (Supplementary Figure 7). The average mortality rate was 1.32 in RG group and 3 in LG group.

Conversion rate 14 publications reported conversion rate with homogeneity test $I^2 = 0\%$, $P > 0.05$, and a fixed effect model analysis showed no statistically significant difference in conversion rate between the two groups ($OR = 0.64$, 95% CI $= 0.40$–$1.00$, $P > 0.05$) (Supplementary Figure 8). The average conversion rate was 0.88 in RG group and 3.03 in LG group.

Reoperation rate 13 publications reported reoperation rate with homogeneity test $I^2 = 0\%$, $P > 0.05$, and a fixed effect model analysis showed no statistically significant difference in reoperation rate between the two groups ($OR = 1.05$, 95% CI $= 0.68$–$1.62$, $P > 0.05$) (Figure 8). The average reoperation rate was 2.14 in RG group and 4.28 in LG group.

Overall survival 12 publications reported 3-year survival rates with homogeneity test $I^2 = 88\%$, $P < 0.05$, and a random effects model analysis showed no statistically significant difference in 3-year survival between the two groups ($OR = 1.19$, 95% CI $= 0.76$–$1.76$, $P > 0.05$) (Figure 8).
The average overall survival was 137.91 in RG group and 321.16 in LG group.

**Heterogeneity and Sensitivity Analysis**

Heterogeneity is considered to be significant when $I^2 > 50\%$ and $P < 0.05$. Our results suggest that there was heterogeneity in the time to first flapus, proximal margin, distal margin, tumor size, and overall survival ($I^2 > 50\%$, $P > 0.05$) (Table 3). Furthermore, substantial heterogeneity was also in operation time, intraoperative bleeding loss, lymph node dissection, and time to first food intake ($I^2 > 50\%$, $P < 0.05$) (Table 3). According to the MINORS score, high-quality literature with a score of more than 18 points was selected for sensitivity analysis.

**Publication of Bias**

Evaluation of publication bias was accomplished using a funnel plot of intraoperative blood loss, lymph node dissection, and postoperative complications. There was no evidence of publication bias in the bilaterally symmetrical funnel plots of overall complications (Supplementary Figures 9, 10, 11).

**DISCUSSION**

In most cases of gastric cancer, gastrostomies are the mainstay of treatment. Almost thirty years ago, minimally invasive gastrostomies were introduced to reduce patient burden. As a result of the increasing availability of surgical robots, a robotic-assisted gastrectomy was performed for the first time in Japan in 2002 (52). Currently, robotic surgery is widely used in general surgery as well as other applications (22). In comparison to laparoscopic gastrectomy (LG), the feasibility and safety of the robotic-assisted (RG) technique were explored in this study.

Robotic surgery has become increasingly popular in a variety of surgeries due to its increased surgical precision and safety. Since the earliest application of robotics in surgery, it has evolved in five distinct categories: endoscopic, stereotactic, bioinspired, millimeter-scale microbots, and autonomous systems. Robotic surgery has shown to have dramatically superior clinical results when compared to laparoscopic and open surgical techniques. In our study, of the 48 publications examined, 38 researches employed the Da Vinci surgical systems while the other 10 did not specify the surgical systems used (Supplementary Figure 12). According to the results of the comparative analysis of RG and LG gastric cancer...
treatment found in this study, there are disparities in efficacy between these treatments.

Based on the meta-analysis, it was found that RG requires a longer surgical procedure time than LG. One of the main reasons is that the robotic surgical system necessitates machine assembly at the beginning of the operation, and Jiménez-Rodríguez et al. (53) reported that the average preparation time for RG was 62.9% ± 24.6% min, but with experience the preparation time gradually decreases. Huang et al. (14) reported that the preparation time could be reduced to thirty minutes after 25 surgical operations. A study by Kang et al. (5) reported that the experienced RG group had a considerably shorter mean operation time than the inexperienced RG group. Furthermore, robotic surgery is a relatively new minimally invasive procedure that necessitates a learning process to master which is significantly shorter than LG. As reported by Mege et al. (54) and Huang et al. (14), the learning curve for LG surgery ranges from 30 to 50 cases, whereas surgeons performing 10–20 RG cases would accomplish a stable level of operative time. Huang et al. (14) compared LG to RG in the middle and later stages of the learning curve, finding LG to have a longer operative time than RG regardless of the stage. Consequently, once the learning curve is passed, the time spent intraoperatively in RG would be shorter than that in LG.

This meta-analysis revealed that the intraoperative blood loss in RG was less than that in LG, and the number of lymph nodes dissected in RG was higher than that in LG. There are abundant blood vessels and lymphatic vessels in the perigastric tissue. The process of LG perigastric tissue separation and lymph node dissection is prone to haemorrhage, which may affect the operator’s ability to identify the tissue structure and to view the operation field. Due to the advantages of the robotic, these issues have been resolved (3–30), such as: (1) Jitter filtering, the robotic arm eliminates the natural tremor in the human hand and improves the stability of the operation; (2) High-definition three-dimensional images, 3D images magnify the surgical field by 10–15 times, revealing the small blood vessels and tissue structure around the stomach, making the blood vessels around the stomach more secure, and improving the accuracy of the procedure; (3) Robotic arms have seven degrees of freedom to simulate the mechanical wrist, which allows for greater flexibility of operation and the ability to work in confined spaces; (4) The operator controls the robotic arm individually, eliminating the problem of incompatibility between the mirror arm and the operator; (5) The operator adopts a sitting position that provides both physical comfort and improves the efficiency of his or her operation; (6) Remote control by the operator so to avoid direct contact with the patient; (7) Reconstruction of the
digestive tract to achieve a full endoscopic anastomosis which is suitable for obesity, barrel chests, high esophageal cut planes, a small costal arch angle, and anterior and posterior abdominal walls. There are several advantages to total endoscopic in vivo anastomosis for patients with the same diameter and width. These attributes, without a doubt, improve surgical precision and stability, minimise mistake rates, and promote minimally invasive surgery.

A patient’s prognosis and degree of surgical cure are affected by the number of lymph nodes dissected at the time of surgery for early gastric cancer. As a treatment for intermediate and advanced gastric cancer, D2 lymph node dissection remains the standard procedure. Nonetheless, it is difficult to dissect D2 lymph nodes in LG. The included studies (3, 8, 22, 24, 28) showed that more lymph nodes had been cleared in the RG group than in the LG group, while the remaining studies showed no significant differences between the two groups in terms of lymph node clearance (6, 7, 11, 14, 17, 55). Across the included studies (3–30), the number of surgically cleared lymph nodes in RG ranged between 13.6 and 91.7, while all

| Study or Subgroup | RG  | LG  | Mean Difference IV, Random, 95% CI |
|-------------------|-----|-----|-----------------------------------|
| Alhossaini 2020   | 8.9 | 7.9 | -0.60 [-0.33, 1.43] |
| Quanihi 2016      | 9.6 | 1   | -0.40 [1.01, 1.79] |
| Eom 2012          | 7.9 | 2.1 | -0.80 [1.80, 2.00] |
| Gao 2019          | 7.0 | 9.3 | -0.35 [-1.20, 0.50] |
| Han 2015          | 8.6 | 4.2 | -0.50 [-2.26, 1.26] |
| Hikage 2021       | 8.2 | 20.5| -1.00 [-3.81, 1.81] |
| Hong 2016         | 7.6 | 8.6 | -0.40 [0.73, 1.73] |
| Hu 2013           | 7   | 0   | -2.20 [-5.93, 1.63] |
| Huang 2014        | 11  | 11.8| -1.40 [-3.10, 1.50] |
| Hyun 2013         | 10.5| 5.9 | 0.00 [-1.11, 1.11] |
| Kang 2012         | 9.8 | 1.2 | -0.80 [-2.15, 0.55] |
| Kim HI 2014       | 7.1 | 15.5| -0.70 [-1.05, 0.36] |
| Kim HI 2016       | 6   | 5.1 | -0.64 [-1.54, 0.26] |
| Kim KM 2012       | 7   | 13  | -0.64 [-1.54, 0.26] |
| Kim YW 2016       | 6.7 | 1   | -2.20 [-5.93, 1.63] |
| Kong 2003         | 9.54| 6.09| 1.80 [-1.00, 4.60] |
| Lan 2017          | 13.9| 19.6| -0.80 [-1.80, 0.20] |
| Lee 2015          | 6.2 | 3.8 | -4.93 [-9.42, -0.44] |
| Li GT 2017        | 10.4| 1.5 | -1.10 [-1.85, -0.35] |
| Li P 2015         | 8.6 | 2.6 | -1.00 [-1.61, -0.39] |
| Li SY 2018        | 7.8 | 1.4 | -1.00 [-1.61, -0.39] |
| Liu 2018          | 11  | 0.6 | -0.70 [-1.05, 0.36] |
| Liu J 2014        | 5.3 | 2.6 | -0.80 [-1.59, -0.01] |
| Liu ZY 2018       | 6.9 | 2.3 | -0.10 [-0.92, 0.72] |
| Liu ZY 2021       | 9   | 0.7 | 0.00 [0.00, 0.30] |
| Lu 2018           | 11.9| 8.95| 0.21 [-1.72, 2.14] |
| Nakaishi 2016     | 14  | 7.25| -1.00 [-4.38, 2.38] |
| Noshiro 2014      | 8   | 5   | -6.00 [-10.12, 0.12] |
| Obama 2018        | 12  | 315.7| 0.00 [0.00, 0.30] |
| Parai 2017        | 8.85| 5.82| -0.10 [-1.62, 1.42] |
| Park 2015         | 7.9 | 4.1 | -0.22 [-1.95, 1.51] |
| Seo 2015          | 6.75| 1.7 | -0.62 [-1.32, 0.08] |
| Shen 2015         | 9.4 | 7.9 | -1.20 [-3.13, 0.73] |
| Shibasaki 2020    | 12  | 32.1| -1.00 [-4.76, 2.76] |
| Shin 2021         | 7.41| 6.79| 0.17 [-0.51, 0.86] |
| Son T 2014        | 8.6 | 12  | 0.70 [-2.82, 4.22] |
| Suda 2015         | 14  | 4.8 | -0.10 [-1.23, 0.07] |
| Teng 2017         | 8.3 | 2.7 | -0.80 [-1.99, 0.39] |
| Uyama 2012        | 12.1| 3.2 | -5.20 [-7.22, -3.18] |
| Wang WJ 2019      | 10.9| 2.8 | -1.40 [-1.91, -0.89] |
| Xue 2016          | 8.5 | 2.9 | -0.40 [-1.76, 0.96] |
| Yang 2017         | 5.9 | 1.9 | -1.80 [-2.41, -1.19] |
| Ye SP 2020        | 9   | 4.5 | -0.50 [-1.31, 0.31] |
| Yoon 2012         | 8.8 | 3.3 | -1.50 [-4.34, 1.34] |
| Zhang K 2018      | 10.8| 4.2 | -0.30 [-2.81, 2.21] |
| Zhang XL 2012     | 6.1 | 2.6 | -0.80 [-1.55, -0.05] |
| Zhou 2014         | 7.8 | 3   | -0.10 [-0.68, 0.48] |
| Total (95% CI)    | 6136| 13912| 100.0% |

Heterogeneity: Tau² = 0.55; Chi² = 227.49; df = 45 (P < 0.00001); I² = 80%

FIGURE 6 | Comparison of length of postoperative hospital stay between RG and LG group.
were able to reach the range of clearance of D2 lymph nodes. It has been revealed that RG can have therapeutic benefits that are comparable to LG and may even exceed them (for example in dissection, abdominal reduction, suturing etc).

We found that the RG group had a shorter first postoperative food intake period than the LG group. We found substantial discrepancies between Kim et al. (8) and Zhang et al. (10) among the independent literature examined. Possible reasons are (8, 10): (1) The robotic arm moves stably and flexibly during RG operation, helping to avoid overstretching and separation of tissues and accidental injury to blood vessels, thus causing less trauma to patients; (2) Adopting the concept of enhanced recovery surgery after perioperative management, Zhang et al. (10) reported earlier postoperative time to get out

| Study or Subgroup | RG Events | LG Events | Total Weight | Odds Ratio M-H, Random, 95% CI | Odds Ratio M-H, Random, 95% CI |
|-------------------|-----------|-----------|--------------|-------------------------------|-------------------------------|
| Alhossaini 2020   | 10        | 25        | 11           | 30                            | 1.15 [0.39, 3.43]             |
| Clanici 2016      | 4         | 30        | 5            | 41                            | 0.7% [0.27, 4.53]             |
| Eom 2012          | 4         | 30        | 4            | 62                            | 0.6% [0.52, 9.62]             |
| Gao 2019          | 22        | 163       | 46           | 339                           | 3.4% [0.68, 1.72]             |
| Han 2015          | 13        | 68        | 15           | 68                            | 1.8% [0.36, 1.92]             |
| Hikage 2021       | 45        | 345       | 169          | 835                           | 5.6% [0.41, 0.84]             |
| Hong 2016         | 30        | 232       | 32           | 232                           | 3.5% [0.54, 1.59]             |
| Huang 2012        | 6         | 39        | 10           | 64                            | 1.1% [0.33, 2.95]             |
| Huang 2014        | 9         | 72        | 6            | 73                            | 1.1% [0.54, 4.74]             |
| Hyun 2013         | 18        | 38        | 32           | 83                            | 2.0% [0.66, 3.11]             |
| Kang 2012         | 14        | 100       | 28           | 282                           | 2.4% [0.74, 2.93]             |
| Kim HI 2014       | 9         | 172       | 20           | 481                           | 1.8% [0.57, 2.85]             |
| Kim HI 2016       | 22        | 185       | 19           | 185                           | 2.6% [0.62, 2.26]             |
| Kim KM 2012       | 44        | 436       | 81           | 861                           | 5.1% [0.73, 1.59]             |
| Kim YW 2016       | 5         | 87        | 26           | 288                           | 1.3% [0.23, 1.65]             |
| Kong 2020         | 37        | 294       | 105          | 750                           | 4.9% [0.69, 1.32]             |
| Lan 2017          | 26        | 196       | 73           | 673                           | 4.0% [0.78, 2.03]             |
| Lee 2015          | 14        | 133       | 34           | 267                           | 2.5% [0.42, 1.56]             |
| Li GT 2017        | 0         | 15        | 2            | 15                            | 0.1% [0.01, 3.96]             |
| Li P 2015         | 8         | 126       | 11           | 124                           | 1.4% [0.27, 1.79]             |
| Li SY 2018        | 5         | 50        | 6            | 56                            | 0.8% [0.26, 3.24]             |
| Liu HB 2018       | 5         | 100       | 9            | 135                           | 1.0% [0.24, 2.27]             |
| Liu J 2014        | 5         | 100       | 5            | 100                           | 0.8% [0.28, 3.57]             |
| Li ZY 2016        | 15        | 112       | 13           | 112                           | 1.9% [0.53, 2.60]             |
| Li ZY 2017        | 8         | 29        | 9            | 41                            | 1.1% [0.45, 4.07]             |
| Lu 2014           | 14        | 101       | 34           | 303                           | 2.6% [1.12, 5.87]             |
| Nakauchi 2016      | 2         | 84        | 51           | 437                           | 0.7% [0.04, 0.77]             |
| Noshiro 2014       | 2         | 21        | 16           | 160                           | 0.6% [0.20, 4.45]             |
| Obama 2018        | 38        | 315       | 62           | 525                           | 4.6% [0.67, 1.58]             |
| Parisi 2017       | 27        | 151       | 18           | 151                           | 2.6% [0.84, 3.07]             |
| Park 2015         | 12        | 145       | 46           | 612                           | 2.5% [0.57, 2.15]             |
| Seo 2015          | 11        | 40        | 12           | 40                            | 0.4% [0.34, 2.33]             |
| Shen 2015         | 9         | 93        | 33           | 330                           | 2.0% [0.66, 2.09]             |
| Shibasaki 2020     | 13        | 359       | 92           | 1042                          | 3.0% [0.30, 1.07]             |
| Shin 2021         | 97        | 421       | 374          | 1663                          | 7.4% [0.80, 1.33]             |
| Son T 2014        | 8         | 51        | 13           | 58                            | 1.3% [0.24, 1.71]             |
| Suda 2015         | 2         | 88        | 54           | 438                           | 0.7% [0.04, 0.69]             |
| Teng 2017         | 3         | 41        | 8            | 58                            | 0.7% [0.12, 1.99]             |
| Uyama 2012        | 2         | 25        | 38           | 225                           | 0.6% [0.10, 1.89]             |
| Wang WJ 2019      | 42        | 251       | 78           | 276                           | 4.7% [0.53, 0.78]             |
| Xue 2016          | 5         | 35        | 7            | 35                            | 0.8% [0.67, 2.35]             |
| Yang 2017         | 9         | 173       | 63           | 511                           | 2.2% [0.39, 0.98]             |
| Ye SP 2020        | 35        | 285       | 48           | 285                           | 4.1% [0.69, 1.11]             |
| Yoon 2012         | 6         | 36        | 10           | 65                            | 1.1% [0.36, 3.32]             |
| Zhang K 2018      | 9         | 27        | 21           | 62                            | 1.4% [0.37, 2.54]             |
| Zhang XL 2012     | 6         | 97        | 5            | 70                            | 0.9% [0.86, 2.93]             |
| Zhou 2014         | 7         | 120       | 17           | 394                           | 1.5% [1.37, 5.6]             |

Total (95% CI) 6136 13937 100.0% 0.88 [0.78, 1.00]

Total events 737 1875

Heterogeneity: Tau² = 0.03, Chi² = 59.30, df = 46 (P = 0.09); I² = 22%

Test for overall effect: Z = 2.01 (P = 0.04)

FIGURE 7 | Comparison of postoperative complications between RG and LG group.
of bed, first gassing and eating time in the RG group compared to the LG group. As a result of the meta-analysis, however, the potential factor could not be the cause of the different postoperative hospital stay between the groups of RG and LG. A slight statistically significant difference was found between the two groups in terms of hospital stay, but the RG did appear to be preferred.

A meta-analysis of the data revealed that there was no difference in the rest of the data between the RG and LG group. Despite this, there is heterogeneity in first postoperative flatus time, postoperative complications, proximal incision margin distance, distal incision margin distance, tumor size, and 3-year survival rate. There may be a variety of reasons for this: (1) The operators included in the study may be in different stages of their RG development, and the indicators are heterogeneous. (2) The tumor size, location, and stage of included studies are different; (3) Preoperative management and surgical methods are also different, contributing to varying results. The findings of a high-quality non-randomized controlled trial, however, were

| Study or Subgroup | RG Events | Total | LG Events | Total | Weight | Odds Ratio M-H, Fixed, 95% CI | Odds Ratio M-H, Random, 95% CI |
|-------------------|-----------|-------|-----------|-------|--------|-----------------------------|-----------------------------|
| Alhossaini 2020   | 1         | 25    | 1         | 30    | 2.2%   | 1.21 [0.07, 20.35]           |                             |
| Gianchi 2016      | 1         | 30    | 2         | 41    | 4.2%   | 0.67 [0.06, 7.78]            |                             |
| Han 2015          | 0         | 68    | 1         | 68    | 3.8%   | 0.33 [0.01, 8.21]            |                             |
| Kang 2012         | 5         | 100   | 0         | 282   | 0.6%   | 32.54 [1.78, 593.95]         |                             |
| Kim HI 2016       | 0         | 185   | 1         | 185   | 3.8%   | 0.33 [0.01, 8.19]            |                             |
| Kim KM 2012       | 7         | 436   | 9         | 861   | 15.2%  | 1.54 [0.57, 4.18]            |                             |
| Kong 2020         | 3         | 294   | 10        | 750   | 14.2%  | 0.76 [0.21, 2.79]            |                             |
| Nakachichi 2016   | 0         | 84    | 7         | 437   | 6.2%   | 0.34 [0.02, 6.00]            |                             |
| Parisi 2017       | 2         | 151   | 5         | 151   | 12.6%  | 0.39 [0.07, 2.05]            |                             |
| Shibasaki 2020    | 4         | 359   | 11        | 1042  | 14.2%  | 1.06 [0.33, 3.34]            |                             |
| Son T 2014        | 2         | 51    | 1         | 58    | 2.3%   | 2.33 [0.20, 26.44]           |                             |
| Suda 2015         | 0         | 88    | 6         | 438   | 5.6%   | 0.38 [0.02, 6.73]            |                             |
| Ye SP 2020        | 5         | 285   | 6         | 285   | 15.0%  | 0.83 [0.25, 2.75]            |                             |
| Yoon 2012         | 0         | 36    | 0         | 65    | Not estimable                   |                             |

Total (95% CI) 2192 4693 100.0% 1.05 [0.68, 1.62]

Heterogeneity: Chi² = 10.31, df = 12 (P = 0.59); I² = 0%
Test for overall effect: Z = 0.22 (P = 0.83)

<FIGURE 8> Comparison of reoperation rate between RG and LG group.

| Study or Subgroup | RG Events | Total | LG Events | Total | Weight | Odds Ratio M-H, Fixed, 95% CI | Odds Ratio M-H, Random, 95% CI |
|-------------------|-----------|-------|-----------|-------|--------|-----------------------------|-----------------------------|
| Gao 2019          | 124       | 163   | 277       | 339   | 10.1%  | 0.71 [0.45, 1.12]            |                             |
| Hikage 2021       | 337       | 345   | 792       | 835   | 8.9%   | 2.29 [1.06, 4.92]            |                             |
| Lee 2015          | 126       | 133   | 249       | 267   | 8.3%   | 1.30 [0.53, 3.20]            |                             |
| Li P 2015         | 123       | 126   | 122       | 124   | 4.8%   | 0.67 [0.11, 4.09]            |                             |
| Li ZY 2018        | 88        | 112   | 84        | 112   | 9.5%   | 1.22 [0.66, 2.28]            |                             |
| Li ZY 2021        | 10        | 29    | 20        | 41    | 7.9%   | 0.55 [0.21, 1.47]            |                             |
| Nakachichi 2016   | 73        | 84    | 388       | 437   | 9.1%   | 0.84 [0.42, 1.69]            |                             |
| Obama 2018        | 294       | 315   | 311       | 525   | 10.0%  | 9.63 [5.98, 15.50]           |                             |
| Shin 2021         | 328       | 421   | 1222      | 1663  | 10.7%  | 1.27 [0.99, 1.64]            |                             |
| Son T 2014        | 47        | 51    | 54        | 56    | 6.0%   | 0.87 [0.21, 3.67]            |                             |
| Zhang K 2018      | 24        | 27    | 60        | 62    | 4.6%   | 0.27 [0.04, 1.70]            |                             |
| Zhou 2014         | 81        | 120   | 276       | 394   | 10.2%  | 0.90 [0.58, 1.39]            |                             |

Total (95% CI) 1926 4857 100.0% 1.19 [0.70, 2.00]

Heterogeneity: Tau² = 0.65; Chi² = 89.98, df = 11 (P < 0.00001); I² = 88%
Test for overall effect: Z = 0.64 (P = 0.52)

<FIGURE 9> Comparison of 3-year survival rate between RG and LG group.
also convincing when evaluating the short-term effects of surgery, as shown by Abraham et al. (56). After reviewing the high-quality literature, it was discovered that there was no significant difference between the two groups in terms of the number of lymph nodes dissected (WMD = 1.87, 95% CI = −1.24, 3.97, \(P > 0.05\)), and the rest of the results remained unchanged, indicating that systematic analysis results are relatively reliable.

This study has some limitations (1) the inclusion of the most recent literature and exclusion of studies with duplicate cases; (2) the inclusion of a relatively large number of studies, which increased the number of relevant cases; and (3) the systematic analysis of long-term survival information, such as the 3-year survival rate. Several limitations exist in this meta-analysis, including: (1) the included literature was retrospective, lacking high-quality randomized controlled trials, some of which had a small number of patients, which may have contributed to publication bias, and (2) the recurrence rate was not examined.

### CONCLUSION

Based on our meta-analysis, RG appears to have superior therapeutic effects than traditional LG for treating gastric cancer and both are safe and practical. Its future application opportunities will improve as more experience is gathered. In the future, large-scale, multi-sampled multicenter randomised controlled studies will be required to increase the reliability of RG in clinical therapy.

### AUTHOR CONTRIBUTIONS

SB: administrative support, provision of study materials or subjects, and manuscript writing. QS; MHA: administrative support, collection and assembly of data, and manuscript writing. YW; QS: provision of study materials or subjects, data analysis, and interpretation. MJ; LW; MA: collection and assembly of data, data analysis and interpretation, and manuscript writing. DW: conception and design, and final approval of the manuscript. All authors have read and approved the manuscript.

### FUNDING

The author(s) declare that no funding was received from any government or private institution, organization, and any other entity.

### ACKNOWLEDGMENTS

The authors are thankful to Yangzhou University for providing the necessary facilities to carry out the meta-analysis. We are also thankful to Negenome Bio Solutions Pvt Ltd for the statistical analyses and for their constant support.

### SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsurg.2022.895976/full#supplementary-material.
REFERENCES

1. Torre LA, Bray F, Siegel RL, Ferlay J, Lortet-Tieulent J, Jemal A. Global cancer statistics, 2012. CA Cancer J Clin. (2015) 65(2):87–108. doi: 10.3322/caac.21262

2. Chen K, Wu D, Pan Y, Cai JQ, Yan JF, Chen DW, et al. Totally laparoscopic gastrectomy using intracorporeally stapler or hand-sewn anastomosis for gastric cancer: a single-center experience of 478 consecutive cases and outcomes. World J Surg Oncol. (2016) 14:115. doi: 10.1186/s12957-016-0968-7

3. Junfeng Z, Yan S, Bo T, Yingxue H, Dongzhu Z, Yongliang Z, et al. Robotic gastrectomy versus laparoscopic gastrectomy for gastric cancer: comparison of surgical performance and short-term outcomes. Surg Endosc. (2014) 28(6):1779–87. doi: 10.1007/s00464-013-3385-6

4. Eom BW, Yoon HM, Ryu KW, Lee JH, Cho SJ, Lee JY, et al. Comparison of robot-assisted and laparoscopic gastrectomy for gastric cancer: multidimensional analysis in a journal.pone.0111499

5. Kim YW, Reim D, Park JY, Eom BW, Kook MC, Ryu KW, et al. Role of the long-term outcomes of robotic radical gastrectomy for gastric cancer. J Gastric Cancer. (2016) 16(4):240–6. doi: 10.3920/j.issn.2095-6959.2016.04.41

6. Peng L, Bing L, Hongyi L, Baociqting. Application of the Da Vinci robot operation system in gastric cancer. J Clin Pathol. (2015) 35(06):1103–6. doi: 10.3976/j.issn.2095-6959.2015.06.045

7. Cianchi F, Indeminiante G, Tallolli G, Ortolani M, Paoli B, Macri G, et al. Robotic vs laparoscopic distal gastrectomy with D2 lymphadenectomy for gastric cancer: a prospective comparative mono-institutional study. BMC Surg. (2016) 16(1):65. doi: 10.1186/s12893-016-0180-z

8. Kim HI, Han SU, Yang HK, Kim YW, Lee HJ, Ryu KW, et al. Multicenter prospective comparative study of robotic versus laparoscopic gastrectomy for gastric adenocarcinoma. Ann Surg. (2016) 263(1):103–9. doi: 10.1097/SLA.0000000000001249

9. Nakauchi M, Suda K, Susumu S, Kadoya S, Inaba K, Ishida Y, et al. Comparison of the long-term outcomes of robotic radial gastrectomy for gastric cancer and conventional laparoscopic approach: a single institutional retrospective cohort study. Surg Endosc. (2016) 30(12):5444–52. doi: 10.1007/s00464-016-4904-z

10. Hong SS, Sun SY, Shin HJ, Cui LH, Huh H, Han SU. Can robotic gastrectomy surpass laparoscopic gastrectomy by acquiring long-term experience? A propensity score analysis of a 7-year experience at a single institution. J Gastric Cancer. (2016) 16(4):240–6. doi: 10.3920/j.issn.2095-6959.2016.04.41

11. Yang SY, Roh KH, Kim YN, Cho M, Lim SH, Son T, et al. Surgical outcomes after open, laparoscopic, and robotic gastrectomy for gastric cancer. Ann Surg Oncol. (2017) 24(1):137–84. doi: 10.1245/s10434-017-5851-1
36. Lan X, Xi H, Zhang K, Cui J, Li M, Chen L. [Comparison of complications following open, laparoscopic and robotic gastrectomy]. Zhonghua Wei Chang Wai Ke Za Zhi. (2017) 20(2):184–9. doi: 10.3760/cma.j.issn.1671-0274.2017.02.014

37. Liu HB, Wang WJ, Li HT, Han XP, Su L, Wei DW, et al. Robotic versus conventional laparoscopic gastrectomy for gastric cancer: a retrospective cohort study. Int J Surg. (2018) 55:15–23. doi: 10.1016/j.ijsu.2018.05.015

38. Lu J, Zheng HL, Li P, Xie JW, Wang JB, Lin JX, et al. A propensity score-matched comparison of robotic versus laparoscopic gastrectomy for gastric cancer: oncological, cost, and surgical stress analysis. J Gastrointest Surg. (2018) 22(7):1152–62. doi: 10.1007/s11605-018-3785-y

39. Obama K, Kim YM, Kang DR, Son T, Kim HI, Noh SH, et al. Long-term oncologic outcomes of robotic gastrectomy for gastric cancer compared with laparoscopic gastrectomy. Gastric Cancer. (2018) 21(2):285–95. doi: 10.1007/s10120-017-0740-7

40. Zhang K, Huang X, Gao Y, Liang W, Xi H, Cui J, et al. Robot-Assisted versus laparoscopy-assisted proximal gastrectomy for early gastric cancer in the upper location: comparison of oncological outcomes, surgical stress, and nutritional Status. Cancer Control. (2018) 25(1):1073274818765999. doi: 10.1177/1073274818765999

41. Li Z, Li J, Bai B, Liu Y, Lian B, et al. Robotic versus laparoscopic gastrectomy with D2 lymph node dissection for advanced gastric cancer: a propensity score-matched analysis. Cancer Manag Res. (2018) 10:705–14. doi: 10.2147/CMAR.S161007

42. Song-yan SL-j L, Xing-bang N, Yu Y, Hong-liang Z, Xiao-hui D. Comparison of robotic and laparoscopic subtotal gastrectomy with D2 lymphadenectomy for gastric cancer. J Clin Pract Diagn Ther. (2018) 32(3):245–7. doi: 10.13507/j.1674-3474.2018.03.011

43. Wang WJ, Li HT, Yu JP, Su L, Guo CA, Chen P, 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. (2019) 33(10):3341–54. doi: 10.1007/s00464-018-6662-7

44. Gao Y, Xi H, Qiao Z, Li J, Zhang K, Xie T, et al. Comparison of robotic- and laparoscopic-assisted gastrectomy in advanced gastric cancer: updated short- and long-term results. Surg Endosc. (2019) 33(2):528–34. doi: 10.1007/s00464-018-6327-5

45. Alhossaini RM, Altamran AA, Cho M, Roh CK, Seo WJ, Choi S, et al. Lower rate of conversion using robotic-assisted surgery compared to laparoscopic in completion total gastrectomy for remnant gastric cancer. Surg Endosc. (2020) 34(2):847–52. doi: 10.1007/s00464-019-08638-3

46. Ye SP, Shi J, Liu DN, Jiang QG, Lei X, Tang B, et al. Robotic- versus laparoscopic-assisted distal gastrectomy with D2 lymphadenectomy for advanced gastric cancer based on propensity score matching: short-term outcomes at a high-capacity center. Sci Rep. (2020) 10(1):6502. doi: 10.1038/s41598-020-63616-1

47. Shibasaki S, Suda K, Nakauchi M, Nakamura K, Kikuchi K, Inaba K, et al. Non-robotic minimally invasive gastrectomy as an independent risk factor for postoperative intra-abdominal infectious complications: a single-center, retrospective and propensity score-matched analysis. World J Gastroenterol. (2020) 26(11):1172–84. doi: 10.3748/wjg.v26.i11.1172

48. Kong Y, Cao S, Liu X, Li Z, Wang L, Lu C, et al. Short-Term clinical outcomes after laparoscopic and robotic gastrectomy for gastric cancer: a propensity score matching analysis. J Gastrointest Surg. (2020) 24(3):531–9. doi: 10.1007/s11605-019-04158-4

49. 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. (2021) 274(1):128–37. doi: 10.1097/SLA.0000000000003845

50. Hikage M, Fujii K, Kamiya S, Tanizawa Y, Bando E, Notsu A, et al. Robotic gastrectomy compared with laparoscopic gastrectomy for clinical stage II/III gastric cancer patients: a propensity score-match analysis. World J Surg. (2021) 45(5):1483–94. doi: 10.1007/s00268-020-05939-8

51. Li ZY, Liu JJ, Yu PW, Zhao YL, Shi Y, Luo ZY, et al. Robotic total gastrectomy for carcinoma in the remnant stomach: a comparison with laparoscopic total gastrectomy. Gastroenterol Rep. (2021) 9(6):583–8. doi: 10.1093/gastro/ goab021

52. van Boxel GI, Ruurda JP, van Hillegersberg R. Robotic-assisted gastrectomy for gastric cancer: an European perspective. Gastric Cancer. (2019) 22(3):909–19. doi: 10.1007/s11605-019-04158-4

53. Jimenez-Rodriguez RM, Diaz-Pavon JM, de la Portilla de Juan F, Prendes-Sillero E, Dussort HC, Padillo J. Learning curve for robotic-assisted laparoscopic rectal cancer surgery. Int J Colorectal Dis. (2013) 28(6):815–21. doi: 10.1007/s00384-012-1620-6

54. Mege D, Hain E, Lakks Z, Maggiori L, Prost ALD), Panis Y. Is trans-anal total mesorectal excision really safe and better than laparoscopic total mesorectal excision with a perineal approach first in patients with low rectal cancer? A learning curve with case-matched study in 68 patients. Colorectal Dis. (2018) 20(6):O143–51. doi: 10.1111/codi.14238

55. Pugliese R, Maggioni D, Sansonna F, Costanzi A, Ferrari GC, Di Lernia S, et al. Subtotal gastrectomy with D2 dissection by minimally invasive surgery for distal adenocarcinoma of the stomach: results and 5-year survival. Surg Endosc. (2010) 24(10):2594–602. doi: 10.1007/s00464-010-1014-1

56. Abraham NS, Byrne CJ, Young JM, Solomon MJ. Meta-analysis of well-designed nonrandomized comparative studies of surgical procedures is as good as randomized controlled trials. J Clin Epidemiol. (2010) 63(3):238–45. doi: 10.1016/j.jclinepi.2009.04.005

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher’s Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Copyright © 2022 Baral, Arawker, Sun, Jiang, Wang, Wang, Ali and Wang. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.