ABSTRACT

Gastrectomy is considered the gold standard treatment for gastric cancer patients. Currently, there are two minimally invasive surgical methods to choose from, robotic gastrectomy (RG) and laparoscopic gastrectomy (LG). Nevertheless, it is still unclear which is superior between the two. This meta-analysis aimed to investigate the effectiveness and safety of RG and LG for gastric cancer. A systematic literature search was performed using PubMed, Embase, and the Cochrane Library databases until September 2018 in studies that compared RG and LG in gastric cancer patients. Operative and postoperative outcomes analyzed were assessed. The quality of the evidence was rated using the Grading of Recommendations, Assessment, Development and Evaluations. Twenty-four English studies were analyzed. The meta-analysis revealed that the RG group had a significantly longer operation time, lower intraoperative blood loss, and higher perioperative costs compared to the LG group. However, there were no differences in complications, conversion rate, reoperation rate, mortality, number of lymph nodes harvested, days of first flatus, postoperative hospitalization time, and survival rate between the two groups. RG was shown to be associated with decreased intraoperative blood loss and increased perioperative cost and operation time compared to LG. Several higher-quality original studies and prospective clinical trials are required to confirm the advantages of RG.

KEY WORDS: Gastric cancer, laparoscopic gastrectomy, meta-analysis, robot gastrectomy

INTRODUCTION

According to Bray et al., gastric cancer is the third most common cause of cancer-related death worldwide, and there were over 1,000,000 new cases and an estimated 783,000 deaths attributed to gastric cancer in 2018. Currently, gastrectomy with lymph node dissection is the gold standard treatment for gastric cancer. Since minimally invasive gastrectomy was performed in the 1990s, laparoscopic gastrectomy (LG) has been widely accepted as a treatment for gastric cancer. Compared to open surgical procedures, LG has been associated with better cosmetic results, less estimated blood loss, reduced pain, faster recovery, and favorable oncological outcomes. However, LG still has several disadvantages, including its two-dimensional (2D) visualization, patient's restricted dexterity of movement, amplification of hand tremors, and inconvenient surgical field exposure, bringing challenges to lymph node dissection. Moreover, the technical complexities and substantial learning curves of LG restrict its wide adaptation in surgery in clinical practice. Since the US Food and Drug Administration granted permission, robotic procedures have been performed in many fields of surgery, and robotic gastrectomy (RG) was first reported in 2003. Being another minimally invasive surgery procedure, the robotic surgery system offers several advantages, such as its 3D high-definition visualization, seven degrees of wrist-like motion, high-definition view of the operative field, and less fatigue, thus assisting the surgeons in overcoming the technical difficulties and limitations encountered when performing traditional laparoscopic surgery. Moreover, the learning curve, which is associated

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with surgeons gaining familiarity and proficiency, in RG is shorter than that in LG.[9]

Although several studies have revealed that RG was associated with less intraoperative blood loss and shorter postoperative length of stay than LG,[10,11] the real superiority of RG versus LG in the treatment of gastric cancer remains controversial. Hence, we performed this review and meta-analysis to compare the feasibility and efficacy between RG and LG in treating gastric cancer. Moreover, the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system was used to evaluate the outcomes of this meta-analysis.

MATERIALS AND METHODS

Literature search
A systematic review was performed using PubMed, Embase, and the Cochrane Library databases until September 2018 in all studies that compared RG and LG in treating gastric cancer. The search terms included “gastric carcinoma,” “gastric cancer,” “gastrectomy,” “gastric resection,” “robotic,” and “minimally invasive.” The search was limited to studies published in English. References of the acquired articles were also carried out to identify additional studies.

Study selection
Two investigators (Hua Qiu and Dongjun Yu) reviewed all the records found and subsequently browsed the titles and abstracts independently. The studies that satisfied the following criteria were included in this meta-analysis: (1) comparative studies comparing the outcomes of RG and LG in the treatment of gastric cancer and (2) full-text articles containing at least one of the outcomes that we were interested in. The following studies were excluded: (1) noncomparative studies such as reviews, conference reports, letters, and case reports; (2) studies including nongastric cancer patients; (3) studies that lacked sufficient data for statistical analysis; and (4) duplicate studies.

Data extraction and quality assessment
Two reviewers (Hua Qiu and Dongjun Yu) independently extracted the following data: author, region, years of publication, study design, characteristics of the study population, operative time, intraoperative blood loss, conversion rate, the number of lymph nodes harvested, proximal and distal margin distances, the days of first flatus, postoperative length of hospital stay, postoperative complications, mortality, perioperative cost, and survival rates. Disagreements were resolved through discussion. The Newcastle–Ottawa scale[12] was used to assess the quality of nonrandomized studies. The evaluation system contains the following three factors: patient selection, comparability between the groups, and assessment of outcome. The score ranges from 0 to 9, and studies with a score equal to or higher than 6 were deemed qualified.

Subgroups analysis
The resection type, body mass index (BMI), age, and depth of invasion are factors considered to affect the surgical outcomes as reported in several studies.[13-15] To eliminate bias, we performed several subgroup analyses to analyze the impact of the resection type, BMI, age, and depth of invasion.

Statistical analysis
Review Manager version 5.3 (Cochrane Collaboration, Oxford, England) software was used to perform this meta-analysis. The differences between continuous variables and dichotomous variables were evaluated using the weighted mean difference (WMD) and odds ratios (ORs) with the 95% confidence interval (95% CI), respectively. Moreover, the standard mean difference (SMD) with the 95% CI was performed when the unit was different. When the studies only offered the medians, we calculated the means and standard deviations and range according to the method described by Hozo et al.[16] The heterogeneity was quantified using the $I^2$ statistic.

Level of evidence
We rated the quality of the evidence using the GRADE, and the evidence profile was created using the GRADE profiler 3.6 software (The GRADE Working Group). There was quality degradation when the following considerations existed: the risks of biases, inconsistency, indirectness, imprecision, and publication biases. We evaluated the evidence qualities of the following outcomes: operative time, intraoperative blood loss, conversion rate, number of lymph nodes harvested, the days of first flatus, postoperative complications, postoperative length of hospital stay, and mortality.

RESULTS

Search results and study characteristics
The process of reference selection is illustrated in Figure 1. A total of 516 potentially relevant studies were initially found in the literature review. Subsequently, 354 studies were eliminated as they were duplicates. After examining the titles and abstracts, we excluded 24 articles because of the following reasons: non-English, reviews, conference reports, letters, case reports, protocols, and studies including nongastric cancer patients. We excluded 14 studies that were based on overlapping patient cohorts after carefully browsing the full text. Finally, a total of 24 nonrandomized studies[17-40] were eligible for this meta-analysis, with 2741 patients undergoing RG and 5672 patients undergoing LG. The study characteristics and methodological quality assessment of the 24 studies are shown in Table 1.

Operative time
The operative time was examined in all 24 studies. The pooled analysis including 8413 patients revealed that RG required a longer operative time compared to LG (WMD, 44.11; 95% CI, 24.20–64.01; $P < 0.0001$), with high heterogeneity among the studies ($I^2 = 99\%$) [Figure 2].
Intraoperative blood loss
The intraoperative blood loss was presented in 23 studies. The pooled analysis including 8225 patients revealed that the intraoperative blood loss was significantly lower for RG compared to LG (WMD, −17.78; 95% CI, −25.62−−9.94; \(P < 0.00001\)), with high heterogeneity among the studies (\(I^2 = 89\%\)) [Figure 3].

Days of first flatus
The days of first flatus was mentioned in 13 studies. The pooled analysis including 4127 patients revealed that there was no statistically significant difference between the two procedures (WMD, −0.20; 95% CI, −0.53−−0.14; \(P = 0.25\)), with high heterogeneity among the studies (\(I^2 = 98\%, P < 0.00001\)) [Figure 4].

Conversion rate
The conversion rate was recorded in six studies. The pooled analysis including 2876 patients revealed that there was no statistically significant difference between the two procedures (OR, 1.34; 95% CI, 0.59−3.01; \(P = 0.49\)), with no observed heterogeneity among the studies (\(I^2 = 0\%\)) [Figure 5].

Postoperative complication
The overall morbidity was mentioned in 23 studies. The pooled analysis including 8293 patients revealed that there was no statistically significant difference between the two procedures (OR, 0.88; 95% CI, 0.75−1.02; \(P = 0.09\)), with low heterogeneity among the studies (\(I^2 = 13\%\)) [Figure 6]. No significant differences in the rate of delayed gastric emptying (OR, 1.30; 95% CI, 0.61−2.80; \(P = 0.50\); \(I^2 = 0\%\)), intestinal obstruction (OR, 1.26; 95% CI, 0.65−2.44; \(P = 0.49\); \(I^2 = 0\%\)), intra-abdominal infection (OR, 0.95; 95% CI, 0.55−1.63; \(P = 0.85\); \(I^2 = 0\%\)), wound infection (OR, 1.20; 95% CI, 0.65−2.44; \(P = 0.49\); \(I^2 = 0\%\)), anastomotic leakage (OR, 0.88; 95% CI, 0.57−1.37; \(P = 0.58\); \(I^2 = 0\%\)), and pancreas-related complications (OR, 0.52; 95% CI, 0.20−1.35; \(P = 0.18\); \(I^2 = 0\%\)) were identified between the two procedures [Table 2].

![Figure 1: Flow diagram for identification of selected articles](image1)

![Figure 2: Forest plot and meta-analysis of the operation time](image2)
Mortality
The mortality was presented in four studies. The pooled analysis including 1345 patients revealed that there was no statistically significant difference between the two procedures (OR, 1.34; 95% CI, 0.36–4.96; P = 0.66), with no observed heterogeneity among the studies (I² = 0%) [Figure 7].

Number of lymph nodes harvested
The number of lymph nodes harvested was presented in 21 studies. The pooled analysis including 7005 patients revealed that RG was associated with a significant increase in the number of lymph nodes harvested compared to LG (WMD, 1.92; 95% CI, 0.34–3.5; P = 0.02), with high heterogeneity among the studies (I² = 86%) [Figure 8].

Postoperative hospitalization time
The postoperative length of hospital stay was presented in 23 studies. The pooled analysis revealed that there was no statistically significant difference between the two procedures (WMD, −0.36, 95% CI, −0.88–0.16; P = 0.18), with high heterogeneity among the studies (I² = 87%, P < 0.00001) [Figure 9].
Qiu, et al.: An updated systematic review and meta-analysis of robotic gastrectomy for gastric cancer

Perioperative costs

The perioperative costs were recorded in five studies. The pooled analysis revealed that the RG group was associated with higher perioperative costs compared to the LG group (SMD, 2.06; 95% CI, 1.05–3.06; P < 0.0001), with high heterogeneity among the studies (I² = 98%) [Figure 10].

Survival rate

The 3-year overall survival (OS) rate only presented in four studies. The pooled analysis revealed that the 3-year OS rate was comparable between the two procedures (OR, 1.12; 95% CI, 0.81–1.54; P = 0.50), with no observed heterogeneity among the studies (I² = 0%) [Figure 11]. The 5-year OS rate was recorded in three studies. The pooled analysis indicated that the 5-year OS rate was comparable between the two procedures (OR, 0.54; 95% CI, 0.22–1.33; P = 0.18), with high heterogeneity among the studies (I² = 79%; P = 0.008) [Figure 12]. The 5-year disease-free survival (DFS) rate was mentioned in two studies. The pooled analysis indicated that the 5-year DFS rate was comparable between the two procedures (OR, 0.79; 95% CI, 0.47–1.33; P = 0.38), with no observed heterogeneity among the studies (I² = 0%) [Figure 13].
Table 2: Systematic review of postoperative complication

| Outcomes of complications | Number of studies | Sample size | Heterogeneity (P, I²) (%) | Overall effect size | 95% CI of overall effect | P |
|---------------------------|-------------------|-------------|---------------------------|--------------------|-------------------------|---|
| Delayed gastric emptying  | 6                 | 501/1037    | 0.96, 0                   | OR=1.30            | 0.61-2.80               | 0.5 |
| Intestinal obstruction    | 10                | 1294/2729   | 0.72, 0                   | OR=1.26            | 0.65-2.44               | 0.49 |
| Intra-abdominal infection | 7                 | 905/2117    | 0.57, 0                   | OR=0.95            | 0.55-1.63               | 0.85 |
| Wound infection           | 10                | 1414/2867   | 0.68, 0                   | OR=1.20            | 0.76-1.87               | 0.43 |
| Anastomotic leakage       | 13                | 1692/3591   | 0.81, 0                   | OR=0.88            | 0.57-1.37               | 0.58 |
| Pancreas complication     | 7                 | 583/1179    | 0.69, 0                   | OR=0.52            | 0.20-1.35               | 0.18 |

RG=Robotic gastrectomy; LG=Laparoscopic gastrectomy, CI=Confidence interval, OR=Odds ratio

Figure 6: Forest plot and meta-analysis of the overall morbidity

Figure 7: Forest plot and meta-analysis of the mortality

Subgroup analysis of resection type
Considering distal gastrectomy, the meta-analysis revealed significantly lower operation time and low intraoperative blood loss in the RG group compared to the LG group, while the days of first flatus, overall complications, postoperative hospitalization time, and the number of lymph nodes harvested were comparable between the two procedures. As for total gastrectomy, the meta-analysis revealed that the operation time, intraoperative blood loss, days of first flatus, overall complications, postoperative hospitalization time, and number of lymph nodes harvested were comparable between the two procedures.
The results of the subgroup analysis on resection type are shown in Table 3.

**Subgroup analysis of body mass index**
Considering BMI <25, the meta-analysis revealed significantly longer operation time and increased number of lymph nodes harvested in the RG group compared to the LG group, while intraoperative blood loss, overall complications, and postoperative hospitalization time were comparable between the two procedures. As for BMI ≥25, the meta-analysis revealed significantly longer operation time in the RG compared to the LG group, while intraoperative blood loss, overall...
Table 3: Results of the subgroup analysis of resection type

| Outcomes              | Number of studies | Sample size | Heterogeneity (P, P) (%) | Overall effect size | 95% CI of overall effect | P     |
|-----------------------|-------------------|-------------|--------------------------|---------------------|--------------------------|-------|
| Operation time (min)  |                   |             |                          |                     |                          |       |
| DG                    | 9                 | 507         | 1122                     | <0.001, 97          | WMD=42.07                | 22.25-61.89 | <0.01 |
|                       | 6                 | 218         | 508                      | <0.001, 99          | WMD=−35.36               | −88.00-17.28 | 0.19  |
| Blood loss (mL)       |                   |             |                          |                     |                          |       |
| DG                    | 9                 | 507         | 1122                     | <0.001, 90          | WMD=−18.52               | −30.35-6.70 | <0.01 |
|                       | 6                 | 218         | 508                      | <0.001, 90          | WMD=−16.22               | −66.97-32.52 | 0.50  |
| Days of first flatus  |                   |             |                          |                     |                          |       |
| DG                    | 3                 | 112         | 118                      | 0.75, 0             | WMD=−0.45                | −0.96-0.07 | 0.09  |
|                       | 4                 | 165         | 297                      | <0.001, 91          | WMD=−0.24                | −0.51-0.14 | 0.08  |
| Overall complications |                   |             |                          |                     |                          |       |
| DG                    | 8                 | 449         | 1055                     | 0.86, 0             | OR=0.72                  | 0.50-1.04 | 0.08  |
|                       | 5                 | 176         | 443                      | 0.37, 6             | OR=0.85                  | 0.51-1.41 | 0.53  |
| Hospital stay (days)  |                   |             |                          |                     |                          |       |
| DG                    | 9                 | 507         | 1122                     | <0.001, 91          | WMD=−0.30                | −1.19-0.59 | 0.51  |
|                       | 5                 | 282         | 440                      | 0.79, 0             | WMD=−0.21                | −1.17-0.75 | 0.67  |
| Retrieved LNs         |                   |             |                          |                     |                          |       |
| DG                    | 9                 | 507         | 1122                     | <0.001, 90          | WMD=3.24                 | −0.57-7.04 | 0.10  |
|                       | 5                 | 167         | 443                      | 0.1, 49             | WMD=1.31                 | −0.67-3.29 | 0.19  |

RG=Robotic gastrectomy, LG=Laparoscopic gastrectomy, DG=Distal gastrectomy, TG=Total gastrectomy, LNs=Lymph nodes, CI=Confidence interval, WMD=Weighted mean difference, OR=Odds ratio
complications, postoperative hospitalization time, and number of lymph nodes harvested were comparable between the two procedures. The results of the subgroup analysis on BMI are shown in Table 4.

**Subgroup analysis of age**
Considering age <65, the meta-analysis revealed that the operation time, intraoperative blood loss, postoperative hospitalization time, and number of lymph nodes harvested were comparable between the two procedures. As for age ≥ 65, the meta-analysis revealed significantly longer operation time and low intraoperative blood loss in the RG group compared to the LG group, while postoperative hospitalization time and number of lymph nodes harvested were comparable between the two procedures. The results of the subgroup analysis on age are shown in Table 5.

**Subgroup analysis of depth of invasion**
Considering early gastric cancer, the meta-analysis revealed that the operation time was significantly longer in the RG group compared to the LG group, while intraoperative blood loss, overall complications, and postoperative hospitalization time were comparable between the two procedures. As for advanced gastric cancer, the meta-analysis revealed

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**Table 4: Results of the subgroup analysis of body mass index**

| Outcomes                        | Number of studies | Sample size | Heterogeneity (P, I²) (%) | Overall effect size | 95% CI of overall effect | P     |
|---------------------------------|-------------------|-------------|---------------------------|---------------------|--------------------------|-------|
| Operation time (min)            |                   |             |                           |                     |                          |       |
| BMI <25                         | 3                 | 199 300    | 0.14, 50                  | WMD=43.30           | 35.02-51.59              | <0.01 |
| BMI ≥25                         | 3                 | 84 162     | 0.01, 76                  | WMD=29.96           | 2.57-57.35               | 0.03  |
| Blood loss (mL)                 |                   |             |                           |                     |                          |       |
| BMI <25                         | 3                 | 199 300    | 0.003, 82                 | WMD=−13.76          | −38.12-10.61             | 0.27  |
| BMI ≥25                         | 3                 | 84 162     | 0.007, 80                 | WMD=−44.55          | −98.66-9.56              | 0.11  |
| Overall complications           |                   |             |                           |                     |                          |       |
| BMI <25                         | 2                 | 174 246    | 0.37, 0                   | OR=0.86             | 0.45-1.66                | 0.65  |
| BMI ≥25                         | 2                 | 61 133     | 0.41, 0                   | OR=1.69             | 0.74-3.88                | 0.21  |
| Hospital stay (days)            |                   |             |                           |                     |                          |       |
| BMI <25                         | 2                 | 174 246    | 0.05, 75                  | WMD=−0.32           | −1.88-1.24               | 0.69  |
| BMI ≥25                         | 2                 | 71 133     | 0.37, 0                   | WMD=−0.47           | −1.56-0.61               | 0.39  |
| Retrieved LNs                   |                   |             |                           |                     |                          |       |
| BMI <25                         | 3                 | 199 300    | 0.54, 0                   | WMD=2.51            | 058-4.43                 | 0.01  |
| BMI ≥25                         | 3                 | 84 162     | 0.01, 78                  | WMD=−6.24           | −12.53-0.05              | 0.05  |

RG=Robotic gastrectomy, LG=Laparoscopic gastrectomy, BMI=Body mass index, LNs=Lymph nodes, CI=Confidence interval, WMD=Weighted mean difference, OR=Odds ratio

**Table 5: Results of the subgroup analysis of age**

| Outcomes                        | Number of studies | Sample size | Heterogeneity (P, I²) (%) | Overall effect size | 95% CI of overall effect | P     |
|---------------------------------|-------------------|-------------|---------------------------|---------------------|--------------------------|-------|
| Operation time (min)            |                   |             |                           |                     |                          |       |
| Age <65                         | 2                 | 161 397    | 0.11, 60                  | WMD=7.64            | 2.23-14.20               | <0.01 |
| Age ≥65                         | 2                 | 59 132     | 0.41, 0                   | WMD=8.22            | 0.27-15.01               | 0.04  |
| Blood loss (mL)                 |                   |             |                           |                     |                          |       |
| Age <65                         | 2                 | 161 397    | 0.02, 82                  | WMD=−7.37           | −24.59-9.13              | 0.37  |
| Age ≥65                         | 2                 | 59 132     | 0.72, 0                   | WMD=−25.91          | −36.36-15.45             | <0.01 |
| Hospital stay (days)            |                   |             |                           |                     |                          |       |
| Age <65                         | 2                 | 161 397    | <0.001, 97                | WMD=−1.07           | −2.93-0.79               | 0.26  |
| Age ≥65                         | 2                 | 59 132     | 0.02, 81                  | WMD=−0.70           | −2.54-1.15               | 0.46  |
| Retrieved LNs                   |                   |             |                           |                     |                          |       |
| Age <65                         | 2                 | 161 397    | 0.13, 55                  | WMD=3.80            | 0.08-7.51                | 0.05  |
| Age ≥65                         | 2                 | 59 132     | 0.33, 0                   | WMD=1.93            | −1.84-5.71               | 0.32  |

RG=Robotic gastrectomy, LG=Laparoscopic gastrectomy, LNs=Lymph nodes, CI=Confidence interval, WMD=Weighted mean difference
significantly longer operation time and low intraoperative blood loss in the RG group compared to the LG group, while the overall complications and postoperative hospitalization time were comparable between the two procedures. As for nonserosal invasion, the meta-analysis revealed significantly longer operation time and low intraoperative blood loss in the RG group compared to the LG group, while the overall complications, postoperative hospitalization time, and number of lymph nodes harvested were comparable between the two procedures. As for serosal invasion, the meta-analysis revealed significantly longer operation time, significantly increased number of lymph nodes harvested, and significantly low intraoperative blood loss in the RG group compared to the LG group, while the overall complications and postoperative hospitalization time were comparable between the two procedures. The results of the subgroup analysis on the depth of invasion are shown in Table 6.

**DISCUSSION**

Gastrectomy with extensive lymphadenectomy is considered the gold standard in the treatment of gastric cancer. Nevertheless, different surgical strategies could influence the intraoperative and postoperative outcomes and directly affect the quality of life of the patients. With the rapid development of techniques and the increasing interest in minimally invasive surgery, LG has become increasingly used, which has been associated with a better short-term outcome and an equal long-term efficacy compared with conventional open gastrectomy. With the development of robotic surgery, RG was gradually developed as an alternative to minimally invasive surgery for the treatment of gastric cancer. However, the clinically significant benefits of robotic application on intraoperative effects, postoperative outcomes, and oncological outcomes of gastric cancer patients are yet to be sufficiently determined. The meta-analysis revealed that the complications, conversion rate, reoperation rate, mortality, days of first flatus, postoperative hospitalization time, 3-year survival rate, and 5-year survival rate were comparable between the two procedures, which were similar to other recent studies. However, intraoperative blood loss decreased, and perioperative cost, operation time, and number of lymph nodes harvested were increased in the RG group.

Intraoperative blood loss is one of the most important indices that surgeons are concerned about during surgery. Theoretically, robotic surgery is a more precise technique that could potentially reduce blood loss. With regard to intraoperative blood loss, this meta-analysis revealed significantly decreased intraoperative blood loss in the RG group compared to the LG group, which might be attributed to the robotic procedure being more stable on the surgeon’s hands, hence drastically decreasing musculoskeletal fatigue and physiologic tremor over time in the surgeons. In addition, the robotic device provides augmented flexibility in a confined narrow operative space, and the 3D high-definition field of view allows surgeons to effectively minimize the risk of tissue and blood vessel injuries, which may be related to decreased intraoperative blood loss.

As for the operative time, RG takes longer than LG. The following are the reasons why longer operation time is associated with

| Outcomes                  | Number of studies | Sample size | Heterogeneity (P, I²) (%) | Overall effect size | 95% CI of overall effect | P   |
|---------------------------|-------------------|-------------|---------------------------|---------------------|-------------------------|-----|
| Operation time (min)      |                   |             |                           |                     |                         |     |
| EGC                       | 2                 | 185/748     | <0.001, 92                | WMD=47.37           | 10.33-84.41             | 0.01|
| AGC                       | 4                 | 441/555     | <0.001, 97                | WMD=35.78           | 2.69-68.86              | 0.03|
| Serosal invasion          | 2                 | 118/285     | 0.84, 0                   | WMD=29.96           | 17.28-42.64             | 0.01|
| Nonserosal invasion       | 2                 | 87/157      | 0.23, 32                  | WMD=28.96           | 5.23-52.68              | 0.02|
| Blood loss (mL)           |                   |             |                           |                     |                         |     |
| EGC                       | 2                 | 185/746     | <0.001, 93                | WMD=−0.55           | −49.27-48.17            | 0.98|
| AGC                       | 4                 | 441/555     | <0.001, 84                | WMD=−30.83          | −47.34-14.32            | <0.01|
| Serosal invasion          | 2                 | 118/285     | 0.53, 0                   | WMD=−40.17          | −70.80-9.55             | 0.01|
| Nonserosal invasion       | 2                 | 87/157      | 0.47, 0                   | WMD=−65.58          | −104.94-26.22           | <0.01|
| Overall complications     |                   |             |                           |                     |                         |     |
| EGC                       | 2                 | 185/746     | 0.67, 0                   | OR=1.28             | 0.73-2.23               | 0.39|
| AGC                       | 4                 | 441/555     | 0.08, 56                  | OR=0.73             | 0.39-1.36               | 0.32|
| Serosal invasion          | 2                 | 118/285     | 0.96, 0                   | OR=1.01             | 0.49-2.09               | 0.98|
| Nonserosal invasion       | 2                 | 87/157      | 0.59, 0                   | OR=1.40             | 0.58-3.38               | 0.46|
| Hospital stay (days)      |                   |             |                           |                     |                         |     |
| EGC                       | 2                 | 185/746     | 0.88, 0                   | WMD=−0.02           | −0.72-0.69              | 0.97|
| AGC                       | 3                 | 339/494     | 0.69, 0                   | WMD=−0.22           | −0.83-0.40              | 0.49|
| Serosal invasion          | 2                 | 118/285     | 0.58, 0                   | WMD=−0.32           | −1.18-0.55              | 0.48|
| Nonserosal invasion       | 2                 | 87/157      | 0.31, 33                  | WMD=−0.21           | −1.66-1.25              | 0.78|
| Retrieved LN             |                   |             |                           |                     |                         |     |
| Serosal invasion          | 2                 | 118/285     | 0.70, 0                   | WMD=2.33            | 0.30-4.35               | 0.02|
| Nonserosal invasion       | 2                 | 87/157      | <0.001, 96                | WMD=3.77            | −16.31-8.77             | 0.56|

RG=Robotic gastrectomy, LG=Laparoscopic gastrectomy, BMI=Body mass index, LNs=Lymph nodes, CI=Confidence interval, WMD=Weighted mean difference, OR=Odds ratio, EGC=Early gastric cancer, AGC=Advance gastric cancer
RG. First, the robotic procedure is an innovative technology, hence requiring an ample amount of time to adapt to it. This meta-analysis represents some studies on the surgeons’ primary experiences with RG and some surgeons who were likely still in the learning phase. As reported, the operation time for RG stabilizes after at least finishing 15 cases and subsequently decreases gradually, and surgeons who have experience performing LG can perform RG successfully even in their first surgery and reach a plateau in operation time after 20 cases. Moreover, the learning curve for RG was a critical factor, which might exert an additional influence on this indicator. As surgeons become more skillful in performing robotic procedures, the operative time for RG might decrease. Second, in the RG group, the facility is more sophisticated and requires additional setup and docking time before the operations. The setup procedure often takes half an hour to complete. Lu et al. stated that the total operation time and purely operation time (subtracting time required for docking and undocking) are both longer than laparoscopic surgical system. Unfortunately, most of the included studies in this review and meta-analysis did not elaborate on whether the preparation times for devices included the operation times; thus, data that allowed us to perform a further analysis were insufficient. Third, because of the insufficient tactile feedback, the surgeons can only evaluate the applied force on the tissue, which depends on the analyzed visual information during the operation, which may lengthen the operation time. However, the prolonged operation time was not associated to any increase in open conversions, postoperative complications, or mortality.

The postoperative morbidity and mortality were important indicators in estimating the operational safety and feasibility. In this meta-analysis, the overall morbidity was comparable between the two procedures. The risk of complications is associated with conversion rate and intraoperative blood loss. In this meta-analysis, conversion rate and the intraoperative blood loss were comparable between the two groups. Thus, it is understandable that there was similar incidence of complications between the two groups. Anastomotic leakage is an important abdominal complication that leads to an increase in mortality after gastrectomy. In this meta-analysis, the anastomotic leakage rate in the RG group equally matched to those of the LG group. Hitherto, there is also no obvious evidence supporting the idea that the surgical procedures might affect the anastomotic leakage rate after gastrectomy. Moreover, obesity with heavy mesentery is associated with a higher incidence of intraoperative and postoperative surgical complications. The subgroup analysis of BMI mainly revealed similar result. In addition, the mortality in the RG group is equal to LG group. Thus, it is convincitively accepted that both RG and LG are considered safe treatments in gastric cancer patients.

Adequate lymphadenectomy is important for long-term oncological outcomes. According to Son et al., the number of retrieved lymph nodes during extraperigastric lymphadenectomy, especially in the case of splenic pedicle and splenic hilum and in the suprapancreatic areas, was significantly higher for the robotic group compared to the laparoscopy group (15.9 ± 12.2, P = 0.002). According to another included study, RG is accompanied by a significantly high number of lymph nodes harvested in total (37.1 ± 12.9 vs. 34.1 ± 12.1, P = 0.04) and particularly at the extraperigastric stations (16.3 ± 7.7 vs. 3.2 ± 5.3, P = 0.001). The meta-analysis revealed that the number of lymph nodes harvested was statistically different between the RG group and the LG group. However, the subgroup analysis of resection type and depth of invasion revealed that the number of lymph nodes harvested was comparable between the two procedures. Therefore, case-matching studies on the type of gastrectomy and extent of lymphadenectomy that are closely associated between RG and LG should be analyzed in the future.

The main disadvantage of RG is that it is costly. The high price of robotic surgery could be attributed to initial purchasing costs, disposable consumables costs, and maintenance costs. A high therapy cost will affect the preferences of the majority of patients. In this meta-analysis, the hospitalization costs of RG were significantly higher compared to LG. However, when this disadvantage may be overcome, the robotic approach will be more widely used.

We estimated the quality of the evidence using the GRADE approach, and the results are shown in Figure 14. The quality of the evidence was considered only low (intraoperative blood loss, operation time, number of lymph nodes harvested, days of first flatus, mortality, overall morbidity, and postoperative hospitalization time) and very low (reoperation and conversion rate) attribute to the limited evidence derived from nonrandomized controlled trials (RCTs), and another reason was the existence of publication bias. It is difficult for us to hypothesize that the association depends on the existing researches; hence, further RCTs are needed to measure the significant differences between intraoperative and postoperative outcomes.

The following limitations of this meta-analysis should be considered: (1) most of the information were derived from retrospective nonrandomized comparisons, a key limitation that may have introduced a certain bias in the study; (2) it is difficult to eliminate the heterogeneity in patient characteristics and the skills and experience of the surgeons between the RG and LG groups; (3) the inclusion of different gastrectomy types and the extent of lymphadenectomy also have possibly introduced bias; and (4) a publication bias and lack of long-term follow-up data are some of the other notable limitations of our study. With all of these limitations, further multicenter, prospective RCTs should be performed to identify the potential advantages and disadvantages of RG.
CONCLUSIONS

This meta-analysis revealed that RG was associated with decreased intraoperative blood loss, increased perioperative cost and operation time, and number of lymph nodes harvested compared to LG. The effectiveness and safety of RG is similar to LG. Based on the GRADE system, the quality of the evidence of the investigation is low; hence, more high-quality studies, large samples, multiple centers, and long-term follow-up RCTs are needed to provide strong evidence to confirm the advantages of RG.

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Conflicts of interest

There are no conflicts of interest.

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