Efficacy Evaluation of Subtotal and Total Gastrectomies in Robotic Surgery for Gastric Cancer Compared with that in Open and Laparoscopic Resections: A Meta-Analysis

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Abstract

\textbf{Purpose(s):} Robotic gastrectomy (RG), as an innovation of minimally invasive surgical method, is developing rapidly for gastric cancer. But there is still no consensus on its comparative merit in either subtotal or total gastrectomy compared with laparoscopic and open resections.

\textbf{Methods:} Literature searches of PubMed, Embase and Cochrane Library were performed. We combined the data of four studies for RG \textit{versus} open gastrectomy (OG), and 11 studies for robotic RG \textit{versus} laparoscopic gastrectomy (LG). Moreover, subgroup analyses of subtotal and total gastrectomies were performed in both RG \textit{vs.} OG and RG \textit{vs.} LG.

\textbf{Results:} Totally 12 studies involving 8493 patients met the criteria. RG, similar with LG, significantly reduced the intraoperative blood loss than OG. But the duration of surgery is longer in RG than in both OG and LG. The number of lymph nodes retrieved in RG was close to that in OG and LG (WMD = 0.78 and 95\% CI, 2.15 – 0.59; WMD = 0.63 and 95\% CI, 2.24 – 3.51). And RG did not increase morbidity and mortality in comparison with OG and LG (OR = 0.92 and 95\% CI, 0.69 – 1.23; OR = 0.72 and 95\% CI, 0.25 – 2.06) and (OR = 1.06 and 95\% CI, 0.84 – 1.34; OR = 1.55 and 95\% CI, 0.49 – 4.94). Moreover, subgroup analysis of subtotal and total gastrectomies in both RG \textit{vs.} OG and RG \textit{vs.} LG revealed that the scope of surgical dissection was not a positive factor to influence the comparative results of RG \textit{vs.} OG or LG in surgery time, blood loss, hospital stay, lymph node harvest, morbidity, and mortality.

\textbf{Conclusions:} This meta-analysis highlights that robotic gastrectomy may be a technically feasible alternative for gastric cancer because of its affirmative role in both subtotal and total gastrectomies compared with laparoscopic and open resections.

Introduction

Gastric cancer is the fourth most common malignancy and second leading cause of cancer death in the world [1]. Surgical resection remains the only curative treatment option and open gastrectomy with lymphadenectomy took a leading position in the treatment of gastric cancer for a long time. Kitano \textit{et al.} firstly reported the laparoscopy-assisted distal gastrectomy for gastric cancer in 1994 [2]. Since then, LG has been gradually spread worldwide [3–5].

Minimally invasive surgery represents a developing trend for its unique characteristics. However, conventional laparoscopic surgery itself, accompanied by some limitations such as instrument movement, amplification of hand tremor, two-dimensional imaging, and ergonomic discomfort for the surgeons. Robotic surgery, an emerging technology, was invented to overcome the disadvantages of conventional laparoscopic surgery in 1997 [6]. For robotic surgery, several robotic devices have been developed, but only the Da Vinci Surgical System was widely used [7]. To date, robotic surgery has been maturely adopted in many fields of advanced surgical procedures worldwide, especially for prostate cancer [8]. In the field of gastric cancer, robotic gastrectomy (RG) has been reported to be beneficial for patients, with less injury and also with compatible short-term oncologic outcomes to open gastrectomy (OG) or laparoscopic gastrectomy (LG) [9–20].
However, sample size, a single institution design and different appraise system of complications limited these studies to conclude objective result. To overcome these limitations, a meta-analysis of RG vs. OG or LG for gastric cancer was performed to determine the relative merits of RG for gastric cancer.

Methods

Publication Search

Three electronic databases (PubMed, EMBASE, and Cochrane Library) were searched [last search was updated on 01 June 2013, using the search terms: robotics OR robot PLUS gastrectomy PLUS cancer OR carcinoma OR adenocarcinoma OR malignancy PLUS open OR laparoscope]. Article language was limited to English. All eligible studies were retrieved, and their bibliographies were checked for other relevant publications. Review articles and bibliographies of other relevant studies identified were hand-searched to identify additional eligible studies. Only published studies with full-text articles were included. When the same patient population was included in several publications, only the most recent or complete study was used in this meta-analysis.

Inclusion Criteria

The inclusion criteria were as follows: (a) controlled studies of RG vs. LG or RG vs. OG for gastric cancer; (b) report on at least one of the outcome measures mentioned below; and (c) sufficient published data to estimate an odds ratio (OR) with 95% confidence interval (CI).

Exclusion criteria

Abstracts, letters, editorials and expert opinions, reviews without original data, case reports and studies lacking control groups were excluded. The following studies or data were also excluded: (1) they reported on gastric surgery for benign lesions and gastrointestinal stromal tumor (GIST) and did not contain a distinct group they reported on gastric surgery for benign lesions and gastroin-estinal stromal tumor (GIST); (2) the outcomes and parameters of patients were not clearly reported; (3) it was impossible to extract the appropriate data from the published results; and (4) there was overlap between authors or centers in the published literature.

Quality Assessment

The methodological quality of the studies included was assessed. Jadad Scale and MINORS were usually used to assess the quality of RCTs and non-RCTs, respectively [21,22].

Data Extraction

Information was carefully extracted from all eligible studies by two of the authors (Zong L and Seto Y), according to the inclusion criteria listed above. The following information were collected from each study: first author’s surname, publication date, district, resection extent, reconstruction method, BMI index, TNM stage, study type, and total number of patients in RG group and OG group or LG group, respectively. We did not define a minimum number of patients for inclusion in our meta-analysis.

Statistical Analysis

Odds ratios with 95% CI were used for the comparisons of dichotomous variables (e.g., morbidity, and mortality) between surgical methods according to the method of Woolf. Heterogeneity assumption was confirmed by the X²-based Q-test. A P-value greater than 0.10 for the Q-test indicated a lack of heterogeneity among the studies, therefore, the OR estimate for each study was calculated by the fixed-effects model (the Mantel-Haenszel method). Otherwise, the random-effects model (the DerSimonian and Laird method) was used. The significance of the pooled OR was determined by the Z-test and P > 0.05 was considered statistically significant. Weighted mean difference (WMD) with 95% confidence intervals (95% CI) was calculated for continuous variables (e.g., operation time, and blood loss). WMD was pooled by using the inverse variance model. Sensitivity analyses were carried out to determine if modification of the inclusion criteria for this meta-analysis affected the final results. An estimate of potential publication bias was carried out using the funnel plot, in which the OR for each study was plotted against its log (OR). An asymmetric plot suggested possible publication bias. Funnel plot asymmetry was assessed using Egger’s linear regression test, a linear regression approach to measure funnel plot asymmetry on the natural logarithm scale of the OR. The significance of the intercept was determined by the t-test, as suggested by Egger (P < 0.05 was considered representative of statistically significant publication bias). All statistical tests were performed with Review Manager Version 5.0 (The Cochrane Collaboration, Oxford, England).

Results

Study Characteristics

Of the 14 published pieces of literature [9–20,23], 12 studies were eligible in this meta-analysis. Two studies published by the same team from the same institute within the same study interval were regarded as 1 trial, but both studies were included and shared the same study number because some separately published data was complementary [17,23]. Hence, a total of 12 studies including 8493 patients were used in the pooled analyses. Table 1 lists the studies identified and their main characteristics. Of the 12 groups, sample size ranged from 39 to 5839 (Figure 1).

Robotic gastrectomy versus open gastrectomy

The mean operation time of RG was 68.47 minutes longer than OG, but intraoperative blood loss and hospital stay were significantly reduced by RG (WMD = 68.47 and 95% CI, 63.40–73.54; WMD = −106.63 and 95% CI, −163.13–−50.13; WMD = −2.49 and 95% CI, −3.72–−1.27). The difference of lymph node harvest between RG and OG was not statistically significant (WMD = −0.78 and 95% CI, −2.15–0.59). Moreover, Meta-analyses on morbidity and mortality indicated that there was no significant differences between RG and OG (OR = 0.92 and 95% CI, 0.69–1.23; OR = 0.72 and 95% CI, 0.25–2.06). Also, specifically for anastomotic leakage, no difference was observed between two groups (OR = 1.72 and 95% CI, 0.97–3.07). Subgroup analysis of subtotal gastrectomy, and subtotal and total gastrectomies for above parameters all showed a similar trend with the combined results (Table 2) (Figure 2).

Robotic gastrectomy versus Laparoscopic gastrectomy

Operation time was significantly longer in RG compared with LG (WMD = 57.15 and 95% CI, 42.26–72.05). Both as the minimally invasive surgery, RG did not showed a priority in intraoperative blood loss (WMD = −28.59 and 95% CI, −56.57–−0.62). As for postoperative hospital stay, there was no significant difference (WMD = −0.16 and 95% CI, −0.87–0.55). In analysis of lymph node harvest, it did not attain statistical significance between RG and LG (WMD = 0.63 and 95% CI, −2.24–3.51). Further analysis revealed that RG did not carry additional postoperative morbidity, as well as anastomotic leakage, and mortality when compared with LG (OR = 1.06 and 95% CI, 0.84–1.34; OR = 1.10 and 95% CI, 0.66–1.82; OR = 1.53 and 95% CI, 0.49–4.94) (Table 3) (Figure 3). However, Meta-analysis
### Table 1. Main characteristics of all studies included in the meta-analysis.

| Study       | Study Period | District | Size | Study Group | Resection extent | Reconstruction method | BMI | Stage | Study type |
|-------------|--------------|----------|------|-------------|-------------------|-----------------------|-----|-------|------------|
| Caruso et al | 2011         | Italy    | 149  | RG/OG       | Total/Subtotal 12/7/37/83 | NA                    | 27±3/28±4 | NA    | Controlled |
| Eom et al   | 2012         | Korea    | 92   | RG/LG       | Subtotal 30/62       | NA                    | 24.2/24.1| 81/9/2| Controlled |
| Huang et al | 2012         | Taiwan   | 689  | RG/LG/OG    | Total/Subtotal 7/32/7/57/179/407 | B-I/B-II/Roux-en-Y | 24.2±3.7/24.3±3.3/23±3.6 | 282/122/285| Controlled |
| Hyun et al  | 2012         | Korea    | 121  | RG/LG       | Total/Subtotal 9/29/18/65 | B-I/B-II/Roux-en-Y | 23.8±2.6/23.8±2.9 | 97/14/10| Controlled |
| Kang et al  | 2012         | Korea    | 382  | RG/LG       | Total/Subtotal 16/84/37/245 | B-I/B-II/Roux-en-Y | 23.7±3.7/23.6±3.5 | NA    | Controlled |
| Kim et al   | 2010         | Korea    | 39   | RG/LG/OG    | Subtotal 12/11/16 | NA | 21.3±3.4/25.3±2.5/25.2±1.9 | 27/9/3 | Controlled |
| Kim et al   | 2012         | Korea    | 5839 | RG/LG/OG    | Total/Subtotal 109/158/1232/327/703/3309 | B-I/B-II/Roux-en-Y | 23.6±3.1/23.5±2.8/23.3±8.0 | NA    | Controlled |
| Park et al  | 2012         | Korea    | 150  | RG/LG       | Subtotal 30/120 | NA | NA | NA | Controlled |
| Pugliese et al | 2010     | Italy    | 64   | RG/LG       | Subtotal 16/48 | NA | NA | NA | Controlled |
| Song et al  | 2009         | Korea    | 40   | RG/LG       | Subtotal 20/20 | NA | 23.4±2.1/22.4±2.1 | 39/1/0 | Controlled |
| Woo et al   | 2011         | Korea    | 827  | RG/LG       | Total/Subtotal 62/172/108/481 | B-I/B-II/Roux-en-Y | 23.5±3.5/23.5±3 | NA | Controlled |
| Yoon et al  | 2012         | Korea    | 101  | RG/LG       | Total 36/65 | NA | 23.2±2.5/23.6±3.4 | 84/14/3 | Controlled |

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on another surgical outcome evaluation system with Clavien-Dindo grades also did not show significant differences in any subdivided grade. Subgroup analysis of subtotal gastrectomy, total gastrectomy, and subtotal and total gastrectomies was also performed for above parameters and no single subgroup showed a heterogeneous result with the combined one (Table 3) (Figure 4).

Publication Bias

Begg's funnel plot was performed to assess publication bias. The heterogeneity tests for comparing the 12 combined studies showed heterogeneity in some analyses such as operation time, blood loss and so on; however, when significant heterogeneity occurred among the studies, random-effects model was used.

Discussion

Radical gastrectomy with lymphadenectomy has been widely applied in open surgery as standard surgical treatment for gastric cancer. Although minimally invasive surgery improves quality of life, it should be ensured that this technique does not increase morbidity and mortality [24]. With the developing of technique, minimally invasive surgery has gained a revolutionized application in general surgery from last century. But for gastric cancer, minimally invasive surgery experienced a controversy focusing on morbidity and mortality for a long time. Laparoscopic gastrectomy with limited lymphadenectomy is rapidly increasing and quickly admitted in early gastric cancer because of the mass and individual screening in Japan [25]. But the data was still incomplete to support the widespread use of laparoscopic gastrectomy for advanced gastric cancer in last decade [26].

Open gastrectomy with D2 lymphadenectomy is a technically demanding operation for advanced gastric cancer compared with D1, although there is the potential for appreciable morbidity and mortality [27,28]. Therefore, the assessment in favor of D2 lymphadenectomy makes it an integral part of laparoscopic surgery for advanced gastric cancer. Recently strong evidence from a multi-center retrospective study of laparoscopic surgery over open surgery confirmed the therapeutic role of Laparoscopic gastrectomy in advanced gastric cancer [29].

Robotic surgery, as an innovation of laparoscopic surgery, might be a simpler way to expand the indications of minimally invasive surgery for gastric cancer. However, controlled prospective studies are needed to evaluate the role of robotics in the management of gastric cancer. Some studies have demonstrated that robotic total and subtotal gastrectomies with D2-lymphadenectomy are technically feasible and safe, with acceptable surgical and oncological short-term results [15,30–32]. It is particularly notable that only a few reports have examined the technical feasibility of robotic surgery for gastric cancer till 2011 [9,14,17–19], and the number of patients included in these studies was too
Table 2. Meta-analyses results for robotic gastrectomy vs. open gastrectomy.

| Parameters                  | Studies | Sample Size | Heterogeneity | OR or WMD | Effect 95% CI | P      |
|-----------------------------|---------|-------------|---------------|-----------|---------------|--------|
| Operation time              | 3       | 481 4674    | P = 0.74, I^2=0% | 68.47     | 63.40–73.54   | P<0.0001 |
| Subgroup of SG              | 1       | 16 12      | NA            | 77.20     | 54.75–99.65   | P<0.0001 |
| Subgroup of SG and TG       | 2       | 465 4662   | P = 1.00, I^2=0% | 68.00     | 62.79–73.21   | P<0.0001 |
| Intraoperative blood loss   | 3       | 481 4674    | P = 0.003, I^2=83% | −106.63   | −163.13–−50.13 | P = 0.0002 |
| Subgroup of SG              | 1       | 16 12      | NA            | −48.50    | −91.07–5.93   | P=0.03   |
| Subgroup of SG and TG       | 2       | 465 4662   | P = 0.04, I^2=77% | −39.05    | −217.08–61.02 | P = 0.0005 |
| Hospital stay               | 3       | 481 4674    | P = 0.06, I^2=64% | −2.49     | −3.72–1.27    | P<0.0001 |
| Subgroup of SG              | 1       | 16 12      | NA            | −1.60     | −2.41–0.79    | P<0.0001 |
| Subgroup of SG and TG       | 2       | 465 4662   | P = 0.34, I^2=0% | −3.07     | −4.14–2.01    | P<0.0001 |
| Lymph node harvest          | 4       | 520 5260    | P = 0.55, I^2=0% | −0.78     | −2.15–0.59    | P = 0.27 |
| Subgroup of SG              | 1       | 16 12      | NA            | −2.03     | −10.15–5.75   | P = 0.59 |
| Subgroup of SG and TG       | 3       | 504 5248   | P = 0.37, I^2=0% | −0.73     | −2.13–0.66    | P = 0.30 |
| Anastomotic leakage         | 4       | 520 5260    | P = 0.53, I^2=0% | 1.72      | 0.97–3.07     | P = 0.06 |
| Subgroup of SG              | 1       | 16 12      | NA            | NE        | NE            | NA     |
| Subgroup of SG and TG       | 3       | 504 5248   | P = 0.53, I^2=0% | 1.72      | 0.97–3.07     | P = 0.06 |
| Morbidity                   | 4       | 520 5260    | P = 0.65, I^2=0% | 0.92      | 0.69–1.23     | P = 0.59 |
| Subgroup of SG              | 1       | 16 12      | NA            | 0.13      | 0.01–2.92     | P = 0.20 |
| Subgroup of SG and TG       | 3       | 504 5248   | P = 0.97, I^2=0% | 0.95      | 0.71–1.27     | P = 0.72 |
| Mortality                   | 4       | 520 5260    | P = 0.52, I^2=0% | 0.72      | 0.25–2.06     | P = 0.54 |
| Subgroup of SG              | 1       | 16 12      | NA            | 0.13      | 0.01–2.92     | P = 0.20 |
| Subgroup of SG and TG       | 3       | 504 5248   | P = 0.72, I^2=0% | 0.98      | 0.32–2.96     | P = 0.97 |

SG, subtotal gastrectomy; TG, total gastrectomy; NA, not applicable; NE, not estimable; OR, odds ratio; WMD, weighted mean difference; CI, confidence interval. doi:10.1371/journal.pone.0103312.t002
**Figure 2.** RG vs. OG: a) Operation time; b) Intraoperative blood loss; c) Hospital stay; d) Lymph node harvest; e) Anastomotic leakage; f) Morbidity; g) Mortality.

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Table 3. Meta-analyses results for robotic gastrectomy vs. laparoscopic gastrectomy.

| Parameters                      | Studies | Sample Size | Heterogeneity | OR or WMD | Effect 95% CI | P     |
|--------------------------------|---------|-------------|---------------|-----------|---------------|-------|
| Operation time                 | 8       | 898 1961    | P=0.00001, I²=88% | 57.15     | 42.26–72.05   | P<0.0001 |
| Subgroup of SG                 | 3       | 52 79      | P=0.03, I²=72% | 86.73     | 56.61–116.84  | P<0.0001 |
| Subgroup of TG                 | 1       | 36 65      | NA            | 95.60     | 55.26–135.94  | P<0.0001 |
| Subgroup of SG and TG          | 4       | 810 1817   | P=0.0002, I²=85% | 38.09     | 25.44–50.74   | P<0.0001 |
| Intraoperative blood loss      | 7       | 862 1896   | P=0.0001, I²=92% | -28.59    | -56.57–9.62   | P=0.05  |
| Subgroup of SG                 | 3       | 52 79      | P=0.0007, I²=86% | -11.00    | -61.25–39.26  | P=0.67  |
| Subgroup of SG and TG          | 4       | 810 1817   | P<0.00001, I²=95% | -39.54    | -79.71–0.63   | P=0.05  |
| Hospital stay                  | 7       | 882 1950   | P=0.59, I²=0%  | 0.16      | -0.87–0.55    | P=0.65  |
| Subgroup of SG                 | 2       | 36 68      | P=0.65, I²=0%  | -0.29     | -1.36–0.79    | P=0.60  |
| Subgroup of TG                 | 1       | 36 65      | NA            | -1.50     | -4.34–1.34    | P=0.30  |
| Subgroup of SG and TG          | 4       | 810 1817   | P=0.35, I²=8%  | -0.11     | -0.89–1.11    | P=0.83  |
| Lymph node harvest             | 8       | 837 1743   | P=0.0001, I²=78% | 0.63      | -2.24–3.51    | P=0.67  |
| Subgroup of SG                 | 3       | 52 79      | P=0.07, I²=62% | -3.77     | -9.63–2.09    | P=0.21  |
| Subgroup of TG                 | 1       | 36 65      | NA            | 3.40      | -1.87–8.67    | P=0.21  |
| Subgroup of SG and TG          | 4       | 749 1599   | P=0.39, I²=0%  | 2.33      | 1.05–3.62     | P=0.0004|
| Anastomotic leakage            | 11      | 997 2207   | P=0.96, I²=0%  | 1.10      | 0.66–1.82     | P=0.71  |
| Subgroup of SG                 | 5       | 112 261    | NA            | 2.03      | 0.18–23.22    | P=0.57  |
| Subgroup of TG                 | 1       | 36 65      | NA            | 0.24      | 0.01–4.87     | P=0.36  |
| Subgroup of SG and TG          | 5       | 849 1881   | P=0.99, I²=0%  | 1.16      | 0.68–1.96     | P=0.59  |
| Morbidity                      | 11      | 997 2207   | P=0.65, I²=0%  | 1.06      | 0.84–1.34     | P=0.60  |
| Subgroup of SG                 | 5       | 112 261    | P=0.37, I²=7%  | 1.29      | 0.61–2.72     | P=0.51  |
| Subgroup of TG                 | 1       | 36 65      | NA            | 1.10      | 0.36–3.32     | P=0.87  |
| Subgroup of SG and TG          | 5       | 849 1881   | P=0.57, I²=0%  | 1.04      | 0.81–1.34     | P=0.76  |
| Mortality                      | 11      | 997 2207   | P=0.96, I²=0%  | 1.55      | 0.49–4.94     | P=0.45  |
| Subgroup of SG                 | 5       | 112 261    | NA            | 3.13      | 0.18–53.21    | P=0.43  |
| Subgroup of TG                 | 1       | 36 65      | NA            | NE        | NE            | NA     |
| Subgroup of SG and TG          | 5       | 849 1881   | P=0.99, I²=0%  | 1.36      | 0.38–4.88     | P=0.63  |
| Clavien-Dindo grade            |         |             |               |           |               |       |
| I+II                           | 9       | 965 2148   | P=0.22, I²=26% | 1.15      | 0.86–1.53     | P=0.35  |
| Subgroup of SG                 | 3       | 80 202     | P=0.50, I²=0%  | 1.77      | 0.69–4.54     | P=0.23  |
| Subgroup of TG                 | 1       | 36 65      | NA            | 2.46      | 0.62–9.82     | P=0.20  |
| Subgroup of SG and TG          | 5       | 849 1881   | P=0.13, I²=43% | 1.06      | 0.77–1.44     | P=0.73  |
| III                            | 9       | 965 2148   | P=0.82, I²=0%  | 1.07      | 0.72–1.60     | P=0.73  |
| Subgroup of TG                 | 3       | 80 202     | P=0.99, I²=0%  | 2.07      | 0.33–13.01    | P=0.44  |
| Subgroup of TG                 | 1       | 36 65      | NA            | 0.28      | 0.03–2.43     | P=0.25  |
small to generalize its application for gastric cancer [14,17,18].
Recently some large sized studies have been conducted to evaluate
the efficacy and safety of robotic gastrectomy for gastric cancer
[11,13,15,19]. But single comparison and conflict results limited
them to conclude persuasible conclusions. However, those
examined in the present study allowed meta-analyses to be
performed, providing a better view of the safety and efficacy of RG
in gastric cancer. In reality, it is difficult to conduct a high-quality
RCT to evaluate a new surgical intervention because of some
obstacles such as learning curve effects, ethical and culture
resistance, and urgent or unexpected conditions during operation
in surgical treatment. For these reasons, to include non-RCTs is
an appropriate strategy to extend the source of evidence [33].

In the first part of RG versus OG, our analyses highlighted the
advantage of RG in minimal injury because less intraoperative
blood loss and shorter postoperative hospital stay were observed.
But its complication in technique correspondently brought RG
significantly longer operation time than OG. Further analyses of
lymph node harvest, anastomotic leakage, morbidity, and mortal-
ity between RG and OG did not show significant differences.
Although no controlled study for single total gastrectomy was
included in subgroup analysis, we deduced that RG was feasible
and safe in either subtotal gastrectomy or total gastrectomy
compared with OG by similar evidences in subtotal and total
mixed group and subtotal single group.

Continually, in comparison of RG and LG, we found it was
similar in surgical injury for these two methods because of no
significant difference in intraoperative blood loss. The disadvan-
tage of longer surgical duration was also observed in RG, although
significant heterogeneity existed. The heterogeneity might be
caused by surgeons’ experience. However, it is important to stress
that surgeons had got considerable experience of LG before RG,
which helped them adapt quickly to the robotic procedure.
Therefore, the effect of learning curve was limited in RG. Also,
higher BMI might be another important factor to increase
operation time and several reports described the association
between gender and BMI as increased operation time [34,35]. But
Park et al thought that this factor could be overcome by surgeon’s
expertise [36]. To explore the influence of BMI to our study, we
made comparisons of BMI among three groups and no significant
difference was observed (data not shown). Importantly, for
analyses of lymph node harvest, anastomotic leakage, morbidity,
and mortality, similar results were achieved between RG and LG
in either subtotal gastrectomy or total gastrectomy. We also make
a pooled analyses using Clavien-Dindo (C–D) classification. Still,
no significant difference was observed. What’s far more important
to limit the application of RG is the higher cost compared with
LG. Due to the limited published study, meta-analysis for cost
evaluation was not performed. But nevertheless, recent study by
Park et al showed the total cost for RG was significantly higher
than LG with a difference of €3189 [16].

In summary, we found that Robotic subtotal and total
gastrectomies combined with lymphadenectomy are technically
feasible and safe for gastric cancer, and can produce satisfying
short-term postoperative outcomes. However, a weakness of
present study was lack of randomized controlled studies included
and significant heterogeneity was observed in operative time,
intraoperative blood loss, length of hospital stay and lymph node
harvest. In addition, total and subtotal gastrectomy was pooled
together in most of included studies, which limited us to make a
more precise conclusion. Also, economic value and long-term
survival outcome are the mandatory appraisal index. Importantly,
high-quality randomized controlled studies should be conducted to
evaluate the role of robotic surgery for gastric cancer in future.

Table 3. Cont.

| Parameters                        | Studies | Sample Size | Effect Size | Heterogeneity | OR or WMD | P       | 95% CI      | P     |
|-----------------------------------|---------|-------------|-------------|---------------|-----------|---------|-------------|-------|
| Subgroup of SG and TG             | IV      | 965        | 2.148       | 0.70          | 0.34-1.43 | 0.032   | 0.06-1.70   | 0.60  |
| Subgroup of TG                    | 3       | 36         | 0.70        | 0.00          | NA        | NA      | NA          | NA    |
| Subgroup of SG and TG             | V       | 849        | 1.818       | 0.70          | 0.34-1.43 | 0.032   | 0.06-1.70   | 0.60  |
| Subgroup of SG                    | 3       | 36         | 0.70        | 0.00          | NA        | NA      | NA          | NA    |
| Subgroup of TG                    | 1       | 36         | 0.70        | 0.00          | NA        | NA      | NA          | NA    |
| Subgroup of SG and TG             | V       | 849        | 1.818       | 0.70          | 0.34-1.43 | 0.032   | 0.06-1.70   | 0.60  |

SG, subtotal gastrectomy; TG, total gastrectomy; NA, not applicable; NE, not estimable; OR, odds ratio; WMD, weighted mean difference; CI, confidence interval.
Figure 3: RG vs. LG. 

- a) Operation time
- b) Intraoperative blood loss
- c) Hospital stay
- d) Lymph node harvest
- e) Anastomotic leakage
- f) Morbidity
- g) Mortality

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### Table A

| Study or Subgroup | Robotic team Events Total | Laparoscopic team Events Total | Weight | Odds Ratio M.H. Fixed, 95% CI | Odds Ratio M.H. Fixed, 95% CI |
|------------------|---------------------------|-------------------------------|-------|-------------------------------|-------------------------------|
| **2.8.1 Statistical group** |
| East 2012        | 3 00 | 3 20 | 1 20 | 0 00 | 0 20 | 1 20 | 2 20 | 3 22 | 1.19 (0.88, 1.60) |
| Song 2004        | 1 00 | 1 30 | 1 30 | 2 00 | 2 30 | 2 30 | 2 30 | 0 20 | 0.47 (0.94, 2.48) |
| Total events     | 8 00 | 8 20 | 8 20 | 8 00 | 8 20 | 8 20 | 8 20 | 8 00 | 1.19 (0.88, 1.60) |
| Substantial (95%) Cb | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 1.19 (0.88, 1.60) |
| Total events     | 8 00 | 8 20 | 8 20 | 8 00 | 8 20 | 8 20 | 8 20 | 8 00 | 1.19 (0.88, 1.60) |
| **2.8.2 Total group** |
| Yeung 2012       | 5 36 | 4 68 | 3 68 | 4 68 | 3 68 | 3 68 | 3 68 | 3 68 | 2.40 (0.92, 6.02) |
| Substantial (95%) Cb | 36 | 4 68 | 3 68 | 3 68 | 3 68 | 3 68 | 3 68 | 3 68 | 2.40 (0.92, 6.02) |
| Total events     | 6 36 | 6 68 | 6 68 | 6 68 | 6 68 | 6 68 | 6 68 | 6 68 | 2.40 (0.92, 6.02) |
| Total events     | 6 36 | 6 68 | 6 68 | 6 68 | 6 68 | 6 68 | 6 68 | 6 68 | 2.40 (0.92, 6.02) |

### Table B

| Study or Subgroup | Robotic team Events Total | Laparoscopic team Events Total | Weight | Odds Ratio M.H. Fixed, 95% CI | Odds Ratio M.H. Fixed, 95% CI |
|------------------|---------------------------|-------------------------------|-------|-------------------------------|-------------------------------|
| **2.9.1 Statistical group** |
| East 2012        | 1 36 | 1 66 | 1 66 | 1 66 | 1 66 | 1 66 | 1 66 | 1 66 | 1.19 (0.88, 1.60) |
| Park 2012        | 1 36 | 1 66 | 1 66 | 1 66 | 1 66 | 1 66 | 1 66 | 1 66 | 1.19 (0.88, 1.60) |
| Song 2009        | 0 36 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 1.19 (0.88, 1.60) |
| Total events     | 2 36 | 2 66 | 2 66 | 2 66 | 2 66 | 2 66 | 2 66 | 2 66 | 1.19 (0.88, 1.60) |
| Substantial (95%) Cb | 80 | 2 66 | 2 66 | 2 66 | 2 66 | 2 66 | 2 66 | 2 66 | 1.19 (0.88, 1.60) |
| Total events     | 2 36 | 2 66 | 2 66 | 2 66 | 2 66 | 2 66 | 2 66 | 2 66 | 1.19 (0.88, 1.60) |

### Table C

| Study or Subgroup | Robotic team Events Total | Laparoscopic team Events Total | Weight | Odds Ratio M.H. Fixed, 95% CI | Odds Ratio M.H. Fixed, 95% CI |
|------------------|---------------------------|-------------------------------|-------|-------------------------------|-------------------------------|
| **2.9.1 Statistical group** |
| East 2012        | 0 36 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | Not estimable |
| Park 2012        | 0 36 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | Not estimable |
| Song 2009        | 0 36 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | Not estimable |
| Total events     | 0 36 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | Not estimable |
| Substantial (95%) Cb | 80 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | Not estimable |
| Total events     | 0 36 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | Not estimable |

### Table D

| Study or Subgroup | Robotic team Events Total | Laparoscopic team Events Total | Weight | Odds Ratio M.H. Fixed, 95% CI | Odds Ratio M.H. Fixed, 95% CI |
|------------------|---------------------------|-------------------------------|-------|-------------------------------|-------------------------------|
| **2.11.1 Statistical group** |
| East 2012        | 0 36 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | Not estimable |
| Park 2012        | 0 36 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | Not estimable |
| Song 2009        | 0 36 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | Not estimable |
| Total events     | 0 36 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | Not estimable |
| Substantial (95%) Cb | 80 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | Not estimable |
| Total events     | 0 36 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | 0 66 | Not estimable |

### Footnotes

- Figure 4. RG vs. LG: a) Clavien-Dindo grade I and II; b) Clavien-Dindo grade III; c) Clavien-Dindo grade IV; d) Clavien-Dindo grade V.
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