Three-dimensional vs 2-dimensional laparoscopic gastrectomy for gastric cancer

A systematic review and meta-analysis

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Abstract

Background: Both 3-dimensional (3D) laparoscopic gastrectomy (LG) and 2-dimensional (2D) LG are commonly used for gastric cancer (GC). To investigate their safety and efficacy, we performed this meta-analysis.

Methods: PubMed, The Cochrane Library, Science Direct, Embase, and Web of Science were systematically searched to identify relevant studies. The total number of lymph node dissections (LNDs), operation time, blood loss, postoperative hospital stay, postoperative complications, and hospitalization cost were extracted as major endpoints.

Results: Among 904 articles that were enrolled, 9 studies were included for analysis. The 3D group was observed to have shorter operation times [95% confidence interval (CI): −0.54 to −0.06; *P*=.01] and less blood loss (95% CI: −0.41 to −0.19; *P*<.00001) than the 2D group. Compared with the 2D group, slightly higher hospitalization cost was found in the 3D group (95% CI: 0.06–0.37; *P*=.008). However, the outcomes among the total LNDs, postoperative hospital stay, and postoperative complications were similar. Subgroup analysis suggested that the 3D LG group had more 11p (2.22 ± 1.80 vs 1.47 ± 1.99, *P*=.019) and 8a (2.52 ± 1.88 vs 1.48 ± 1.43, *P*=.001) LNDs compared to the 2D LG group.

Conclusions: 3D LG has advantages for GC, with shorter operation times, less blood loss, and possibly more LNDs. However, the cost was slightly higher than that of 2D LG.

Abbreviations: 2D = 2-dimensional, 3D = 3-dimensional, CIs = confidence intervals, GC = gastric cancer, LG = laparoscopic gastrectomy, LND = lymph node dissection, MD = mean deviation, PRISMA = Preferred Reporting Items for Systematic Review and Meta-Analysis, RCT = Randomized Clinical Trial, RR = risk ratio, RS = retrospective studies, SMD = standardized mean difference.

Keywords: gastric cancer, 3-dimensional, 2-dimensional, laparoscopic surgery, meta-analysis

1. Introduction

Gastric cancer (GC) is the third major cause of cancer deaths worldwide, with an estimated 720,000 deaths worldwide each year. Minimally invasive surgery has been recognized as the main choice for patients with early GC due to its advantages and safety. Two-dimensional (2D) laparoscopic gastrectomy (LG) has been gradually used for patients with early GC since the 1st report of traditional laparoscopy in 1994 by Kitano et al. The 2D laparoscopy procedure poses some challenges for novices because of defects in stereoscopic vision: difficulty in identifying anatomical structures; inability to judge distances between tissues; limited range of motion in laparoscopic instruments; and a longer learning curve. With the progress of medical technology, 3-dimensional (3D) laparoscopy has overcome the shortcomings of traditional 2D laparoscopy to a certain extent.

There is a debate about whether 2D/high-definition (HD) system (Karl Storz, Tuttingen, Germany or Olympus Corporation, Tokyo, Japan) equipped with a laparoscope with 30° direction of view and a diameter of 10mm or 3D/HD system (Olympus Corporation) equipped with a flexible 0° direction of view and a 10-mm-diameter laparoscope is better. Several reviews observed that the 3D group compared with the 2D group had shorter operative times, lower error rates, higher early abstinence rates, and a shorter learning curve for beginners. In contrast, Ruan et al found more blood loss in the 3D group in comparison with the 2D group. However, several studies have shown that both the 3D group and 2D group were similar in the total number of lymph node dissections (LNDs), operative time, blood loss, and postoperative complications. There is a lack of strong prospective evidence about whether 3D LG is superior to 2D LG.
Therefore, to comprehensively assess the clinical outcomes of 3D LG vs 2D LG, we performed the present meta-analysis for GC with respect to operative indexes, postoperative complications, and hospitalization cost.

2. Materials and methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statements was used to perform this systematic review and meta-analysis. No ethical approval and patient consent are required because all analyses were based on previously published studies.

2.1. Search strategy

PubMed, Science Direct, The Cochrane Library, Embase, Scopus, and Web of Science data were searched to identify all eligible studies up to March 14, 2019. The following are effective terms and related variants were used in the database searches: “three-dimensional,” “two-dimensional,” and “gastric cancer.” The complete keyword search strings we used for PubMed were: (three-dimensional [Mesh] OR 3-D [Title/Abstract] OR 3-D [Title/Abstract]) AND (two-dimensional [Mesh] OR 2-D [Title/Abstract] OR 2-D [Title/Abstract]) AND (gastric cancer [Mesh] OR stomach cancer [Title/Abstract] OR stomach neoplasm [Title/Abstract] OR gastric neoplasm [Title/Abstract] OR cancer of stomach [Title/Abstract]). Furthermore, we obtained reference lists of all included relevant publications for additional potential articles by hand searching. The search had no language restriction.

2.2. Selection criteria

The inclusion criteria were as follows: all patients were confirmed to have GC; studies compared 3D LG vs 2D LG; and outcomes included total LNDs, operation time, blood loss, postoperative hospital stay, postoperative complications, and hospitalization cost. We did not enroll review articles, expert opinions, letters, noncomparative studies, commentary articles, case reports, and editorials in this meta-analysis.

2.3. Data extraction

The data were extracted independently by 2 reviewers. A 3rd investigator was involved in the discussion if there was a disagreement between the 2 reviewers. Several characteristics (publication year, 1st author, number of participants, study design, type of gastrectomy, and age of participants) and outcome indexes (LND, operation time, blood loss, postoperative hospital stay, postoperative complications, and hospitalization cost) were extracted from included studies.

2.4. Quality assessment

The Newcastle–Ottawa scale (NOS, 9 points) was used for nonrandomized controlled trials in our study. Nine questions were assessed on three major items: selection, comparability, and exposure. The methodological quality of a study was deemed “High” if the NOS points were >7. If the points were >4, we considered the study to be of “medium” quality. In addition, we also used the Cochrane collaboration’s tool for RCTs to assess the risk of bias included in our meta-analysis.

2.5. Statistical analysis

These analyses were calculated by using Review Manager Version 5.3 software and STATA version 12.0 software. For dichotomous variables, the relative ratio (RR) with 95% confidence interval (CI) was used. For continuous variables, standardized mean differences (SMDs) with a 95% CI were calculated as summary statistics. We used a Chi-squared test and I^2 (I^2=[Q – df]/Q) × 100%) to access the interstudy heterogeneity among studies. A random-effects model was performed when there was significant heterogeneity (I^2 > 50% or P < .1) between the studies. In contrast, if no heterogeneity was observed between the studies (I^2 < 50% or P > .1), a fixed model was applied. Subgroup analyses of operative indexes (LND, operation time, and blood loss), postoperative hospital stay, postoperative complications, and hospitalization cost were used to assess whether the results would change according to the study design. In addition, Begg funnel plot and Egger tests were performed for exploration of the publication bias. P < .05 indicated statistical significance.

3. Results

3.1. Search results and study quality assessment

Figure 1 presents the process of article selection: 904 full-text articles were 1st identified from the aforesaid 6 databases. After filtering, 9 studies involving 1508 patients (3D group, 739 patients; 2D group, 769 patients) were enrolled for the final evaluation. Of the 9 studies, 4 were RCTs and 5 were retrospective studies (RS). The characteristics of all studies are collected in Table 1. In addition, based on the NOS score, each study was considered high quality. As shown in Figure 2, no severe risk of bias was found according to the results of the Cochrane risk of bias tool for the RCTs included in our meta-analysis.

3.2. Number of lymph node dissections

The number of LNDs was reported in 5 studies with 948 patients between the 2 groups. The results of LNDs between them were 35.69 (3D) and 33.16 (2D), respectively. The mean deviation (MD) was 0.53. The results showed the total LNDs between the 2 groups was similar (95% CI: −0.06 to 0.35; P = .17; Fig. 3). In subgroup analysis, Liu et al[20] revealed that the 3D group had more 11p (P = .019) and 8a (P = .001) LNDs than the 2D group.

3.3. Operation time

Operation time was reported in 7 of the 9 included studies. The mean operative time in the 3D group was 178.23 and 185.31 minutes in the 2D group. The MD was 7.07 minutes. The results showed that operation times were significantly shorter in the 3D group compared with the 2D group (95% CI: −0.54 to −0.06; P = .01; Fig. 4A).

3.4. Blood loss

Six studies with 1287 patients compared the amount of blood loss. The amount of blood loss in the 3D group was 90.02 and 113.30 mL in the 2D group. The MD was 23.28 mL. The results showed that blood loss was significantly less in the 3D group.
compared with the 2D group (95% CI: –0.41 to –0.19; P < .00001; Fig. 4B).

3.5. Postoperative complications
From the 3 studies, 659 participants were enrolled to assess postoperative complications between the 2 groups. The results showed there was no statistically significant difference in postoperative complications between the 2 groups (RR = 1.02, 95% CI: 0.70–1.58; P = .80; Fig. 5A).

3.6. Postoperative hospital stay
From the three studies, 461 patients were analyzed for postoperative hospital stays between the 2 groups. The mean

| Table 1  | Characteristics of the included studies in the meta-analysis. |
|----------|-------------------------------------------------------------|
| First author | Publication year | Study design | Patients (n) (3D/2D) | Age X ± SD (3D/2D) | Operation time, min X ± SD (3D/2D) | Blood loss, mL X ± SD (3D/2D) | Total gastrectomy (3D/2D) | Partial gastrectomy (3D/2D) | Quality (score) |
| Chen[13] | 2014 | RS | 40/40 | 49.0 ± 10/7.0 ± 5.2 | 168.00 ± 36.00/190.00 ± 48.00 | 110.00 ± 18.00/120.00 ± 21.00 | 0/0 | 60/80 | 8 |
| Jiang[14] | 2015 | RS | 40/40 | – | 174.30 ± 33.20/174.50 ± 32.10 | 153.80 ± 25.50/169.70 ± 15.50 | – | – | 7 |
| Reim[15] | 2015 | RCT | 78/101 | – | 130.63 ± 36.00/189.00 ± 163.00 | – | – | – | – |
| Ji[16] | 2016 | RS | 56/60 | 61.9 ± 10.4/60.0 ± 11.7 | 186.20 ± 22.80/198.10 ± 36.40 | 73.60 ± 28.50/88.10 ± 32.30 | 21/24 | 35/36 | 7 |
| Lin[17] | 2016 | RCT | 97/99 | – | 180.60 ± 22.80/180.00 ± 37.20 | 59.60 ± 45.60/69.90 ± 62.40 | – | – | – |
| Lu[18] | 2016 | RCT | 109/11 | 59.4 ± 10.3/58.0 ± 11.7 | 184.00 ± 36.00/178.00 ± 37.00 | 58.00 ± 75.00/78.00 ± 72.00 | 21/24 | 35/36 | – |
| Ji[19] | 2017 | RCT | 48/45 | 56.0 ± 8.0/56.0 ± 7.0 | 185.00 ± 25.00/190.00 ± 27.00 | 75.00 ± 25.00/85.00 ± 20.00 | 48/45 | 0/5 | 8 |
| Zheng[20] | 2017 | RCT | 211/208 | 59.0 ± 10.0/59.0 ± 10.7 | 174.00 ± 33.00/176.00 ± 35.00 | 61.00 ± 83.00/82.00 ± 119.00 | 117/132 | 94/76 | – |
| Liu[20] | 2018 | RCT | 97/99 | 55.9 ± 10.2/55.5 ± 12.5 | 180.30 ± 36.70/191.47 ± 47.19 | 160.83 ± 150.66/170.31 ± 147.19 | 0/0 | 60/84 | 8 |

2D = 2-dimensional, 3D = 3-dimensional, RCT = randomized clinical trial, RS = retrospective study, SD = standard deviation.
Figure 2. Forest plot of lymph node dissections associated with 3-dimension vs 2-dimension.

Figure 3. Forest plot of operation times (A) and blood loss (B) associated with 3-dimension (3D) vs 2-dimension (2D). CI = confidence interval.
postoperative hospital stay for the 3D group was 12.20 days, and for the 2D group, it was 12.65 days. The MD was 0.45 days. The results showed there was no statistically significant difference in postoperative hospital stays between the 2 groups (95% CI: -0.30 to 0.06; \( P = 0.20 \); Fig. 5B).

### 3.7. Hospitalization cost

Three studies that assessed 615 participants reported hospitalization cost as an outcome. The cost in the 3D group was $12,562.32, while in the 2D group, it was $12,085.80. The MD was $476.53. The results showed that the 3D group had a slightly higher hospitalization cost compared with the 2D group (95% CI: 0.04–0.35; \( P = 0.02 \); Fig. 6).

### 3.8. Subgroup analysis

Subgroup analysis was also performed according to the study design (RCT or RS) included in the selected studies. For RCTs, the analysis showed that the 3D LG was associated with less
blood loss compared with 2D LG (95% CI: –0.40 to –0.11; \( P=0.0004 \)). For RS, the analysis showed that 3D LG was associated with shorter operation times (95% CI: –0.71 to –0.21, \( P=0.003 \)), fewer LNDs (95% CI: 0.13–0.56, \( P=0.002 \)), and higher hospitalization costs (95% CI: 0.05–0.62, \( P=0.02 \)) compared with 2D LG (Table 2).

3.9. Cumulative meta-analysis

Cumulative meta-analysis of operation time (Fig. 7), blood loss (Fig. 8), and LND (Fig. 9) demonstrated that, as high-quality studies were included, the SMDs of the final results became robust within a narrow range. After inclusion of Ji’s study,\(^{116}\) the SMD and 95% CI for operation time and blood loss decreased to <1 and became stable.

3.10. Sensitivity analysis

Both operation time and blood loss were observed to have significant heterogeneity. We evaluated stability and sensitivity according to the influence of each study. The results showed that the outcomes of operation time and blood loss were stable and reliable (Fig. 10).

3.11. Publication bias

A funnel plot based on the operation time (Begg test \( P=0.035; \) Egger test \( P=0.048; \) Fig. 11A) and blood loss (Begg test \( P=0.174; \) Egger test \( P=0.152; \) Fig. 11B) were conducted to evaluate publication bias. The pooled results suggested that there may be publication bias in some of the results.

4. Discussion

Although the 3D laparoscopic system was introduced in the early 1990s,\(^{119}\) surgeons in clinics have disregarded this system until recently because the old version of the 3D laparoscopic system caused some surgeons discomfort, such as headache, dizziness, and eye strain due to blurring of vision in 3D vision.\(^{21,22}\) However, these drawbacks of the 3D laparoscopic system have been minimized with the development of medical and optical devices. Therefore, compared with the 2D laparoscopic system, the 3D laparoscopic system has become more comfortable for the surgeon, especially when the surgeon performs difficult surgery that requires meticulous dissection. This is the 1st meta-analysis to compare 3D and 2D LG for GC. The results showed that the 3D group was associated with shorter operation times, less blood loss, and slightly higher hospitalization costs than the 2D group. The total LNDs, postoperative hospital stays, and postoperative complications were similar between the 2 groups.

Our meta-analysis found that 3D laparoscopy was not superior than 2D laparoscopy in terms of total LNDs. Possible reasons include the surgeons were not well experienced in using 3D views; and the patients in our studies were not enough. While the subgroup analysis suggested that the 3D group dissected more 11p and 8a lymph nodes as compared with the 2D group.\(^{20}\) Yoon et al\(^{23}\) also reported a higher LN yield in the 3D laparoscopy group. These results may be explained by the advantages of 3D view: preoperative 3D evaluation of the vascular anatomy may help the safe and rapid ligation of vessels and detection,\(^{116}\) the lymph nodes,\(^{24}\) and the 3D system provides a good stereoscopic vision sense of anatomical structure to act resolutely when dissecting vessels, organs and tissues, which may have advantages to dissect the lymph nodes.\(^{25}\) Therefore, we

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**Table 2**

| Variables                      | Study design | n  | Number of patients (3D/2D) | Heterogeneity | \( F \) | \( P \)-value | Effect size | Model  | 95% CI       | \( P \)-value |
|--------------------------------|--------------|----|---------------------------|---------------|-------|----------------|-------------|--------|--------------|----------------|
| Operation time                 | RCTs         | 2  | 308/307                   | 0%            | .36   | –0.01          | Fixed       | –0.17–0.15 | .92          |                |
| Blood loss                     | RS           | 5  | 244/249                   | 48%           | .10   | –0.46          | Fixed       | –0.71–0.21 | .0003        |                |
| LND                            | RCTs         | 3  | 386/408                   | 9%            | .33   | –0.25          | Fixed       | –0.40–0.11 | .0004        |                |
| Postoperative complications    | RCTs         | 1  | 211/208                   | 0%            | .39   | 0.58           | Fixed       | 0.22–1.52  | .27          |                |
| Postoperative hospital stay    | RCTs         | 1  | 109/112                   | –              | –     | –0.02          | Fixed       | –0.28–0.25 | .90          |                |
| Hospitalization cost           | RCTs         | 1  | 211/208                   | 0%            | .69   | 0.35           | Fixed       | 0.07–0.64  | .01          |                |

2D = 2-dimensional, 3D = 3-dimensional, CI = confidence interval, LND = lymph node dissection, RCTs = randomized clinical trials, RS = retrospective study.

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Figure 7. Cumulative meta-analysis related to operation time with 3-dimension (3D) vs 2-dimension (2D). CI = confidence interval, SMD = standardized mean difference.

Figure 8. Cumulative meta-analysis related to blood loss with 3-dimension (3D) vs 2-dimension (2D). CI = confidence interval, SMD = standardized mean difference.
speculated that 3D LG might be better than 2D LG in LNDs for GC. This inference still needs to be validated by more RCTs. Our results showed that the 3D group had a significantly shorter operation time and less blood loss compared with the 2D group. This finding can be delineated by several different factors: 3D laparoscopy with 3D visualization provided the surgeons with a simpler presentation of the anatomical formations; 3D laparoscopy with 3D visualization helped the surgeons locate the lymph nodes accurately; and the spatial distribution of blood vessels and the anatomic relation between blood vessels were

![Figure 9. Cumulative meta-analysis related to lymph node dissections with 3-dimension (3D) vs 2-dimension (2D). CI = confidence interval, SMD = standardized mean difference.](image)

![Figure 10. Meta-based influence analysis for comparisons of operation time (A), blood loss (B) and lymph node dissections (C).](image)
likely clearer. Similar results were also confirmed by Ozsoy’s and Fergo’s studies.\textsuperscript{7,8} Considering these advantages of 3D laparoscopy, surgeons have confidence to perform surgeries and can rapidly improve surgical skills as well as reduce errors rate with HD 3D vision.\textsuperscript{26} In terms of hospitalization expenses, our results showed that the 3D group was associated with a slightly higher but acceptable hospitalization cost compared with the 2D group. This greatly facilitates the development and promotion of 3D operation surgeries. In addition, the operation time of the 3D group was shorter, and the corresponding anesthesia and intraoperative costs were also reduced. Two other 3D displays (3D robotic-assisted and glasses-free 3D endoscopic system) have emerged in recent years.\textsuperscript{27,28} They showed less mortality and morbidity in laparoscopic surgery and effectively reduced the side effects and poor lighting for operators. Although they had advanced characteristics (3D visualization, small-wristed instruments, and raised degree of rotational freedom and motion\textsuperscript{29}), the cost of conducting the 3D robotic system or the glasses-free 3D display might be too expensive for hospitals and patients. Therefore, the traditional 3D system may be the optimum choice for many centers.

In our meta-analysis, we also acknowledge several limitations. First, not all included studies were RCTs (4 RCTs and 5 RS), which might raise the risk of selection and publication bias. Second, the levels of surgeons’ experiences were different, and it is unclear for novices whether 3D laparoscopic surgery can also shorten the operation time and the learning curve. It remains to be proven by more medical evidence. Third, all patients came from Asia (8 studies in China and 1 study in South Korea), and we did not assess the impact of 3D laparoscopic on long-term outcomes. However, our ultimate results attest that the use of the 3D laparoscopic system for gastrectomy is effective based on these short-term clinic results. Last, with restrictions of meta-analyses based on the published literatures instead of the original data, it was difficult to acquire unpublished data.

5. Conclusion

Our meta-analysis suggests that 3D LG is superior to 2D LG with shorter operation time, less blood loss, and probably more LNDs. These results give us a reason to suggest that 3D LG should be considered as a preferable option, particularly for surgeries with difficult procedures or complicated anatomical steps. Thus, wider clinical application of 3D laparoscopy is strongly recommended.

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