

Advances in Laparoscopic and Robotic Gastrectomy for Gastric Cancer

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Abstract Robot-assisted gastrectomy has been reported to be a safe alternative to both conventional laparoscopy and the open approach for treating early gastric carcinoma. Currently, there are a limited number of published reports on this technique in the literature. We assessed the current status of robotic and laparoscopic surgery in the treatment of gastric cancer and compared the operative outcomes, learning curves, and oncological outcome of the two approaches. Robotic gastrectomy offers benefits that include increased ease of performing D2 lymph node dissection and reduced blood loss compared with laparoscopic gastrectomy. However, the operative time is longer, and robotic gastrectomy is more costly for the patients. Regarding to the operative and oncological outcomes, there appears to be no significant differences between laparoscopic and robotic gastrectomies after the surgeon overcomes the associated learning curves. Sharing the available knowledge regarding laparoscopic and robotic gastrectomies could shorten these learning curves. For elder patients, minimally invasive surgery that decreases the postoperative recovery time should be considered the preferred

treatment. Prospective randomized studies are required to compare the surgical and oncological outcomes among laparoscopic, robotic, and open surgeries for both early and advanced gastric cancer.

Keywords Laparoscopic · Robotic · Lymph node dissection · Gastric cancer · Elderly

Introduction

Laparoscopic gastrectomy (LG) has been reported to be a valid alternative to open surgery for the treatment of early gastric cancers, particularly in Eastern countries. Conventional laparoscopy presents some challenges for surgeons, including a two-dimensional view, an increase in physiologic tremors, limited manipulation, and ergonomic discomfort. These technical issues have limited the application and adoption of laparoscopy for major abdominal surgical procedures, which require a specific surgical-skill set and ability.

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Robotic technology can overcome most of the challenges of conventional laparoscopy, because it provides the surgeon with an advanced system for viewing and manipulation, and it eliminates physiologic tremors by using a computerized mechanical interface. Additionally, the articulated tools (the EndoWrist™ System) provide seven degrees of freedom to reproduce the movements of the human hand inside the abdominal cavity, thus facilitating manipulation. Furthermore, the robotic console reduces ergonomic discomfort, enabling the surgeon to maintain a comfortable position for many hours if needed. All of these technical advantages are very important for improving the quality of minimally invasive surgery, particularly for longer and more complex procedures. The first experiences with robotic gastrectomy (RG) were published by Giulianotti et al. and Hashizume and Sugimachi in 2003 [1–3]. Retrospective analyses, meta-analyses and reviews confirmed the safety and feasibility of using RG for lymphadenectomies in the treatment of gastric cancer [4, 5]. However, no long-term oncological follow-up data are available for these reports.

Learning Curve

It has been reported that RG requires a shorter learning curve than LG [6–9]; however, most of the published articles report data for surgeons who were already experts at performing LG. In our institution, the surgeon who began performing RG was still learning to perform LG. Our results showed that once the surgeon overcame the learning curves, the operative outcomes for LG and RG were similar. The experience gained from performing RG may decrease the learning period for LG [10]. We believe that LG and RG could be learned at the same time, thereby shortening the learning periods for both procedures. With the aid of robotic arms, surgeons who are already well trained in open and laparoscopic techniques could easily make the transition to performing robotic surgery, and the learning period could be reduced. It is possible that an experienced surgeon could transition directly from open gastrectomy (OG) to RG easily after a few experiences with LG.

Indications for LG and RG

The indication for LG is limited to early gastric cancer because it is more difficult to perform D2 lymph node dissection with LG than with open surgery. Only a small number of series have been reported, and they found no differences in tumor recurrence or survival between OG and LG in advanced gastric cancer cases [11–15]. To date, three published prospective and randomized studies have compared the outcomes of LG and OG with D2 lymph node dissections for the treatment of advanced gastric cancer; these studies took place in Korea

(KLASS 02), Japan (JLSSG 0901) and China (CLASS 01) [16]. We believe these results may provide strong evidence regarding whether minimally invasive surgery is oncologically adequate for treating advanced gastric cancers. In the future, prospective randomized studies should compare the operative and oncological outcomes of OG versus RG, or LG versus RG, for advanced gastric cancers.

Lymphadenectomy

D2 lymph node dissections have been proven to have survival benefits in advanced gastric cancer cases [17]. Currently, D2 lymph node dissections are widely accepted as the standard procedure for gastric cancer surgery. However, in LG, D2 lymph node dissections require a long learning curve and are not routinely performed. The use of robotic instruments with articulation allows surgeons to perform D2 lymph node dissections more easily than with laparoscopic instruments [4, 18, 19]. The technical advantages offered by robotic surgery may help to standardize minimally invasive D2-lymphadenectomies and enable surgeons to perform these procedures routinely in their clinical practice.

The critical points in lymph node dissections during gastric cancer surgeries include the suprapancreatic (7, 8a, 9) and the infrapyloric (6) areas, which are also the most frequent sources of intraoperative bleeding [20, 21]. Although dissection of the station 14v lymph node has been excluded in the latest edition of Japanese Classification [22], the possibility of station-14v metastasis is increased in patients with lymph node metastasis in station 6, and the removal of 14v can still be beneficial.

In patients who require a splenic hilum lymph node dissection, the risk of bleeding is quite high and a splenectomy may be required if a vascular injury occurs during the lymph node dissection. With the aid of a robotic system, it is easier to dissect along the major vessels than when performing laparoscopic surgery; thus robotic systems may be helpful with dissections near the splenic hilum.

Recently, Kim et al. [23] published their experience with the use of indocyanine green (ICG) in a fluorescent iodized emulsion for intraoperative sentinel lymph node (SLN) imaging in robotic gastrectomy. The ICG component served as a vital dye and enabled intraoperative SLN navigation using near-infrared (NIR) imaging during the RG. With the aid of NIR imaging following the ICG injection, robotic surgeons could more easily and precisely localize the margin of the lymph nodes during lymph node dissections.

Recently, Lee et al. [24] reported that the benefits of a robotic approach during distal subtotal gastrectomies with D2 lymphadenectomies were more evident in patients with high BMIs than in those with normal BMIs, particularly in terms of blood loss and the consistency of the lymphadenectomy quality. The researchers concluded that robotic surgery

could be an effective alternative to conventional laparoscopic surgery for treating gastric cancer patients with high BMIs.

Intracorporeal and Extracorporeal Anastomosis

Extracorporeal anastomoses in cases of gastroduodenostomy, gastrojejunostomy, and esophagojejunostomy have been reported following laparoscopic gastrectomies; however, high-BMI patients require a significantly larger skin incision for an extracorporeal anastomosis compared with low-BMI patients. As a result, in Western countries that have a greater number of high-BMI patients, intracorporeal anastomoses generally preferred to extracorporeal anastomoses [25–30].

With the aid of robotic instruments, it is easier to perform an intracorporeal anastomosis in an RG than in an LG, especially in Roux-en-Y gastrojejunostomies and esophagojejunostomies. Surgeons perform an intracorporeal anastomosis with confidence using robotic instruments. For an extracorporeal anastomosis, the disadvantages include the larger skin incision of the mini-laparotomy, the lack of adequate vision and the excessive traction on the serosa of the stomach and intestines, which can cause serosal tears and bleeding. Therefore, as long as the surgeons are able to perform the anastomosis safely, an intracorporeal anastomosis would be the preferred choice following a gastrectomy.

For a total gastrectomy, it is technically difficult to perform a purse-string suture on the esophageal stump in conventional laparoscopy. In RG, a hand-sewn purse-string suture of the esophageal stump can easily be performed with the assistance of robotic instruments; consequently, the surgeon could perform an esophagojejunostomy using a circular stapler, just as in open surgery.

Moreover, the use of robotic instruments could enable the surgeon to transition more easily from an extracorporeal anastomosis to an intracorporeal anastomosis than when using conventional laparoscopic instruments.

Perioperative Outcomes

Regarding the perioperative outcomes, the recent significant literature and issues pertaining to G and RG are still under debate. The current issues regarding RG and LG focus on the primary outcomes of the two surgical techniques. Our previous studies [31] showed that the use of the robotic procedure for gastrectomies can provide a more extensive retrieval of lymph nodes after dissection compared with laparoscopic procedures. However, the medical cost of RG is higher than that of LG. RG also results in less blood loss compared with traditional LG, although the operation time is longer in robotic procedures than in laparoscopic procedures. There were no differences in post-operative morbidity between the

two procedures. However, after the learning curves for the two approaches are overcome, LG and RG have similar operative outcomes [10].

Hyun et al. [32] reported a meta-analysis of 9 articles that include a total of 7200 patients. The results showed that there were no significant differences in the peri-operative blood loss between RG and LG. The patients who underwent RG had a relatively shorter hospital stay than those who underwent the laparoscopic procedures, but the differences did not reach statistical significance. The results showed a similar incidence of short-term postoperative complications for RG and LG.

Another meta-analysis conducted by Xiong et al. [33] showed that RG was related to a significantly longer operative time than LG. However, there were no differences in the conversion rates, perioperative complications, overall morbidity and post-operative hospital stays between the two approaches.

In summary, RG is comparable to LG in terms of the post-operative length of hospital stay and short-term postoperative morbidity, although RG requires a relatively longer operative time. Further studies should be undertaken to examine the differences in long-term postoperative outcomes and survival between the two approaches.

Oncological Outcomes

To date, no long-term oncological outcome data have been published in the literature. The published articles [34–37] that compare the oncological outcomes of LG and RG are all short-term and demonstrate no significant difference in survival rates. Further prospective randomized studies comparing the long-term oncological outcomes of LG and RG for both early and advanced gastric cancers are needed.

Minimally Invasive Gastrectomy in the Elderly

As life expectancy continues to increase globally, the proportion of patients over 80 years of age who are undergoing gastrectomies for gastric cancer is increasing. Advanced age is frequently associated with significant comorbidity and a limited functional reserve, which are associated with both a higher rate of complications and a longer hospital stay. Kwon et al. [38] reported the surgical outcomes of 99 gastric cancer patients with over 80 years of age who underwent either minimally invasive surgery (19 LGs and 11 RGs) or open surgery ($n = 69$). In their series, the minimally invasive surgeries demonstrated significantly less blood loss, lower analgesic consumption, faster time to first flatus and soft diet, and a shorter post-operative hospital stay compared with the open surgeries. A multivariate analysis revealed that the type of operation performed had no effect on the occurrence of complications.

Furthermore, the 5-year overall and disease-free survival rates for the patients undergoing curative surgery were similar for the minimally invasive surgery and open surgery patients. Therefore, minimally invasive surgery for gastric cancer may be performed safely and maintains the advantages of minimal invasiveness, even in very elderly patients.

Our previous study [39] regarding the surgical outcomes of open surgery for gastric cancer showed that even in early gastric cancer cases, the overall survival rates of elderly patients were significantly worse than those of younger patients after curative surgery. As the global population ages, increasing numbers of very elderly gastric cancer patients will require surgical treatment. Consequently, the oncological outcomes would not be the primary concern for these elderly patients after surgery. For a more rapid postoperative recovery, the indications for minimally invasive surgery for elderly patients should include both early and advanced gastric cancer.

Conclusions

To date, RG appears to be a valid alternative to either OG or LG for the treatment of early stage gastric carcinomas. The reported results are satisfactory in terms of both the perioperative outcomes and oncological adequacy. The major technical advantages of the robot-assisted approach can best be appreciated during lymph node dissections and in the intracorporeal suturing techniques required during reconstruction. LG and RG could be learned simultaneously to decrease the learning period. However, it is of concern that while RG is more expensive for patients compared with LG, the benefits of RG to the patient might be limited.

The oncologic indications for RG might be extended to include advanced gastric cancers because RG offers technical advantages in lymph node dissections. However, more studies are required to investigate and compare the oncological outcomes of OG, LG and RG for the treatment of advanced gastric cancers. Furthermore, for elderly patients, minimally invasive gastrectomy (including LG and RG) could allow a more rapid postoperative recovery and should be considered the preferred surgical methods.

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Compliance with Ethical Standards

Conflict of Interest All of the authors disclose that there are no financial or personal relationships with other people or organizations that could inappropriately influence their work.

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