Review Article

The Present and Future of Robotic Gastrectomy

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ABSTRACT

Robotic gastrectomy (RG) is a new technology used to perform gastrectomy. A comparison of RG with conventional methods—open gastrectomy (OG) and laparoscopic gastrectomy (LG)—has revealed the advantages and limitations of RG. This study aimed to present the latest research outcomes and current trends in RG. In this paper, we present updates on long-term oncological safety and learning curves as well as a multicenter study on short-term effects. New information on lymph node dissection has been discussed. Researchers have been exploring ways to apply RG in other challenging areas. Among these, bariatric surgery, structure-preserving surgery, and fluorescent imaging have been discussed. Improvements in robotic systems have also been discussed. Although further studies such as randomized controlled studies are needed, we believe that RG will become a significant turning point in the field of minimally invasive surgery.

Keywords: Robotic gastrectomy; Robotic surgery; Laparoscopic gastrectomy; Gastric cancer

INTRODUCTION

Minimally invasive surgery is one of the major global trends emerging in the surgical field. This concept can be practically realized owing to the introduction of laparoscopic surgery in the 1980s [1]. In the field of gastrectomy, laparoscopic gastrectomy (LG) has an advantage over conventional open gastrectomy (OG) because of fewer postoperative complications and shorter hospital stays [2,3]. However, LG has some limitations; less intuitive design and inefficient force transmission have hindered surgeons from performing to their maximal ability [4,5]. Because of these disadvantages, a steeper learning curve is required, and inexperienced surgeons must perform at least 50 cases of LG to achieve optimal performance [4,6].

The da Vinci surgical system (Intuitive Surgical Inc., Sunnyvale, CA, USA) was designed to overcome the weaknesses of LG by offering three-dimensional views, robotic arms with seven degrees of freedom, and tremor reduction [4,7]. The da Vinci's intuitive and operator-friendly environment has helped surgeons adapt easily to the system, and its postoperative outcomes are similar to those of LG. Furthermore, owing to its sophisticated movements, the robot is expected to be applied to extensive lymphadenectomy and anastomosis [4].

Since Hashizume and Sugimachi [8] performed the first robotic gastrectomy (RG) in 2003, the demand for RG has grown over the past decade. In the United States, the number of gastric resections has increased 4.4 times during the period from 2010 to 2014, while that of OG operations has gradually decreased [9]. The need for RG has gradually increased in Japan, where gastric cancer is widely prevalent [10]. In 2015, one study reported that the postoperative morbidity rate significantly decreased in patients who underwent RG than those who had LG (11.4% vs. 2.3%) [11]. The decrease was particularly meaningful considering that no pancreatic fistula, which is a common yet serious complication after gastrectomy, had occurred among the RG group patients [11]. Following Uyama et al.'s single-institution study [10], 15 institutions in Japan registered 330 patients to compare the morbidity rate of RG with that of LG. The postoperative results were in accordance with his findings. Furthermore, a lower number of hospital stays and morbidity rates resulted in savings in the overall healthcare budget, making the cost of RG comparable to conventional LG [10]. Based on these findings, the Japanese government started covering the cost of RG through its national insurance program since April 2018; this decision is expected to help surgeons in using RG more frequently [10].

Most studies shared a common conclusion that RG offers better results than the conventional OG, especially in terms of less blood loss and shorter postoperative hospital stay [12,13]. However, few data support RG's superiority over LG [9]. Son and Hyung [7] reported that more lymph nodes (LNs) could be harvested with RG than with LG, but this finding was not significant. Longer operative time and higher cost to purchase the robot were indicated as serious drawbacks of RG [7,11].

Presently, RG is considered as one of the major methods for performing gastrectomy, along with OG and LG. For nearly 2 decades, researchers have published data comparing RG with other procedures and also explored ways to minimize its drawbacks and apply it to other fields. This study aimed to present the latest research outcomes and current trends in RG.

MULTICENTER STUDY ON SHORT-TERM EFFECTS

Several studies have compared the short-term results of RG with those of LG. Many of these studies, however, were based on data from a single surgeon or a single institution. These comparative studies have the limitation that they cover only a small number of cases. Although a meta-analysis had been published [14], a prospective study was still needed.

For this purpose, a multicenter prospective study (11 institutions) was conducted in South Korea (NCT01309256) [15]. This study included 434 patients (223 for RG and 211 for LG) and 17 surgeons with various levels of experience in LG (50–1,000 cases). The researchers observed the postoperative consequences for 1 year. The study strengthened the conventional belief that RG had similar postoperative outcomes as LG. However, longer operative time and higher cost of RG are 2 major obstacles because of which surgeons hesitate from using RG. A long-term study would be necessary to examine the strengths of RG.

LONG-TERM ONCOLOGICAL SAFETY

Because RG is a relatively novel technology, only a few long-term postoperative results are available. To compare RG with LG more precisely, data on long-term complications were needed [4,16]. In 2015, Coratti et al. [17] conducted a 5-year, single-center study with 98 cases. The author was unable to directly recommend RG over other types of gastrectomy. However, in that article, the survival rate data seemed to indicate that RG's feasibility and safety were comparable to those of the conventional approach [17,18]. Coratti's work was notable for the number of patients evaluated as well, considering that this was a study with the second largest number of cases after the study by Song et al. [19]. In a long-term meta-analysis of over 3000 patients, RG had similar postoperative outcomes in terms of overall survival rate, disease-free survival rate, and relapse-free survival rate [14]. Hong et al. [20] found that there was no significant difference in postoperative complications between RG and LG, based on a seven-year, single-center experience. In 2018, Obama et al. [21] published long-term retrospective oncological outcomes with a median follow-up of 85 months. Their study results were not significantly different from those of previous studies; they showed similar differences in postoperative oncological outcomes between RG and LG.

Despite RG's technological superiority over LG, the results from various studies have shown that RG and LG have similar effects on gastric cancer; these results seem to have fallen short of people's expectations. This might be because of the use of the same surgical procedure in both cases; the use of a robot was the only difference [21]. When other clinically important criteria, such as conversion rate to open surgery and readmission rate were included, RG had a better success rate than LG or OG [22]. Further studies are needed to determine whether these criteria are adequate for comparison. A similar result after a longer period of surveillance emphasizes that RG is as safe and feasible as LG, and that it could be considered as an attractive alternative for gastrectomy.

UPDATES ON LEARNING CURVE

It is known that RG has a shallower learning curve than conventional LG; this implies that inexperienced surgeons can adapt to the use of the robot and perform operations more quickly [4,23]. Extensive LN dissection is particularly difficult for surgeons with LG [24]. The laparoscope itself is less ergonomically friendly [5], and this may have increased the barrier for the use of LG. Surgeons with sufficient prior laparoscopic experience could rapidly use their optimal skills after the first 10 cases itself [25]. This is remarkable considering that 50 cases are required to achieve the maximum ability with LG [6].

A long-term analysis of the learning curve was reported in 2016; to the best of our knowledge, this is the only study that has dealt with the long-term learning curve [20]. For 5 years of experience, RG did not show clinically significant advantages over LG; instead, a longer operative time was reported. With the accumulation of cases, however, surgeons showed some reduction in operative time. In the early years of experience, RG was associated with considerably less blood loss than LG.

Most studies on the learning curve have been conducted with experienced laparoscopic surgeons; hence, further studies with relatively inexperienced surgeons are needed [4,25]. In 2007, a study was conducted with 8 medical students who had no experience with either

laparoscopy or robots [23]. The students showed faster and more accurate performance with robot-assisted laparoscopy. However, the tasks that the students performed did not involve real surgery, but only simple processes, such as capping the needle and tying the knot. Therefore, more clinically based learning curve data are required to confirm these benefits.

A single surgeon with relatively less experience with LG achieved a stable performance with RG after 25 cases [26]. Interestingly, all surgical results from the beginning to the end of the learning curve were acceptable. Thus far, only a few studies have been conducted with inexperienced laparoscopic surgeons. LG has been widely performed by surgeons, and RG was introduced much later than LG. During the period when safety and feasibility of RG were not evident, surgeons with significant LG experience could have attempted to use this novel technique.

Hong et al. [20] and An et al. [26] showed that RG could be performed by surgeons with less experience in minimally invasive surgery. A lesser amount of time and fewer cases were needed with RG [25,26], with better results in the earlier period [20,23]. Based on their earlier experience, Obama et al. [21] stressed the need to improve the performance in minimally invasive surgery with RG; their findings support the idea that RG can be widely used for performing minimally invasive surgery.

In 2019, Kim et al. [27] published an article that covered the largest number of samples for the CUSUM-learning curve study; it involved five surgeons with a total of 502 cases. From the relationship between the number of cases and Clavien-Dindo grade II≤ complications, they reported that there were approximately 4 learning phases, and that at least 88 cases were required to master RG. Another interesting result was that surgeons with more prior experience in laparoscopic surgery needed more time to show progress in robotic surgery. Although statistically debatable, this finding may support the belief that robotic surgery is useful for surgeons with less experience in minimally invasive surgery. In addition, their study systemically analyzed the best option for performing robotic surgery in numerous fields; their work can be widely used as the basis for further studies on the learning curve for robotic surgery.

LN DISSECTION

LN dissection is crucial for the long-term survival of patients with gastric cancer [4]. To enhance the accuracy of staging, some researchers have insisted that D2 LN dissection should be included in the routine process [28,29]. With conventional laparoscopic surgery, D2 LN dissection caused the most intraoperative bleeding even when performed by experienced surgeons [4]. Complex vascularity and limited field of view have prompted surgeons to consider more sophisticated methods [11,30,31].

In earlier studies, the number of LNs retrieved in RG and LG was not significantly different [4,12]. The amount of blood loss during operation, however, was much lower in RG [12]. This might be because of the robot's more sophisticated movements, helping surgeons to easily dissect the LNs along major vessels [32]. A maximum of 83 LNs were harvested, which is statistically equivalent to the number of LNs harvested in open surgery [19]. A better field of view and tremor correction system of the robot helped surgeons retrieve LNs more easily than before [19]. More studies, including randomized clinical trials, are necessary to clearly understand the advantages and disadvantages of RG over LG in LN dissection.

DEVELOPING A NEW FIELD

In recent years, physicians have compared the effectiveness of RG and LG and also explored ways to fully apply this state-of-the-art technology in other challenging areas.

Using robots for bariatric surgery

Robot-assisted bariatric gastrectomy is another field in which surgeons are showing great interest. Myers et al first reported the first Roux-en-Y gastric bypass [33] in 2000, but purely robotic surgery could be performed after 2014 when the da Vinci stapler was introduced [34]. Anastomotic leaks were significantly lower in robotic hand-sewn patients than in laparoscopically stapled patients. Although few studies comparing robotic and laparoscopic sleeve gastrectomy were published in 2016, Jung et al. mentioned a shorter learning curve for residents to be fully trained for sleeve gastrectomy; only 20 procedures were required according to their study [34].

A recent study involving the Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program (MBSAQIP) developed results rather than advocating conventional laparoscopic bariatric surgery [35]. Their four-year comparison data emphasized a significantly longer operation time in both robotic sleeve gastrectomy and gastric bypass than their laparoscopic counterparts [35]. Nevertheless, no significant improvements were found. Rather, readmission rates and length of stay were higher in robotic surgery. These results somewhat seem to contrast conventional beliefs that RG could help lower readmission rates and shorten hospital stay. The difference between patient characteristics and bariatric surgery vs. gastric cancer—might have caused such contrast. As Jung et al. [34] pointed out, laparoscopic sleeve gastrectomy may have already reached a “plateau”; the results are almost close to the optimum point that novel technologies, such as robotic sleeve gastrectomy have much less space to intervene and show its maximum potential. More studies with longer follow-up periods are needed to clarify the difference between laparoscopic and robotic bariatric surgery.

Structure-preserving surgery

Pylorus-preserving pancreaticoduodenectomy (PD) is a complex surgery, and most cases are performed through conventional open surgery [36]. Although the first laparoscopic PD was performed by Gagner and Pomp [37] in 1994, less than 150 cases have been reported in almost 2 decades. With the introduction of the da Vinci robot, a case of pylorus-preserving PD with minimally invasive surgery was successfully reported [36].

Success in PD has led to the expectation that the robotic procedure can provide similar structure-preserving effects in the field of gastrectomy. Pylorus-preserving gastrectomy (PPG) is a treatment for middle-third early gastric cancer cases [38]. As the pylorus was preserved after the gastrectomy, fewer patients complained about dumping syndrome, bile reflux, and malnutrition [39,40]. Until Han et al. first conducted robot-assisted pylorus-preserving gastrectomy (RPPG), laparoscopic-assisted pylorus-preserving gastrectomy (LAPPG) was the only minimally invasive surgery available in PPG [41]. RPPG was found to be as safe and feasible as LAPPG [41].

During D2 LN dissection, splenectomy is considered an inevitable process to completely remove the No. 10 LN [42]. Some studies have suggested that preserving the spleen even after LN dissection is better for the patients' prognosis [43]; even for experienced surgeons,

harvesting the No. 10 LN while preserving the spleen is challenging. A new technique was developed by Yang et al. [42] using the robot. Their long-term results were comparable to those of conventional D2 LN dissection. Chen presented step-by-step manuals for performing spleen-preserving robotic D2 LN dissection [44]. It may be noted that the cutoff points for hilar LN dissection and blood loss were 15 and 20 cases, respectively. Even in this challenging procedure, there was no conversion to open surgery or laparoscopy. Considering the relatively low cutoff points and conversion rate, this result shows that robotic D2 LN dissection without splenectomy could be more widely accepted by surgeons [44]. Because the data on robotic D2 LN without splenectomy have only recently been published, more studies with longer follow-up periods are needed. Further, more extensive LN dissection would become possible with the aid of robotic surgery.

Reduced-port robotic gastrectomy (RPRG)

Reduced-port laparoscopic gastrectomy (RPLG) is one of the most challenging gastrectomy techniques. A reduced port causes less harm to the patient. However, low visibility and difficult ergonomics hindered inexperienced surgeons from performing RPLG. To lower the level of difficulty, Kim et al. [45] grafted the da Vinci robot to reduced port gastrectomy. It is known to be the first time when RPRG with 2 instrument arms was attempted [45]. One unique point was the adoption of a single-port trocar that is used in laparoscopic surgery instead of the conventional Single-Site® platform for robotic surgery. Despite more challenging techniques with limited field of view, there were no significant differences between RPRG and RPLG. Only a longer operation time in RPRG (reasons, including conversion to LG) was statistically meaningful. As single-port RG is thought to be the ultimate goal for minimally invasive surgery [45], it could be considered that RG is passing through a transitional state. A study conducted on 100 consecutive cases with RPRG demonstrated similar results [46]. Although an average of 20 minutes more were consumed in RPRG, surgeons saved 50 mL of blood loss and could retrieve 10 more LNs when compared with conventional laparoscopic distal gastrectomy. It is believed that with the aid of fluorescence imaging, surgeons may retrieve more LNs in less time. To the best of our knowledge, however, RPRG with fluorescence imaging has not been reported yet.

Fusion with fluorescence imaging

Intraoperative bleeding and a limited range of views have prevented surgeons from harvesting an adequate number of LNs. In addition to robotic surgery, advanced imaging techniques using fluorescent dyes have been studied to assist the surgery. A trial was first conducted by Kim et al. [47] by developing an emulsion containing indocyanine green (ICG) and iodized oil. When injected into rats and beagles, the dye enhanced the LNs both on computed tomography and near-infrared imaging (NIR). To the best of our knowledge, Herrera-Almario et al. [48] were the first to integrate ICG and NIR into RG. ICG helped visualize the LNs in real time during the operation; on an average, 29 LNs were harvested in gastric adenocarcinoma. Furthermore, the average amount of time needed to apply the fluorescent dye and visualize the image was only 10 minutes [48]; this implies that the ICG could be applied quickly whenever needed. When injected into the artery, it took only 22 seconds to visualize the infrapyloric artery [49]. Owing to the quick visualization of the infrapyloric artery, surgeons could conduct PPG more easily than before.

Kwon proposed the idea that ICG injection near the tumor site one day before surgery would help physicians perform complete LN dissection and eventually assess intraoperatively whether the LN dissection is adequate or not [50]. Compared to the control group, more LNs

were harvested, and the same results were obtained with LNs from stations 2, 6, 7, 8, and 9. Another major finding was that among patients who were diagnosed with LN metastasis, all metastatic LNs were fluorescent [50]. Cianchi et al. [51] also concluded that RG with ICG fluorescence helped detect additional LNs, although selectivity for metastatic LNs was below expectation. A randomized clinical trial regarding the safety of ICG was published in February 2020 [52]. With a total of 266 patients, either distal or total RG with ICG harvested a greater number of D2 LNs, lowering LN noncompliance [52]. This study was notable because patients with various cancer stages (cT1 to cT4a) were involved, and by far, there were no complications from the ICG injection itself. This may imply that ICG is less likely to be hazardous; rather, it could be widely used as a part of a standard operation for gastrectomy.

Recent advances in imaging techniques have increased the scope of robotics to new areas. With this revolution in imaging, we expect an even shallower learning curve for less experienced surgeons. Data comparing the long-term results of the learning curve for laparoscopic surgery, and robots with or without ICG are needed to determine ICG's feasibility.

Robotic system updates for better postoperative outcomes

Advances in robotic technology are expected to help surgeons as well. Intuitive Surgical Inc., the manufacturer of the da Vinci surgical system, has recently announced its newest product, the da Vinci Xi in 2014. Compared to the conventional da Vinci Si system, the da Vinci Xi offers a better operator-friendly environment, including a universal camera arm and longer instruments [53]. One major improvement was the integration of firefly fluorescence imaging, which aided surgeons to quickly switch to find target LNs and avoid structural damage [53]. Both Roux-en-Y gastric bypass and gastrectomy for gastric cancer proved that da Vinci Xi is as feasible as its conventional counterpart [53,54]. However, a longer time for docking in Xi was noted in both studies. Surgeons chose the standard da Vinci Si's docking protocol even when using the da Vinci Xi, and this might have caused longer docking time in the da Vinci Xi. More time might be needed for surgeons to be fully accustomed to the newer system, and the docking time is expected to be shortened [54]. This study is considered the first comparison between the Si and Xi robots in terms of gastric cancer surgery [54], yet more studies are expected to fully compare the 2 systems.

CONCLUSION

Almost 20 years have passed since the first RG was performed [8]. Compared with LG, RG involves a relatively higher cost and longer operative time; hence, it has not become an attractive surgical option. Moreover, both short-term and long-term results of RG were not significantly different from those of LG. However, these findings have propelled researchers to pioneer into novel fields where the advantages of RG can outweigh those of LG. RG has proven to be a beneficial method for educating surgeons who have just begun studying minimally invasive surgery. RG is a strong candidate for organ-preserving extensive LN dissection, and with the help of a new fluorescent dye, this process will surely lower the barrier for such a challenging operation. Further studies, such as randomized control studies, should be conducted. We believe that RG will become a significant turning point in the field of minimally invasive surgery in the future.

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REFERENCES

1. National Institutes of Health Consensus Development Conference Statement on gallstones and laparoscopic cholecystectomy. *Am J Surg* 1993;165:390-8.
[PUBMED](#) | [CROSSREF](#)
2. Kitano S, Shiraishi N, Uyama I, Sugihara K, Tanigawa N Japanese Laparoscopic Surgery Study Group. A multicenter study on oncologic outcome of laparoscopic gastrectomy for early cancer in Japan. *Ann Surg* 2007;245:68-72.
[PUBMED](#) | [CROSSREF](#)
3. Hyun MH, Lee CH, Kim HJ, Tong Y, Park SS. Systematic review and meta-analysis of robotic surgery compared with conventional laparoscopic and open resections for gastric carcinoma. *Br J Surg* 2013;100:1566-78.
[PUBMED](#) | [CROSSREF](#)
4. Baek SJ, Lee DW, Park SS, Kim SH. Current status of robot-assisted gastric surgery. *World J Gastrointest Oncol* 2011;3:137-43.
[PUBMED](#) | [CROSSREF](#)
5. Dakin GF, Gagner M. Comparison of laparoscopic skills performance between standard instruments and two surgical robotic systems. *Surg Endosc* 2003;17:574-9.
[PUBMED](#) | [CROSSREF](#)
6. Kim MC, Jung GJ, Kim HH. Learning curve of laparoscopy-assisted distal gastrectomy with systemic lymphadenectomy for early gastric cancer. *World J Gastroenterol* 2005;11:7508-11.
[PUBMED](#) | [CROSSREF](#)
7. Son T, Hyung WJ. Robotic surgery for gastric cancer. *J Korean Med Assoc* 2012;55:613-9.
[CROSSREF](#)
8. Hashizume M, Sugimachi K. Robot-assisted gastric surgery. *Surg Clin North Am* 2003;83:1429-44.
[PUBMED](#) | [CROSSREF](#)
9. Konstantinidis IT, Ituarte P, Woo Y, et al. Trends and outcomes of robotic surgery for gastrointestinal (GI) cancers in the USA: maintaining perioperative and oncologic safety. *Surg Endosc* 2020;34:4932-42.
[PUBMED](#) | [CROSSREF](#)
10. Uyama I, Suda K, Nakauchi M, et al. Clinical advantages of robotic gastrectomy for clinical stage I/II gastric cancer: a multi-institutional prospective single-arm study. *Gastric Cancer* 2019;22:377-85.
[PUBMED](#) | [CROSSREF](#)
11. Suda K, Man-I M, Ishida Y, Kawamura Y, Satoh S, Uyama I. Potential advantages of robotic radical gastrectomy for gastric adenocarcinoma in comparison with conventional laparoscopic approach: a single institutional retrospective comparative cohort study. *Surg Endosc* 2015;29:673-85.
[PUBMED](#) | [CROSSREF](#)
12. Kim MC, Heo GU, Jung GJ. Robotic gastrectomy for gastric cancer: surgical techniques and clinical merits. *Surg Endosc* 2010;24:610-5.
[PUBMED](#) | [CROSSREF](#)
13. Caruso S, Patrì A, Marrelli D, et al. Open vs robot-assisted laparoscopic gastric resection with D2 lymph node dissection for adenocarcinoma: a case-control study. *Int J Med Robot* 2011;7:452-8.
[PUBMED](#) | [CROSSREF](#)
14. Liao G, Zhao Z, Khan M, Yuan Y, Li X. Comparative analysis of robotic gastrectomy and laparoscopic gastrectomy for gastric cancer in terms of their long-term oncological outcomes: a meta-analysis of 3410 gastric cancer patients. *World J Surg Oncol* 2019;17:86.
[PUBMED](#) | [CROSSREF](#)
15. Kim HI, Han SU, Yang HK, et al. Multicenter prospective comparative study of robotic versus laparoscopic gastrectomy for gastric adenocarcinoma. *Ann Surg* 2016;263:103-9.
[PUBMED](#) | [CROSSREF](#)
16. Shibasaki S, Suda K, Obama K, Yoshida M, Uyama I. Should robotic gastrectomy become a standard surgical treatment option for gastric cancer? *Surg Today* 2020;50:955-65.
[PUBMED](#) | [CROSSREF](#)

17. Coratti A, Fernandes E, Lombardi A, et al. Robot-assisted surgery for gastric carcinoma: five years follow-up and beyond: a single western center experience and long-term oncological outcomes. *Eur J Surg Oncol* 2015;41:1106-13.
[PUBMED](#) | [CROSSREF](#)
18. Suda K, Nakauchi M, Inaba K, Ishida Y, Uyama I. Robotic surgery for upper gastrointestinal cancer: Current status and future perspectives. *Dig Endosc* 2016;28:701-13.
[PUBMED](#) | [CROSSREF](#)
19. Song J, Oh SJ, Kang WH, Hyung WJ, Choi SH, Noh SH. Robot-assisted gastrectomy with lymph node dissection for gastric cancer: lessons learned from an initial 100 consecutive procedures. *Ann Surg* 2009;249:927-32.
[PUBMED](#) | [CROSSREF](#)
20. Hong SS, Son SY, Shin HJ, Cui LH, Hur H, Han SU. Can robotic gastrectomy surpass laparoscopic gastrectomy by acquiring long-term experience? A propensity score analysis of a 7-Year experience at a single institution. *J Gastric Cancer* 2016;16:240-6.
[PUBMED](#) | [CROSSREF](#)
21. Obama K, Kim YM, Kang DR, et al. Long-term oncologic outcomes of robotic gastrectomy for gastric cancer compared with laparoscopic gastrectomy. *Gastric Cancer* 2018;21:285-95.
[PUBMED](#) | [CROSSREF](#)
22. Yang SY, Roh KH, Kim YN, et al. Surgical outcomes after open, laparoscopic, and robotic gastrectomy for gastric cancer. *Ann Surg Oncol* 2017;24:1770-7.
[PUBMED](#) | [CROSSREF](#)
23. Heemskerk J, van Gemert WG, de Vries J, Greve J, Bouvy ND. Learning curves of robot-assisted laparoscopic surgery compared with conventional laparoscopic surgery: an experimental study evaluating skill acquisition of robot-assisted laparoscopic tasks compared with conventional laparoscopic tasks in inexperienced users. *Surg Laparosc Endosc Percutan Tech* 2007;17:171-4.
[PUBMED](#) | [CROSSREF](#)
24. Jin SH, Kim DY, Kim H, et al. Multidimensional learning curve in laparoscopy-assisted gastrectomy for early gastric cancer. *Surg Endosc* 2007;21:28-33.
[PUBMED](#) | [CROSSREF](#)
25. Park SS, Kim MC, Park MS, Hyung WJ. Rapid adaptation of robotic gastrectomy for gastric cancer by experienced laparoscopic surgeons. *Surg Endosc* 2012;26:60-7.
[PUBMED](#) | [CROSSREF](#)
26. An JY, Kim SM, Ahn S, et al. Successful robotic gastrectomy does not require extensive laparoscopic experience. *J Gastric Cancer* 2018;18:90-8.
[PUBMED](#) | [CROSSREF](#)
27. Kim MS, Kim WJ, Hyung WJ, et al. Comprehensive learning curve of robotic surgery: Discovery from a multicenter prospective trial of robotic gastrectomy. *Ann Surg*. Forthcoming 2019.
[PUBMED](#) | [CROSSREF](#)
28. Pugliese R, Maggioni D, Sansonna F, et al. Subtotal gastrectomy with D2 dissection by minimally invasive surgery for distal adenocarcinoma of the stomach: results and 5-year survival. *Surg Endosc* 2010;24:2594-602.
[PUBMED](#) | [CROSSREF](#)
29. Shimizu S, Uchiyama A, Mizumoto K, et al. Laparoscopically assisted distal gastrectomy for early gastric cancer: is it superior to open surgery? *Surg Endosc* 2000;14:27-31.
[PUBMED](#) | [CROSSREF](#)
30. Kim MC, Choi HJ, Jung GJ, Kim HH. Techniques and complications of laparoscopy-assisted distal gastrectomy (LADG) for gastric cancer. *Eur J Surg Oncol* 2007;33:700-5.
[PUBMED](#) | [CROSSREF](#)
31. Shehzad K, Mohiuddin K, Nizami S, et al. Current status of minimal access surgery for gastric cancer. *Surg Oncol* 2007;16:85-98.
[PUBMED](#) | [CROSSREF](#)
32. Tsai SH, Liu CA, Huang KH, et al. Advances in laparoscopic and robotic gastrectomy for gastric cancer. *Pathol Oncol Res* 2017;23:13-7.
[PUBMED](#) | [CROSSREF](#)
33. Myers SR, McGuirl J, Wang J. Robot-assisted versus laparoscopic gastric bypass: comparison of short-term outcomes. *Obes Surg* 2013;23:467-73.
[PUBMED](#) | [CROSSREF](#)
34. Jung MK, Hagen ME, Buchs NC, Buehler LH, Morel P. Robotic bariatric surgery: a general review of the current status. *Int J Med Robot* 2017;13:e1834.
[PUBMED](#) | [CROSSREF](#)

35. Dudash M, Kuhn J, Dove J, et al. The longitudinal efficiency of robotic surgery: an MBSAQIP propensity matched 4-year comparison of robotic and laparoscopic bariatric surgery. *Obes Surg* 2020;30:3706-13.
[PUBMED](#) | [CROSSREF](#)
36. Parisi A, Desiderio J, Trastulli S, et al. Robotic pylorus-preserving pancreaticoduodenectomy: technical considerations. *Int J Surg* 2015;21 Suppl 1:S59-63.
[PUBMED](#) | [CROSSREF](#)
37. Gagner M, Pomp A. Laparoscopic pylorus-preserving pancreatoduodenectomy. *Surg Endosc* 1994;8:408-10.
[PUBMED](#) | [CROSSREF](#)
38. Japanese Gastric Cancer Association. Japanese gastric cancer treatment guidelines 2010 (ver. 3). *Gastric Cancer* 2011;14:113-23.
[PUBMED](#) | [CROSSREF](#)
39. Shibata C, Shiiba KI, Funayama Y, et al. Outcomes after pylorus-preserving gastrectomy for early gastric cancer: a prospective multicenter trial. *World J Surg* 2004;28:857-61.
[PUBMED](#) | [CROSSREF](#)
40. Nunobe S, Sasako M, Saka M, Fukagawa T, Katai H, Sano T. Symptom evaluation of long-term postoperative outcomes after pylorus-preserving gastrectomy for early gastric cancer. *Gastric Cancer* 2007;10:167-72.
[PUBMED](#) | [CROSSREF](#)
41. Han DS, Suh YS, Ahn HS, et al. Comparison of surgical outcomes of robot-assisted and laparoscopy-assisted pylorus-preserving gastrectomy for gastric cancer: a propensity score matching analysis. *Ann Surg Oncol* 2015;22:2323-8.
[PUBMED](#) | [CROSSREF](#)
42. Yang K, Cho M, Roh CK, et al. Robotic spleen-preserving splenic hilar lymph node dissection during total gastrectomy for gastric cancer. *Surg Endosc* 2019;33:2357-63.
[PUBMED](#) | [CROSSREF](#)
43. Li C, Kim S, Lai JF, et al. Lymph node dissection around the splenic artery and hilum in advanced middle third gastric carcinoma. *Eur J Surg Oncol* 2009;35:709-14.
[PUBMED](#) | [CROSSREF](#)
44. Chen QY, Zhong Q, Zheng CH, Huang CM. Robotic spleen-preserving splenic hilar lymphadenectomy for advanced proximal gastric cancer: a feasible and simplified procedure. *Surg Oncol* 2019;28:67-8.
[PUBMED](#) | [CROSSREF](#)
45. Kim YY, Lee Y, Lee CM, Park S. Lymphadenectomy using two instrument arms during robotic surgery for gastric cancer: a strategy to facilitate reduced-port robotic gastrectomy. *Asian J Surg* 2020;43:459-66.
[PUBMED](#) | [CROSSREF](#)
46. Seo WJ, Son T, Shin H, et al. Reduced-port totally robotic distal subtotal gastrectomy for gastric cancer: 100 consecutive cases in comparison with conventional robotic and laparoscopic distal subtotal gastrectomy. *Sci Rep* 2020;10:16015.
[PUBMED](#) | [CROSSREF](#)
47. Kim H, Lee SK, Kim YM, et al. Fluorescent iodized emulsion for pre- and intraoperative sentinel lymph node imaging: validation in a preclinical model. *Radiology* 2015;275:196-204.
[PUBMED](#) | [CROSSREF](#)
48. Herrera-Almario G, Patane M, Sarkaria I, Strong VE. Initial report of near-infrared fluorescence imaging as an intraoperative adjunct for lymph node harvesting during robot-assisted laparoscopic gastrectomy. *J Surg Oncol* 2016;113:768-70.
[PUBMED](#) | [CROSSREF](#)
49. Kim M, Son SY, Cui LH, Shin HJ, Hur H, Han SU. Real-time vessel navigation using indocyanine green fluorescence during robotic or laparoscopic gastrectomy for gastric cancer. *J Gastric Cancer* 2017;17:145-53.
[PUBMED](#) | [CROSSREF](#)
50. Kwon IG, Son T, Kim HI, Hyung WJ. Fluorescent lymphography-guided lymphadenectomy during robotic radical gastrectomy for gastric cancer. *JAMA Surg* 2019;154:150-8.
[PUBMED](#) | [CROSSREF](#)
51. Cianchi F, Indennitate G, Paoli B, et al. The clinical value of fluorescent lymphography with indocyanine green during robotic surgery for gastric cancer: a matched cohort study. *J Gastrointest Surg* 2020;24:2197-203.
[PUBMED](#) | [CROSSREF](#)
52. Chen QY, Xie JW, Zhong Q, et al. Safety and efficacy of indocyanine green tracer-guided lymph node dissection during laparoscopic radical gastrectomy in patients with gastric cancer: a randomized clinical trial. *JAMA Surg* 2020;155:300-11.
[PUBMED](#) | [CROSSREF](#)

53. Niclauss N, Morel P, Jung MK, Hagen ME. A comparison of the da Vinci Xi vs. the da Vinci Si surgical system for Roux-En-Y gastric bypass. *Langenbecks Arch Surg* 2019;404:615-20.
[PUBMED](#) | [CROSSREF](#)
54. Alhossaini RM, Altamran AA, Choi S, et al. Similar operative outcomes between the da Vinci Xi® and da Vinci Si® systems in robotic gastrectomy for gastric cancer. *J Gastric Cancer* 2019;19:165-72.
[PUBMED](#) | [CROSSREF](#)