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Robotic gastrectomy for gastric cancer: surgical techniques and clinical merits

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Abstract

Background Robotic gastrectomy in the setting of gastric cancer is reported by some investigators. However, no study has compared robotic surgery with open or laparoscopic surgery for patients with gastric cancer. This study aimed to determine the clinical benefits of robotic gastrectomy over open and laparoscopic gastrectomy for the treatment of gastric cancer.

Methods After the introduction of the da Vinci surgical system in November 2007 at the authors' hospital, 18 robotic gastrectomies were performed from 31 December 2007 to 30 June 2008. The prospective data from gastric cancer patients who underwent gastrectomies (16 robotic, 11 laparoscopic, and 12 open) during the same period were retrospectively analyzed.

Results Sex, age, comorbidity, extent of lymphadenectomy, pT stage, lymph node metastasis, and number of lymph nodes retrieved were similar among the three groups. The estimated blood loss was significantly less in the robotic gastrectomy group than in the open group ($p = 0.0312$), and the postoperative hospital stay in the robotic group was significantly shorter than in the open and laparoscopic gastrectomy groups ($p < 0.001$). Postoperative morbidity and time to first flatus were similar in the three groups. There was no open or laparoscopic conversion in the robotic group. No postoperative mortality occurred in any group.

Conclusion Robotic gastrectomy for the treatment of gastric cancer is a feasible and safe procedure in the hands of experienced laparoscopic surgeons. Robotic gastrectomy offers better short-term surgical outcomes than the open and laparoscopic methods. Furthermore, this procedure may be a preferable alternative for the treatment of gastric cancer.

Keywords Comparative study · Gastric cancer · Robotic gastrectomy

The wide acceptance of laparoscopic surgery in the world of general surgery since its introduction in 1988 [1] has resulted in the application of numerous procedures for the minimally invasive approach, benefiting many patients as a result. In the field of gastric cancer, laparoscopic gastrectomy was rapidly adopted in Korea and Japan because it offers a number of patient benefits [2–5]. However, several limitations and disadvantages are associated with conventional laparoscopic surgery including limited range of instrument movement, amplification of hand tremor, two-dimensional imaging, and unnatural positions for the surgeons.

Robotic surgery is superior to conventional laparoscopic surgery in that it has a tremor filter, can scale motions, has three-dimensional imaging, and offers improved dexterity with an internal articulated EndoWrist (Intuitive Surgical Inc., Sunnyvale, CA, USA) that allows seven degrees of freedom [6–8]. These characteristics are especially important when precise lymph node dissection is required for gastric cancer.

Human robotic surgery was introduced by Cadière et al. [9] in March 1997 with the performance of the first telesurgical laparoscopic cholecystectomy. Recently, robotic prostatectomy has gained popularity as a treatment for prostate cancer because of better postoperative outcomes [10].

Robotic gastrectomy has been reported by some investigators in the setting of gastric cancer [11–14]. However,

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no study has compared robotic surgery with open or laparoscopic surgery for patients with gastric cancer. This study aimed to determine the clinical benefits of robotic gastrectomy over open and laparoscopic gastrectomy for the treatment of gastric cancer.

Materials and methods

Patient criteria

After the introduction of the da Vinci surgical system (Intuitive Surgical Inc., Sunnyvale, CA, USA) in November 2007 at our hospital, we performed 18 robotic gastrectomies from 31 December 2007 to 30 June 2008. One patient who underwent D1 + α lymphadenectomy and another patient who underwent total gastrectomy were excluded from the study.

We retrospectively analyzed prospective data for gastric cancer patients in the database of Dong-A University Medical Center who underwent gastrectomies (16 robotic, 11 laparoscopic, and 12 open) during the same period. The clinicopathologic characteristics, postoperative outcomes, and postoperative morbidities were compared among the three groups. Before surgery, the details of the procedure had been explained to all the patients, and appropriate informed consent had been obtained.

Procedure indication

The indication for laparoscopic or robotic gastrectomy at our hospital was gastric cancer at a stage lower than cT2N1M0. Those suitable for endoscopic mucosal resection and those with a history of upper abdominal surgery were excluded from the study.

Surgeon background

All the operations in the current study were performed by one surgeon (M.-C. K.), who had performed more than 400 laparoscopic and 600 open gastrectomies for gastric cancer since April 2003, before performing robotic gastrectomy.

Robotic gastrectomy: operative technique

All patients in the three groups were performed subtotal gastrectomy with D1 + β or D2 lymphadenectomy and partial greater omentectomy. Figure 1 shows the layout of the robot, the operating table, and the anesthetic in the operating room. Blood loss during surgery was calculated based on the weight of the surgical sponges and the volume of suction.

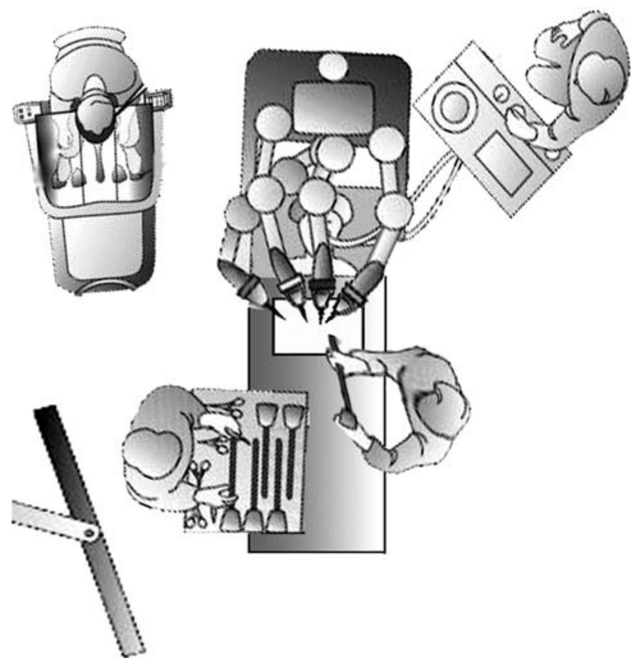


Fig. 1 Arrangement of the operating room and robot

Trocar insertion

After induction of general anesthesia, each patient was placed in the supine position. Figure 2 shows the locations of the trocars. We used one 12-mm trocar for the camera, three 8-mm trocars for the robot arms, and one 12-mm trocar for the surgical assistant. The required length of each trocar was at least 5 or 6 cm, and the robot arm motion functioned easily at 7 or 8 cm. Before the robot was docked, the left lobe of the liver was pierced with a Prolene 2-0 straight needle and pulled up toward the abdominal wall to achieve a maximal visual field during the surgery.

Robot docking

The da Vinci-S surgical system has motor wheels for easy movement, but the bed of the patient is somewhat easier to reposition when necessary. The left-to-right line of the robot body must be perpendicular to the head-to-leg line of the patient. Because the operating table cannot be changed once the robot has been docked, the height and slope of the operating table must be reconfirmed before the robot is docked.

Insertion of surgical instruments

First, the camera is inserted and manually operated. The robotic surgical instruments then are inserted carefully into

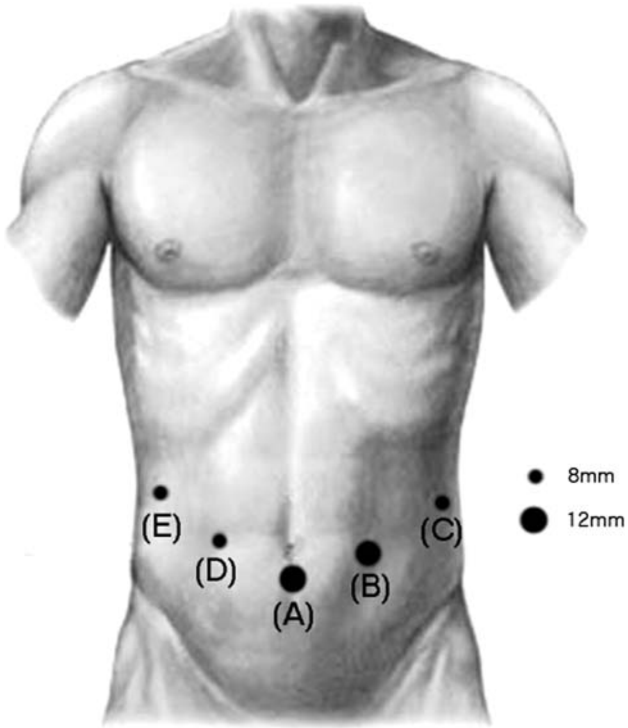


Fig. 2 Locations of the ports in robotic gastrectomy. A Camera port. B Assist port. C First robot arm port. D Second robot arm port. E Third robot arm port

the abdominal cavity while injury to organs in the cavity is avoided.

Operation with the surgeon console

The overall operative process in the abdominal cavity is identical to that of laparoscopic gastrectomy (Fig. 3) [15]. The ultrasonic shears resides in the surgeon's right hand during laparoscopy but in the surgeon's left hand during robotic surgery. The assistant retracts the stomach or pancreas, operates the stapler, applies clips, and removes surgical sponges.

Robot removal

The robot is removed from the patient after the duodenum is divided and the lymph node dissection is completed.

Reconstruction

As in laparoscopically assisted surgery, a 4- to 5-cm incision is made at the upper abdomen; the stomach is cut off; and gastroduodenostomy or gastrojejunostomy is performed. Starting with patient 14, we performed intracorporeal laparoscopic gastrojejunostomy and placed the specimen in a plastic bag. We then enlarged the incision of the umbilical port by about 2.5 to 3.5 cm for removal of the specimen from the peritoneal cavity.

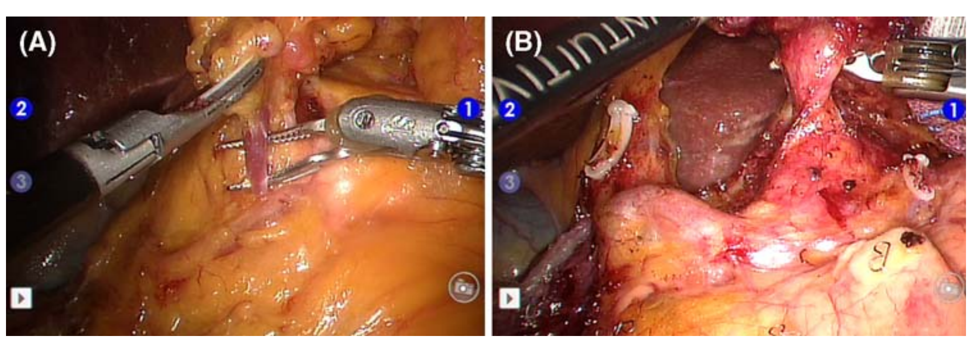
Perioperative management

Unless otherwise indicated, patients in the three groups were managed using a standardized postoperative clinical pathway with no nasogastric intubation or preoperative mechanical bowel preparation, one closed suction drain, sips of water 48 h after the operation, a clear liquid diet on postoperative day 3, and hospital discharge recommended on postoperative day 5 when the patient tolerated a soft diet. All the patients received continuous intravenous injection of mixed analgesics for 3 to 4 days after surgery.

Statistical analysis

Statistical analysis was performed using the unpaired Student's *t*-test and the Mann–Whitney *U* test for continuous variables and the chi-square test for categorical variables. For all three tests, p values less than 0.05 were interpreted as statistically significant. Values are expressed as mean ± standard deviation.

Fig. 3 Intraoperative findings of robotic gastrectomy. **A** LN #6 dissection of the infrapyloric area. **B** LN #7, 8a, 9, 11p dissection of the suprapancreatic area



Results

Table 1 shows the clinicopathologic characteristics of the patients in the three groups. The body mass index (BMI) of the robotic gastrectomy patients was significantly lower than that of the open and laparoscopic patients ($p = 0.0004$). Sex, age, and comorbidity were similar in the three groups. Although the preoperative clinical staging of all the patients was lower than cT2N1M0, one patient in the open group had a pT3 lesion, and two patients in the robotic group had a pT3 lesion. The lymphadenectomy extent, pT stage, lymph node metastasis, and number of retrieved lymph nodes were similar in the three groups.

Table 2 shows the operative outcomes for the patients in the three groups. The estimated blood loss was significantly less in the robotic gastrectomy group than in the open group ($p = 0.0312$), and the postoperative hospital stay in the robotic group was significantly shorter than in the open and laparoscopic gastrectomy groups ($p < 0.001$). However, the operative time was significantly longer in the robotic group than in the open and laparoscopic gastrectomy groups ($p < 0.0001$). The postoperative morbidity and time to first flatus were similar in the three groups.

Two patients in the open gastrectomy group experienced intraabdominal bleeding and wound infections. Paralytic ileus occurred for one patient in the laparoscopic gastrectomy group. However, these complications were managed conservatively without reoperation. No open or laparoscopic conversion occurred in the robotic group. There was no postoperative mortality in any group.

Discussion

Treatment of early-stage gastric cancer (stage 1 or 2) is changing to a large degree. Open gastrectomy, laparoscopic gastrectomy, and endoscopic mucosal resection all are feasible options for the treatment of this disorder [16–18]. However, most early-stage gastric cancers should be treated with open or laparoscopic gastrectomy with extraperigastric lymph node dissection because of possible lymph node metastasis.

Recently, the survival benefit of D2 lymphadenectomy over D1 lymphadenectomy for gastric cancer has been proved [19]. The extent of lymphadenectomy in laparoscopic gastrectomy currently is extended from D1 + β to D2 [20], although it has been introduced from D1 + α. Laparoscopic dissection of the lymph nodes around the superior mesenteric vein (LN #14v), celiac axis (LN #9), and splenic artery (LN #11) is troublesome due to limited range of instrument movement, intentional tremor, and poor vision, even for experienced laparoscopic surgeons.

Table 1 Patients' clinicopathologic characteristics

	Open ($n = 12$)	Laparoscopic ($n = 11$)	Robotic ($n = 16$)	p Value
Sex (M:F)	9:3	10:1	10:6	0.2512
Mean age (years)	56.0 ± 12.4	57.9 ± 13.1	53.8 ± 15.6	0.7541
Mean BMI (kg/m^2)	25.2 ± 1.9	25.3 ± 2.5	21.3 ± 3.4	0.0004
Comorbidity: n (%)	4 (33.3)	5 (45.4)	4 (25.0)	0.5414
Extent of lymphadenectomy				
D1 + β/D2	0/12	3/8	2/14	0.1479
pT stage				
T1/T2/T3	8/3/1	10/1/0	9/5/2	0.4203
Lymph node metastasis				
No/yes	8/4	10/1	14/2	0.2421
No. of retrieved LN	43.3 ± 10.4	37.4 ± 10.0	41.1 ± 10.9	0.3977

BMI body mass index; *LN* lymph node

Table 2 Mean operative outcomes

	Open ($n = 12$)	Laparoscopic ($n = 11$)	Robotic ($n = 16$)	p Value
Estimated blood loss (ml)	78.8 ± 74.1	44.7 ± 37.1	30.3 ± 15.1	0.0312
Operation time (min)	126.7 ± 24.1	203.9 ± 36.4	259.2 ± 38.9	<0.0001
Time to first flatus (days)	3.4 ± 0.9	3.6 ± 0.9	3.2 ± 1.1	0.5193
Postoperative hospital stay (days)	6.7 ± 1.4	6.5 ± 0.8	5.1 ± 0.3	<0.0001
Complication				
No/yes	10/2	10/1	16/0	0.2561

According to the analysis of bleeding during laparoscopic gastrectomy [21], the infrapyloric area, including LN #6 and 14v, is the most frequent source of intraoperative bleeding, and the suprapancreatic area, including LN #7, 8a, and 9, is the second most frequent source. In particular, lymph node dissection around these areas is very difficult to perform in patients with a high BMI. In a study investigating the effect of obesity on LADG, the operative time for obese male patients was significantly longer than for other patients [22].

Robotic gastrectomy for the treatment of gastric cancer has been reported by several investigators, all of whom have insisted that robotic gastrectomy is safe and allows for adequate lymphadenectomy [11–14]. However, no comparative study of robotic gastrectomy using open or laparoscopic gastrectomy has been conducted. In our 2005 study of laparoscopy and open subtotal gastrectomy with D1 + β lymphadenectomy [23], we noted no significant differences between the two procedure groups in number of retrieved lymph nodes or operative morbidity. In the laparoscopy group, the wound size was smaller, and the postoperative recovery was faster, but the operative time was longer. The results of the current study were similar to those seen in the previous laparoscopy versus open study.

In the current study, robotic gastrectomy offered better short-term surgical outcomes than the other two methods. The estimated blood loss in the robotic gastrectomy group was significantly less than in the open gastrectomy group. Robot assistance can facilitate precise lymph node dissection while minimizing blood loss. Furthermore, in this study, the patients who underwent robotic gastrectomy could be discharged at an earlier date than the patients who underwent open or laparoscopic gastrectomy.

Hiki et al. [24] asserted that manual handling of organs during gastrectomy is an important contributor to the inflammatory response after surgery. The small robot instruments may induce less inflammation than the instruments used for the other two groups. Hence, postoperative bowel recovery in the robotic group may occur sooner, although the three groups showed no statistically significant difference.

In addition, other studies have shown that robotic gastrectomy has ergonomic benefits [9, 25, 26] although the current study did not address such issues. Although investigators tend to focus solely on the patient benefits offered by laparoscopic gastrectomy, a well-designed study of surgeon ergonomics also may be required.

As a matter of course, the operative time for robotic gastrectomy was longer than for open or laparoscopic gastrectomy. However, 4-h robotic surgery is considered acceptable in the treatment of gastric cancer. Moreover, the operative time will be reduced as surgeons gain more experience and robotic devices are upgraded.

Concerning clinicopathologic characteristics, the BMI of patients in the robotic gastrectomy group was lower than in the open and laparoscopic gastrectomy groups. Hyung et al. [27] suggested that operative time is significantly influenced by surgeon experience and patient BMI. Therefore, patients with a low BMI were selected for the current study. This selection may have affected the postoperative outcomes for the robotic group such as operative time and blood loss.

Relatively difficult areas to access during laparoscopic lymphadenectomy include LN #14v, #8, #9, and #11p. Such areas could be dissected much more easily in robotic gastrectomy. The EndoWrist, tremor filtration, stable operative platform, and three-dimensional vision offered by the da Vinci surgical system aid the surgeon in avoiding vessel injury and in precisely dissecting lymph nodes.

Nevertheless, robotic gastrectomy has some disadvantages including a smaller field of view compared with the laparoscopic view, laborious movement from one surgical field to another, and difficult exposure of the surgical field using the third robot arm. In our experience, management of the third robot arm was essential for gaining an adequate surgical field because gastrectomy for gastric cancer requires multiquadrant surgical fields.

Although the current study was limited by its small patient numbers and retrospective nature, robotic gastrectomy for the treatment of gastric cancer is a feasible and safe procedure for experienced laparoscopic surgeons. Robotic gastrectomy offered better short-term surgical outcomes than the open and laparoscopic methods in terms of blood loss and hospital stay. Therefore, this procedure may be a preferable alternative for the treatment of gastric cancer.

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