

Robot-assisted laparoscopic total and partial gastric resection with D2 lymph node dissection for adenocarcinoma

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Received: 12 April 2008 / Accepted: 31 July 2008
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Abstract

Background Lymph node dissection and esophageal anastomosis, considered the more demanding steps of laparoscopic gastrectomy for gastric adenocarcinoma, can be performed with the use of a remote-controlled robot.

Methods Thirteen patients with a histologically proved gastric cancer (six stage I, six stage II, and one stage III) were enrolled in a prospective study to assess feasibility and safety of the Da Vinci surgical system in total and partial gastrectomy with extended lymph node dissection. Outcome measures were conversion rate, intra- and post-operative morbidity and mortality, operative time, blood loss, number of lymph nodes harvested, and macroscopic and microscopic evaluation of resection margins.

Results Eight distal, four total, and one proximal laparoscopic gastrectomies were completed without conversion. Extended lymph node dissection, and esophagojejunal and esophagogastric anastomoses were successfully carried out using the da Vinci System. Mean operative time was 286 ± 32.6 min and blood loss was 103 ± 87.5 ml. Mean number of nodes retrieved was 28.1 ± 8.3 and all resection margins were negative. There was no mortality. Trocar bleeding requiring laparoscopy was the only major complication encountered. No recurrence occurred during a mean follow-up time of 12.2 ± 4.5 months.

Conclusions Robot-assisted laparoscopic lymph node dissection and esophageal anastomosis are feasible and safe. Longer follow-up time and randomized studies are needed to evaluate long-term outcome and clinical advantages of this new technology.

Keywords Abdominal · Cancer · Digestive · Technical · Robotic

Current gastric cancer treatment is based on gastric resection and regional lymph node dissection. Even though there is a considerable controversy regarding the appropriate extent of lymph node dissection, in Japan and Europe extended lymph node dissection (D2) is the standard of care for localized gastric cancer and early gastric cancer with a high risk of node metastasis [1–3].

The main advantages of this approach are considered to be prolonged survival and improved staging accuracy [4].

Laparoscopy-assisted partial gastrectomy with D2 lymph node dissection has been recently introduced as a treatment option for distal gastric cancer [5–7].

Oncologic outcome measures of laparoscopic partial gastrectomy are comparable to those of the open counterpart and the postoperative course improved in several retrospective and randomized controlled studies [2, 4–6].

However, widespread diffusion of this technique is limited by the complexity of D2 lymphadenectomy, entailing removal of node stations along the celiac trunk, left gastric artery, and hepatic pedicle [8].

Tumors of the proximal third of the stomach are treated by total gastrectomy in association with an extended lymph node dissection involving splenic, celiac, and cardia nodes. Although the incidence of proximal gastric cancer is

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increasing in the Western world [9], the role of laparoscopic total gastrectomy is still a matter of debate because of inherent difficulties of specific node dissection and esophagojejunal anastomosis [6, 10].

Recently, robotic surgery has been demonstrated to overcome intrinsic limitations of a traditional laparoscopic approach where the anatomical and operative conditions are similar to those encountered during gastric resection [11, 12].

Wristed instruments that allow seven degrees of freedom, tremor filtering, ability to scale motions, and stereoscopic vision improve surgeon dexterity when a fine manipulation of tissues in a close, fixed operating field or when handsewn sutures and knot tying are required [13].

Therefore, we believe that a robotic approach would also be relevant for laparoscopic D2 dissection and esophageal anastomosis.

The aim of this study is to evaluate feasibility and safety of robot-assisted laparoscopic total and subtotal gastrectomy for gastric cancer with extended lymphadenectomy using the Da Vinci surgical system (Intuitive Surgical Inc., Sunnyvale, CA).

Patients and methods

Between October 2006 and May 2007 we conducted a prospective evaluation of the feasibility and safety of robot-assisted laparoscopic subtotal and total gastrectomy with lymph node dissection based on the Japanese recommendations for D2 lymphadenectomy [14].

During this span of time all patients with histologically proven gastric cancer without organ invasion (T4) at pre-operative work-up and laparoscopy underwent minimally

invasive gastrectomy. Distal gastrectomy was performed in patients with antral gastric cancer and total gastrectomy for proximal gastric tumors and esophagogastric junction cancers type 3 of the Siewert classification. Patients with Siewert type 2 tumor underwent en bloc distal esophagectomy with resection of the proximal stomach [15].

All data were collected prospectively. Operative time was calculated as the time between pneumoperitoneum induction and port-site closure. Intraoperative blood loss was measured by subtraction. Patients were evaluated weekly with clinical examinations during the 30 days after discharge and then followed-up every 3 months.

In order to evaluate the accuracy of robotic lymph node dissection and differences with standard open D2 gastrectomy, lymph node harvest rate was compared with that of a series of 14 unselected open D2 gastrectomies (9 total and 5 partial) performed during the first semester of 2006.

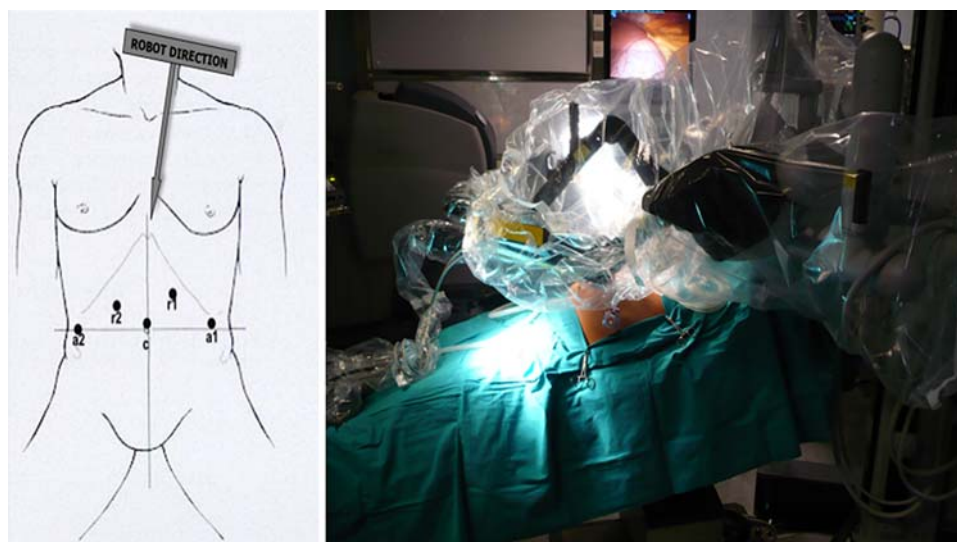
Operative technique

Patient and robot position, port placement

The patient is placed in the supine position with the monitor above the right shoulder. A 12-mmHg pneumoperitoneum is established using a Veress needle. A 12-mm camera port is placed just above the umbilicus. Two 12-mm trocars are placed under direct visualization 2–3 fingerbreadths below the costal margin at the right and left anterior axillary line, respectively (Fig. 1, trocar a1 and a2). The assistant uses these ports to retract the liver (a2) and to aid the surgeon (a1) during the robotic time of the operation.

One 12-mm trocar is placed along the left midclavicular line, 2–3 fingerbreadths below the costal margin and at

Fig. 1 Operative port placement and robot disposition in the operating room



least one handbreadth away from the camera port (r1). The last 12-mm trocar (r2) is placed on the right midclavicular line 2–3 cm below the level of port r1 and at least one handbreadth away from the camera port. These trocars are used during the robotic time to introduce the 8-mm Intuitive cannulae for robotic devices (the “trocar-in-trocar” technique). After placing the ports, the patient is moved to about 20° reverse Trendelenburg position.

Both surgeon and assistant work on the patient’s left side. A dedicated staff nurse sets up and drapes the robot after intraoperative operability assessment. Finally, the robotic cart is docked over the patient’s left shoulder in order to align its axis with the working axis of trocars r1 and r2 (Fig. 1). Robotic scope and endoscopic instruments are installed once laparoscopic time of the operation is concluded.

Partial gastric resection

The first part of the operation is performed laparoscopically.

Colo-epiploic division is performed using harmonic scalpel (Ultracision–Harmonic Scalpel, Ethicon Endo-Surgery Inc, Cincinnati, OH) along the border of the transverse colon. The lesser sac is entered and the posterior attachments of the stomach are divided. The two or three distal short gastric vessels and the left gastro-epiploic vessels are cut with harmonic scalpel. The superior layer of the mesocolon transversum is detached from the right colon angle to the pancreatic head. The right gastroepiploic vessels are identified at the level of the prepancreatic fascia and cut between clips, leaving lymph node station 6 attached to the pyloric wall. The right gastric artery is identified and cut with the harmonic scalpel close to the duodenal wall. The postpyloric duodenal region is now circumferentially dissected and transected using a 45-mm cartridge endostapler (blue load) (Ethicon Endo-Surgery, Cincinnati, USA). Care is taken to include the infraduodenal lymph nodes (stations 6) with the specimen. The stomach and greater omentum are then moved over the left hepatic lobe and the latter held back with a five-finger fan retractor introduced through a2 trocar. The celiac area and porta hepatis are now exposed and under tension.

The three arms of da Vinci robotic system are now brought into the operating field. The 30° robotic camera is inserted through the umbilical port. The robotic arms are set using the “trocar-in-trocar” technique. The orientation of the left and right robot arms reflects the console surgeon’s left and right. The right arm with a “Cadiere forceps” is introduced in the left trocar (r1). The left robotic arm carries a fine hook cautery and is introduced in the r2 trocar. The assistant stands on the patient left side using the suction device through the a1 trocar.

The robotic extended lymphadenectomy begins at the porta hepatis (station 12a) and continues above the pancreas along the common hepatic artery (station 8). The assistant takes care to maintain tension on the ligamentum hepato-duodenalis by gentle pressure on the pancreatic head. The right gastric vein and artery are clipped at the level of the portal vein and hepatic artery, respectively, and node dissection of station 5 is completed. The lymph nodes are removed en bloc along the hepatic artery reaching the origin of the celiac trunk. The lymphatic dissection continues along the celiac trunk (station 9) and the left gastric artery (station 7), which is clipped or tied at its origin (Fig. 2). In presence of an accessory left hepatic artery arising from the left gastric artery both vessels can be preserved and the lymphatic tissue dissected away from the adventitia.

The origin of the splenic artery is then identified and skeletonized of the lymphatic tissue (stations 11). Lymphectomy of the lesser curvature and of right cardia nodes (station 1) then follows (stations 3), continuing the dissection line along the left gastric artery.

Once the lymphadenectomy is completed, the assistant divides the stomach using multiple endostapler applications (blue or green loads) (Ethicon Endo-Surgery, Cincinnati, USA) from the a1 trocar. The specimen, including the stomach, omentum, and the lymphatic tissue, is placed on the liver surface. The assistant aids the console surgeon in manipulating the bowel to identify the ligament of Treitz. The small bowel is then transected by the assistant 15–20 cm away from the Treitz with a 45-mm cartridge endostapler (Ethicon Endo-Surgery, Cincinnati, USA). An antecolic, side-to-side gastrojejunostomy is realized on the posterior wall of the gastric stump

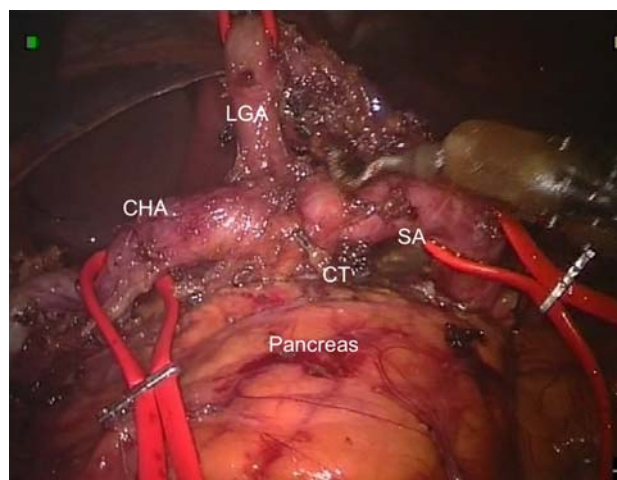


Fig. 2 The celiac trunk (CT) and its branches are completely exposed after node dissection. CHA, common hepatic artery; LGA, left gastric artery; SA, splenic artery

introducing a 45-mm cartridge endostapler (blue load) from the a1 trocar.

Two robotic needle holders are loaded and the gastroenterotomy is closed with a single-layer running suture. A side-to-side jejunojunal anastomosis is realized in the same manner. The specimen is then removed using a large endocatch introduced through the umbilical port as previously described [16].

One suction drain is routinely positioned close to the duodenal stump.

Total gastric resection

Trocar disposition and robot setup for total gastric resection are as described in partial gastric resection. After duodenal transection and lymphadenectomy of stations 5–6–12a–7–9–8–11, conducted as described above, all short gastric vessels are divided close to the splenic hilum with the robotic harmonic scalpel. Lymphatic tissue around the splenic artery is completely removed up to the splenic hilum. The diaphragmatic crura are dissected and the distal esophagus fully mobilized (Fig. 3). The robotic hook is suitable for this part of the procedure. Vagal nerves are cut and the cardia nodes (stations 1 and 2) harvested with the specimen. The stomach is grasped by the assistant and pulled distally in order to stretch the esophageal wall.

The anterior wall of the esophagus is cut with scissors and the anterior part of a purse-string suture is passed with two robotic needle holders. Once the anterior suture is completed, the posterior esophageal wall is sectioned and the purse-string suture completed. In this way withdrawal of the esophageal stump into the chest is avoided and all sutures are safely placed. The specimen is completely mobilized and placed over the right hepatic lobe. The anvil

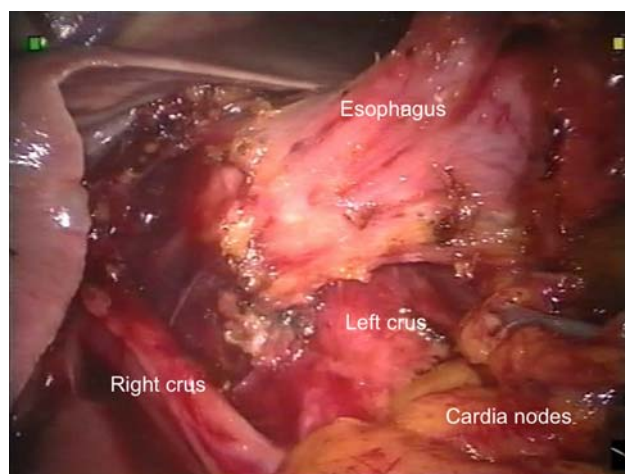


Fig. 3 The terminal esophagus fully mobilized. Diaphragmatic crura are exposed and freed from the surrounding adipose and lymphatic tissue

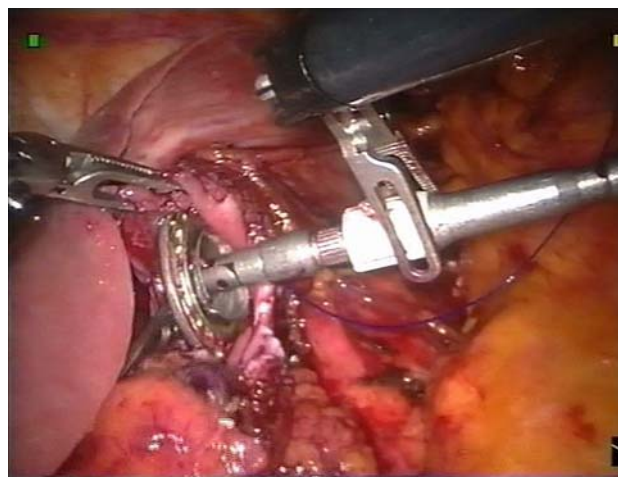


Fig. 4 The anvil head is introduced into the esophageal stump and secured with the purse-string suture

head of a no. 25 circular stapler (Proximate ILS, Ethicon, Somerville, NJ, USA) is introduced through the a1 port and secured to the esophageal stump by the robotic arms (Fig. 4). A 5–6-cm subxiphoid midline laparotomy is performed and the specimen extracted. The jejunal loop at 40 cm below the ligament of Treitz is easily extracted and divided with a linear stapler. A stapled end-to-side esophagojejunal anastomosis is performed, introducing the instrument shaft with the proximal jejunal stump through the minilaparotomy. The jejunal stump is then closed, firing one load of 45-mm cartridge endostapler. The Roux-en-Y reconstruction is finally completed with an extracorporeal handsewn jejunojunal anastomosis. A suction drain is placed between the duodenal stump and esophagojejunal anastomosis.

Proximal gastric resection

Abdominal trocars are disposed as previously described. A narrow gastric tube is formed by multiple linear stapler fires. Duodenal mobilization is accomplished without pyloroplasty. Omentectomy and short gastric vessels division are carried out using the harmonic scalpel. The gastroepiploic arcade is preserved. Robotic node dissection of station 7–8–9–10–11 is carried out as described above. Node dissection and esophageal mobilization continue through the hiatus up to the left pulmonary vein using the robotic hook. The patient is then positioned in a left-lateral-to-nearly-prone position. Thoracic trocar and robot positioning are as described by Kernstine et al. [17].

The azygos vein is ligated and divided to fully mobilize the distal esophagus with the periesophageal lymphatic tissue. Esophagus is transected with a cranial margin of 6 cm from the tumor. The anvil head is introduced through a small subxiphoid laparotomy and secured to the

esophagus with a purse-string suture as described for total gastrectomy. The specimen is extracted through the laparotomy and the intrathoracic esophagogastric anastomosis is carried out as described by Costi et al. [18].

A chest tube and an abdominal drain are left in place.

Statistical analysis

Data in the text and tables are given as mean \pm standard deviation (SD). Data were subjected to Student's *t*-test and were considered significantly different at $p \leq 0.05$. Statistical analysis was carried out using Prism 4.0.3 data analysis software for Windows (GraphPad Software, San Diego, CA, USA).

Results

Thirteen consecutive patients with stage I–II and III gastric cancer successfully underwent laparoscopic robot-assisted subtotal (nine patients) and total (four patients) gastrectomy with lymph node dissection.

Patient characteristics are summarized in Table 1. The patient with Siewert 2 esophagogastric junction tumor underwent neoadjuvant chemotherapy that was discontinued 1 month before surgery.

Intraoperative data

There were no conversions or intraoperative complications. Blood losses were small and no transfusions were required. Mean operative time for total and distal gastrectomy was 286 min, including a median time of 15 min for robot setup (Table 2). Proximal gastric resection with distal

Table 1 Patient characteristics

Age (years)	68.4 \pm 11.9
Gender (M:F)	1:1
BMI (kg/m ²)	26.13 \pm 4.73
ASA status	
II	8
III	4
Comorbidity	
Diabetes	2
Valvular heart disease	2
Chronic atrial fibrillation	1
Hypertension	4
Occlusive vascular disease	1
Chronic anemia	2
Primary bronchiectasia	1

BMI, body mass index; ASA, American Society of Anesthesiologists

Table 2 Intraoperative data and early outcome

Type of gastrectomy	
Total	4
Distal	8
Proximal	1
Operative time (min)	
Overall	286 \pm 32.6
Total gastrectomy	294.6 \pm 18.5
Partial gastrectomy	282 \pm 40.2
Proximal gastrectomy–esophagectomy	480
Estimated blood loss (ml)	103 \pm 87.5
Hospital stay (days)	11.2 \pm 4.3
Follow-up time (months)	12.2 \pm 4.5
Morbidity	
Duodenal stump leakage	1
Trocar bleeding	1
Prolonged ileus	1
Hyperamylasemia	1
Pulmonary edema	1
Pleural effusion	1

esophagectomy was more time consuming for the complexity of the procedure requiring the mobilization of the patient and robot.

All the procedures were completed according to the Japanese recommendations for lymph node dissection [14].

Pathologic features

Pathologic data are listed in Table 3. In all cases adequate tumor-free resection margins were obtained and the number of lymph nodes harvested was sufficient for accurate staging.

The mean number of lymph nodes harvested during robot-assisted and open D2 lymph node dissection was not significantly different (28.1 \pm 8.3 and 23.78 \pm 12.21, respectively).

Outcome

Patients were hospitalized a mean of 11 days (range 8–15 days). All but one patient with a prolonged ileus resumed a liquid diet on postoperative day 5 after routine postoperative contrast swallow. All patients discontinued analgesic assumption 3 days after surgery. The 30-day mortality was 0%. One patient with trocar bleeding requiring laparoscopy on postoperative day 2 represented the only case of major morbidity. One patient developed a low-output biliary leakage from the duodenal stump that was managed conservatively. A case of transient asymptomatic hyperamylasemia (167 UI/ml) was recorded in one

Table 3 Pathologic features

Stage	
Ia	3
Ib	3
II	6
III	1
Histology	
Intestinal type	11
Diffuse type	1
Mixed	1
Site of tumor	
Cardias (Siewert type 3)	3
Cardias (Siewert type 2)	1
Fundus	1
Body	2
Antrum	6
Nodes retrieved	28.1 ± 8.3
Resection margins in distal gastrectomy (cm)	
Proximal	9.7 ± 5.4
Distal	4 ± 2.9
Resection margins in proximal gastrectomy (cm)	
Proximal	6
Distal	4
Resection margin in total gastrectomy (cm)	
Proximal	3.7 ± 1.4

patient, who underwent an extensive and complex lymph node dissection in the celiac area. Stage Ib, II, and III patients ($n = 9$) underwent planned adjuvant chemotherapy within 3 weeks from surgery. One patient died of acute myocardial infarction 5 months after surgery. Port-site or local recurrences were not detected during a mean follow-up time of 12 months.

Discussion

Robotics is a useful tool to facilitate traditional laparoscopic surgery, allowing complex procedures to be carried out with a minimally invasive approach. Anderson et al. have already shown the feasibility of a precise and bloodless robot-assisted lymph node dissection during laparoscopic partial gastrectomy [19]. In our study we evaluated the extent of robot-assisted node dissection in comparison with a historical series of open D2 gastric resections, demonstrating that robotic procedure does not compromise radicality and staging accuracy. Similarly, the mean number of harvested nodes compares favorably with the numbers reported for laparoscopic gastric resection [6, 8]. Although these data do not support a better outcome of robot-assisted node dissection, there are subjective

surgeon-specific advantages, such as improved visibility and ease of accurate dissection, which will be harder to quantify and compare.

Total and proximal gastric resections are demanding operations when carried out in a minimally invasive fashion. A more accurate dissection of lymph node stations no. 1, 2, and 11 is needed, as well as a complete esophageal mobilization. Laparoscopic dissection of lymph nodes no. 10 and 11 without resection of the distal pancreas and the spleen is hard to accomplish because of the possibilities of injury to the splenic vessels, spleen, and pancreas [20]. Conversely, this fixed operating field represents the main indication for robotic surgery. Dissection of the splenic vessels is comfortably carried out by means of image magnification, tremor filtering, and fine robotic arm movements. The small branches of the splenic vessels are easily identified and preserved allowing a pancreas–spleen-preserving D2 node dissection. Isolation of diaphragmatic crura—a key step to an en bloc dissection of cardia nodes—is greatly facilitated by wristed instruments that allow complete encircling of the distal esophagus. Purse-string suture is easily carried out using the robotic arms, but greater skill is necessary to secure the anvil head, avoiding retraction of the esophageal stump. It is possible that the four-arm da Vinci S will facilitate also this difficult step of the operation. The small minilaparotomy is required for safe extraction of the huge specimen, including stomach, greater omentum, and all the regional node stations, and allows direct visualization of the anvil head secured to the esophagus in order to complete the anastomosis. It is our opinion that this minilaparotomy does not impair the advantages of a minimally invasive operation. In fact, incision dimensions are minimal and can be tailored to the specimen size.

Main criticisms of robot-assisted surgery are longer operating times, cost, and the difficulty to demonstrate a real advantage for the patient over laparoscopic surgery [13, 21]. Operating times and costs are undoubtedly higher than in open and laparoscopic gastric surgery. Operating times can be lowered after completion of the learning curve of both surgical and nursing staff, but prompt reduction of costs in the near future is harder to achieve. In fact, objective advantages of robotics over laparoscopic surgery have yet to be identified. This could rely on the parameters considered in the comparative studies conducted until now, such as length of stay and operating time, and the lack of a long-term follow-up. Some authors have considered a faster learning curve and surgeon's autonomy as factors to investigate in forthcoming comparative studies [11]. The possibility to extend minimally invasive surgery for the treatment of locally advanced gastric cancer is a more intriguing matter of investigation. To date, laparoscopic treatment of advanced gastric cancer is limited to only a

few centers because of concerns about oncologic adequacy and technical complexity of laparoscopic procedures [22]. On the contrary, patients with advanced gastric cancer could benefit from such a minimally invasive approach. In fact, more than 30% of patients who have undergone open radical resection do not begin adjuvant treatments because of postoperative complications or effects of surgery on their quality of life [23].

Adjuvant chemoradiation has been shown to be beneficial after radical or suboptimal surgical resection, and also chemotherapy alone seems to increase life expectancy in node-positive gastric cancer patients [24, 25].

In the near future, new approaches to gastric cancer management will provide novel opportunities of treatment, including immunochemotherapy and molecular-targeted therapies [26].

In this context, minimally invasive surgery could play a key role in improving postoperative course and accelerating times to adjuvant treatments.

Our study shows that laparoscopic robot-assisted total and partial gastric resections with D2 node dissection are feasible and safe operations. Postoperative course was excellent and all patients requiring chemotherapy were fit to undergo treatment without delay. Therefore, it is reasonable that robotics could facilitate minimally invasive surgery of advanced gastric cancer, enhancing patient adherence to multidisciplinary protocols.

Conclusions

Our study shows the feasibility and safety of robotic partial and total gastric resection for adenocarcinoma. Both D2 lymphectomy and esophageal anastomoses were made easier technically by robotic technology. Postoperative outcome was excellent, allowing planned chemotherapy without delay. Our results seem to justify the execution of controlled prospective trials to evaluate the role of robotic surgery in the treatment of gastric cancer.

Acknowledgment The authors would like to thank Dr. Luigi Maria Lapalorcia for language revision.

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