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SURGICAL ENDOSCOPY
and Other Interventional Techniques

Pilot series of robot-assisted laparoscopic subtotal gastrectomy with extended lymphadenectomy for gastric cancer

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Abstract
Background: Robotic surgery is evolving as a therapeutic tool for thoracic and urologic applications; however, its use in gastric cancer surgery has not been extensively reported. The objective of this pilot series was to assess the feasibility of using robotic surgery in performing an extended lymphadenectomy for gastric cancer.
Methods: Between June 2005 and July 2006, seven patients (3 female, 4 male) underwent combined laparoscopic subtotal gastrectomy with omentectomy and robot-assisted extended lymphadenectomy using the da Vinci® Surgical System for early distal gastric tumors. The mean age of the patients was 64 years. Tumor staging ranged from 0 to II. Six patients had adenocarcinoma and one patient had a high-grade dysplastic adenoma.
Results: All procedures were completed successfully without conversion. The median operating time was 420 min. There was one intraoperative complication requiring a colon resection for a devascularized segment. The median number of nodes harvested was 24 (range = 17–30). Resection margins were negative in all specimens. Patients were hospitalized a median of 4 days (range = 3–9). Thirty-day mortality was 0%. Patients resumed a solid diet a median of 4 days postoperatively. Median followup was 9 (range = 0–10) months. There have been no tumor recurrences to date.
Conclusion: Extended lymphadenectomy for gastric cancer using robotic surgery is safe and allows for an adequate lymph node retrieval. Our preliminary results suggest that this novel technique offers short hospital stays and low morbidity for patients undergoing surgical resection of distal gastric malignancies. Future studies will be necessary to better define the role of robotic surgery in gastric cancer treatment.

Key words: Gastric cancer — Lymphadenectomy — Robotics — Minimally invasive surgery — Robot-assisted gastrectomy

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The main goal in gastric cancer treatment is long-term survival while maintaining quality of life. Laparoscopy-assisted gastrectomy has been used as a treatment strategy to improve postoperative outcome in patients with early-stage gastric cancer. However, use of this technique has been limited by the inherent difficulty of an extended lymph node dissection (D2). Although laparoscopic D2 lymphadenectomy has been described and found to be feasible by experienced laparoscopic surgeons [13, 21, 25–28], it is technically challenging and can be associated with significant bleeding during dissection around the hepatic, celiac, and splenic arteries. Given the growing literature supporting extended lymphadenectomy [10, 23, 29], we employed robotic technology to facilitate lymph node dissection.

Robot-assisted surgery has the advantages over conventional laparoscopy of improved dexterity with an internal articulated endoscopic wrist that allows seven degrees of freedom, tremor filter, ability to scale motions, and stereoscopic vision [19]. These attributes are especially important when precise dissection is required. Robotic surgery for gastric cancer has been reported in centers in Japan and in Italy [7, 11, 12]. However, experience is limited and even less data are available with regard to oncologic parameters. In this report we describe our technique and the initial results of robot-assisted laparoscopic subtotal gastrectomy with extended lymphadenectomy for gastric cancer using the da Vinci® Surgical System (Intuitive Surgical Inc., Sunnyvale, CA). To our knowledge this is the first report of robotic surgery for gastric cancer in the United States.

Methods

Between June 2005 and July 2006, we performed seven robot-assisted laparoscopic subtotal gastrectomies with extended lymphadenectomy for distal early gastric cancer. All patients with early-stage disease (stage 2 or less) by preoperative imaging during this time period were offered a minimally invasive gastrectomy. Patient characteristics are given in Table 1. All procedures were performed by two attending surgeons (AP and JE) at the City of Hope Medical Center. All relevant

Table 1. Patient Features

Age (year)	64 (52–80)[a]
Gender (M:F)	4:3
BMI	25.8 (19.3–29.3)[a]
ASA	
II	1
III	3
IV	3

[a] median and ranges

data were collected through a respective chart review. The details of the procedure were explained to all patients and appropriate informed consent was obtained.

Operative technique

After the induction of general anesthesia, the patient is placed in the supine position. A split table allowing the surgeon to operate in between the patient's legs is particularly useful. Monitors are placed above the patient's head. An operating surgeon and one assistant perform this procedure. The first part of the operation is performed laparoscopically and consists of the following procedures: A pneumoperitoneum to 15 mmHg is established using a Veress needle technique. A 10-mm camera port is placed just above the umbilicus. Under direct visualization three 8-mm robotic trocars are placed, two in the upper abdomen bilaterally at the midclavicular line and one in the right anterior axillary line for liver retraction. In addition, a 10-mm port for the assistant is placed between the left robotic port and the camera port (Fig. 1). After placing the ports, the patient is moved to about 30° reverse Trendelenburg position.

Once the abdominal cavity has been found to be free of metastatic disease, an on-table endoscopy is performed to identify and mark the tumor if it cannot be seen laparoscopically. Following this an omentectomy is performed using a harmonic scalpel. This can be accomplished operating from either side or in between the patient's legs. Following this the lesser sac is entered and the posterior attachments of the stomach are divided again using the harmonic scalpel. Next, the right gastroepiploic vessels are identified and divided using a vascular stapler, clips, or the ultrasonic scalpel. The postpyloric duodenal region is now circumferentially dissected and transected using an Endo GIA™ stapler (blue load) (Tyco Healthcare, Mansfield, MA). Care is taken to include the infraduodenal lymph nodes with the specimen.

The four-arm da Vinci robotic system is now brought into the field above the patient's head by the circulating nurse. In robotic surgery, the arms are named as one looks at the machine after docking; thus, in this case the left arms will be attached on the patient's right side and vice versa. The surgeon moves to the console and the assistant moves to the patient's left side. A 30° robotic camera is used. The left-most lateral arm is used to elevate the liver superiorly, and the left midclavicular arm is used for a bipolar dissector. The right robotic arm carries a fine hook cautery. The robotic extended lymphadenectomy begins along the common hepatic artery above the pancreas and continues into the portal hepatis distally. During this dissection the right gastric vessels are divided between endoclips. The lymph nodes are removed en bloc along the hepatic artery to the origin of the celiac trunk (Fig. 2). Proximally, the lymphatic dissection is continued along the celiac truck, and the left gastric vessels are ligated at their origin (Fig. 3), again using endoclips or ties. The origin of the splenic artery is then identified and skeletonized of lymphatic tissue along its course up to the splenic helium. Following this, the lesser curvature of the stomach is stripped of lymphatic tissue. Thus, nodes along stations 1 - right paracardial, 3 - lesser curvature, 4sb, d - greater curvature, 5 - suprapyloric, 6 - infrapyloric, 7 - left gastric, 8a - common hepatic, 9 - celiac, 11p - splenic, and 12a - hepatoduodenal ligament are included in the specimen. This is based on the Japanese recommendations for a D2 lymphatic dissection for middle and lower gastric cancer [14].

Once the lymphadenectomy is completed, the stomach is divided using the Endo GIA stapler (blue or green load) by the assistant from the patient's left side. The specimen, including the stomach, omentum, and the lymphatic tissue, is placed into a large endocatch bag for removal through a suprapubic minilaparotomy incision. The procedure is completed by performing an anticolic, side-to-side gastrojejunostomy using an Endo GIA 60 stapler (blue load), fired from the assistant's port on the patient's left side. At this point two robotic needle holders are loaded and the gastroenterotomy is closed in two layers with 3-0 vicryl. The anastomosis is tested for integrity with 200–300 ml of methylene blue.

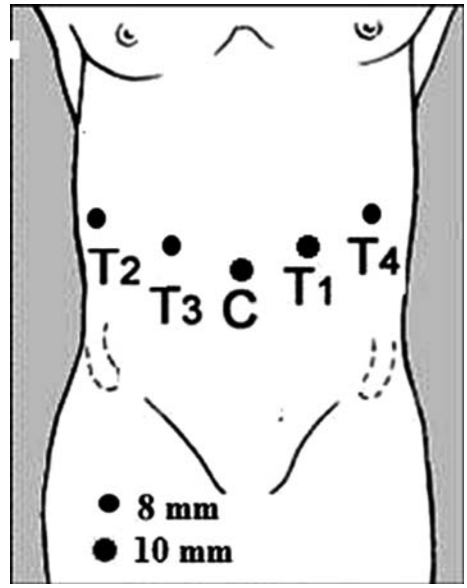

Fig. 1. Port placement.

Results

Seven consecutive patients with early distal gastric cancer successfully underwent laparoscopic robot-assisted subtotal gastrectomy with extended lymphadenectomy. Pathologic findings for this cohort are listed in Table 2. The median number of nodes harvested was 24, and 29% of patients had positive nodes. Resection margins were negative in all specimens. The median distance between the tumor and the proximal and distal margins was 4.5 cm and 6.2 cm, respectively.

Short-term outcomes, including operative details and postoperative course, are shown in Table 3. All procedures were completed successfully without conversion. The 30-day mortality was 0% and there were no major postoperative complications. The median estimated blood loss (EBL) was 300 cc and three patients received blood transfusions because of a low hemoglobin level before resection. One patient developed pulmonary edema on postoperative day (POD) 8. This occurred in an 80-year-old patient who was treated with diuretic therapy with complete resolution of symptoms. He was discharged home on POD 9.

Patients were hospitalized a median of four days. Five patients were admitted to ICU postoperatively for a median of one day because of age and or comorbidities. Seventy-one percent of patients were able to resume a liquid diet within one day postoperatively, and 57% resumed a soft gastrectomy diet within four days. Median followup was 9.7 months. Three-month followup weights were available for five patients, and there

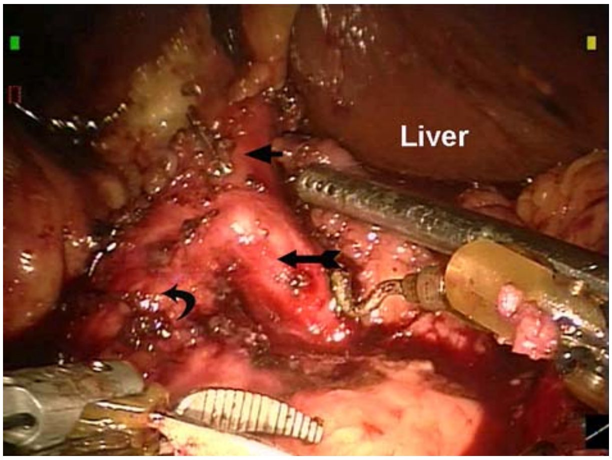

Fig. 2. Hepatic artery skeletonized of lymphatic tissue. Curved arrow is the gastroduodenal artery. The arrowhead points to the hepatic artery and the arrow demonstrates the common hepatic artery.

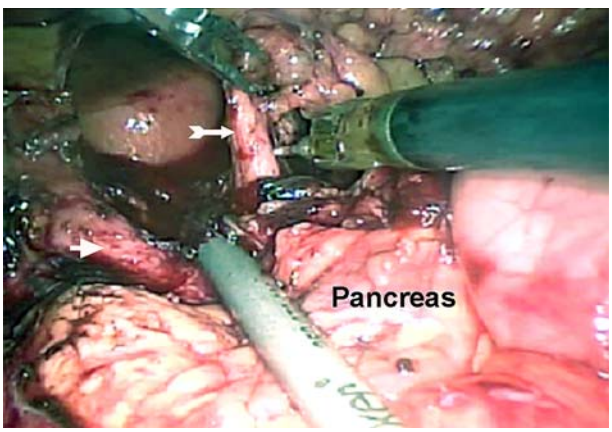

Fig. 3. Origin of left gastric artery. Arrowhead points to the common hepatic artery and the arrow to the left gastric artery.

Table 2. Pathological Features

Stage	
0	1
Ia	2
Ib	2
II	2
Histology	
Adenocarcinoma	3
Signet Cell	3
Dysplastic Adenoma	1
Site of tumor	
Body	4
Antrum	2
Pylorus	1
Nodes Retreived[a]	24 (17–30)
Tumor Size (cm)[a]	2.7 (.3–5.5)
Resection margins (cm)	
Proximal[a]	4.5 (3.5–11)
Distal[a]	6.2 (4.5–16.5)

[a] median and ranges

Table 3. Short-term outcomes

Operative time (mins)	420 mins (390–480)[a]
EBL	300 cc (100–900)[a]
Conversion	None
Hospital stay	
Total	4 days (3–9)[a]
ICU	1 day (0–2)[a]
Time to diet	
Liquid	1 day (1–6)[a]
Solid	4 days (2–8)[a]
Follow-up Time	9.7 months (2.1–13.5)[a]
Complications	
Intraoperative	colonic ischemia
Major	None
Minor	blood transfusion 3
	pulmonary edema 1

[a] median and ranges

was no significant difference from preoperative weights. The mean preoperative weight was 65 kg vs. 63.2 kg at three months ($p = 0.09$). There have been no port site or local tumor recurrences at this time.

Discussion

Laparoscopy-assisted surgery for early gastric cancer has been demonstrated to be surgically feasible [1, 2, 4, 8, 9, 13, 16, 17, 20–22, 24–28]. However, long-term oncologic data has yet to be reported. There is even less data available on robotic surgery for gastric cancer. In a small series reported by Adachi et al. [1], quality of life was improved in gastric cancer patients who underwent laparoscopic gastrectomy versus those who had conventional open gastrectomy. Several authors have recommended a minimally invasive approach for patients with early gastric cancer [1, 16].

The need for radical lymph node dissection for more advanced gastric cancer has been a topic of much debate. A recent randomized controlled trial comparing D1 nodal dissection (perigastric lymph nodes in close proximity to the primary tumor along the lesser and greater curvature) with D3 dissection (in addition, lymph nodes around the left gastric, common hepatic, and splenic arteries and in the hepatoduodenal ligament, the retropancreatic region, and the superior mesenteric vein) found a five-year survival advantage of 5.9% for D3 dissections [29]. Two other trials have suggested a survival benefit for patients undergoing extended lymphadenectomy who have N2 disease [10, 23]. However, other studies comparing D1 with D2 dissections have failed to show a similar survival benefit [3, 6].

The ability to perform a totally laparoscopic gastrectomy with radical lymph node dissection has been reported [13, 21, 25–28]. However, widespread use of this technique is limited by the technical challenge of performing this meticulous procedure, especially in patients with abundant intrabdominal fat. Others have demonstrated success with laparoscopy-assisted techniques in which the lymphadenectomy is performed laparoscopically but a minilaparotomy is used for some portions of the operation [4, 8, 9, 16, 17, 24].

Robotic technology has been employed in areas of surgery in which precise movements are required in small operative fields such as cardiac [18] and prostate [15] surgery. In our series we used a combination of laparoscopic mobilization with robotic dissection and reconstruction, taking advantage of each modality's unique advantages. In our experience robotic surgery is poorly suited for dissections involving multiple quadrants and heavy structures; thus, we routinely use standard laparoscopic techniques for the omentectomy. However, when precise dissection is needed, such as during the lymphadenectomy along major abdominal vessels, we prefer to take advantage of the stability and superior movements of the robotic arms. Importantly, the median body mass index (BMI) of our patients was 25.8, suggesting that robotic technology may facilitate laparoscopic extended lymphadenectomy in North American patients who have higher BMI than their Asian counterparts. We have performed laparoscopic D2 lymphadenectomy at our institution and have found that by using robotic technology this dissection can be performed with greater ease, possibly allowing more surgeons to complete this type of dissection in a minimally invasive fashion. The median number of nodes retrieved in this study is similar to that reported by other investigators who used laparoscopic or open techniques for D2 lymph node dissection [4, 6, 8, 16, 26].

The median operative time certainly reflects a learning curve, both for the operating room staff and for the surgeons. In September 2004 a fellowship-trained minimally invasive surgeon (AP) joined the Department of Surgery and served as a mentor for staff surgeons and surgical fellows. Robot-assisted gastrectomies were subsequently offered to patients. In addition, the operative time includes docking the robot, which can add 30–45 min to the procedure.

With increased operative time, the cost of the procedure is increased over a standard open or laparoscopic gastrectomy. We estimate that the added cost of robotic gastric surgery over conventional laparoscopic surgery is approximately $750 per case, accounting for the robotic drapes and robotic instruments.

We have found a shorter length of hospital stay and earlier return to oral feeding after robotic surgery compared with historic controls undergoing open surgery for gastric cancer [3, 5]. We were also able to demonstrate a low postoperative morbidity rate despite a patient group with advanced age and substantial comorbidities. Thus, further studies are needed to determine the actual overall expense that robotic surgery adds to the healthcare costs for patients with gastric cancer treated with robot-assisted procedures.

Conclusion

The purpose of this study was to describe the use of robotic technology in gastric cancer surgery in a pilot series. Therefore, our conclusions are limited by small sample size and lack of comparison to the standard open technique. However, we have found that extended lymphadenectomy for gastric cancer using robotic technology is safe and has a low morbidity and allows for an adequate lymph node retrieval. Further trials are required to investigate the potential effects of this minimally invasive approach in terms of quality of life, recurrence, survival, and cost in patients with gastric malignancies.

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