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Minimally Invasive Gastric Surgery

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Keywords

Stomach neoplasm; laparoscopy; gastrectomy; robot-assisted surgery

Introduction

Since Kitano et al described their initial report of laparoscopic distal gastrectomy (1) the indications and uses of minimally invasive gastrectomy have expanded and now include early and advanced gastric cancer as well as subtotal and total gastrectomies. The incorporation of new technologies such as high definition video systems, a wide arrange of stapling devices and the evolution of energy devices and vessel sealers have allowed minimally invasive gastrectomy to expand its indications as well as to use this approach for more complex cases. In addition, the development of robotic platforms, with instruments with expanded range of motion and importantly the possibility to include functional imaging, have opened a new chapter in the minimally invasive treatment of gastric cancer.

More importantly, there has been an increasing trend in the incidence of gastric cancer and GE junction tumors (2), and many surgeons will likely have to treat more cases of gastric cancer. A thorough knowledge of the advantages of minimally invasive gastrectomy as well as adequate patient selection for this technique will lead to better outcomes for these patients. The purpose of this review is to present relevant available literature in regards to the use of minimally invasive surgery for gastric cancer.

Laparoscopic assisted distal gastrectomy for early gastric cancer

Retrospective series

Initial case series for laparoscopic assisted distal gastrectomy (LADG) were reported in the mid 1990's (3–5). Shiraishi and Ohgami (5, 6) reported initial experiences with no mortalities. Adachi (7) reported in 2000 a retrospective study in which 49 patients were compared to 53 patients with open gastrectomy, finding decreased analgesic use, decreased time to first flatus (3.9 vs. 4.5 days), with no difference in proximal margin (6.2 vs. 6 cm)

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and number of lymph nodes harvested (18 vs. 22.1). Additional series reported in the early 2000's (8, 9) showed that LADG could lead to decreased time to flatus and length of stay. Kim (10) reported 71 patients who underwent LADG compared to 147 patients who underwent open distal gastrectomy (ODG). No significant differences in the number of lymph nodes retrieved was found between the groups, with LADG favoring length of stay and similar complication rates.

Mochiki (11) reported their five-year experience including 89 patients who underwent LADG and 60 with ODG. Complication rate was 9% vs. 18% and duration of epidural 2 vs. 4 days favoring LADG. Lee (12) evaluated 136 patients with LADG and 120 ODG. Mean operative time was 156 vs. 159 minutes ($p = 0.666$). Lymph node harvesting was smaller, with 31.3 versus 40 nodes retrieved and a shorter hospital stay. Kawamura (13) also reported similar pathological stage as well as similar number of lymph nodes harvested (44.8 and 49.2). Kiyama (14) reported 101 cases treated with LADG compared to 49 with ODG. Blood loss was higher in the ODG group (139 vs. 460ml), fewer lymph nodes were harvested in the LADG (27 vs. 34), and hospital stay longer in the ODG group. Lee et al (15) matched 106 patients with LADG and 105 ODG. Postoperative complications in the LADG group was 4.7 vs. 13.3% in the ODG ($p = 0.046$). In a large retrospective study, Lee (16) evaluated 629 with ODG and 1002 LADG. Postoperative complications were less frequent in the LADG (25.3 vs. 40.1% $p < 0.001$), as well as decreased major complications (2.1% vs. 5.4% $p < 0.001$).

Randomized Controlled Trials for Early Gastric Cancer

A series of randomized control trials have evaluated the role of LADG in early gastric cancer. Kitano et al published the first randomized trial in 2002. In this study, 14 patients were randomized to LADG and 14 to ODG. Patients randomized to LADG had decreased pain scores, less impaired pulmonary function with no reduction in curability (17). In a subsequent trial, Lee et al (18) randomized 23 patients to LADG and 24 to ODG. There were less pulmonary complications in the LADG ($p = 0.043$) and less lymph nodes harvested in the LADG (38.1 vs. 31.8 $p = 0.098$). In the only Western population trial published to date, Huscher (19) randomized 30 patients to LADG and 29 to ODG. Lymph nodes retrieved were 33.4 OG vs. 30.0 LG no statistical difference. Operative mortality was 6.7% vs. 3.3% and morbidity 27.6 vs. 26.7%. The five-year OS was 55.7% for the ODG and 54.8% for LADG. Also in 2005 Hayashi evaluated 14 patients in the LADG and 14 in an ODG group (20). Patients in the LADG has shorter period of epidural anesthesia and shorter time to oral intake. Pathological examination revealed similar lymph node retrieval (28 vs. 27). Kim in 2008 (21) randomized 164 patients with cT1N0M0 to LADG ($n = 82$) or ODG ($n = 82$). Patients in the LADG had decreased blood loss, total amount of analgesics, hospital stay and wound size. Importantly LADG was associated with improved quality of life measures.

A frequent critique of the above mentioned trials was the limited number of patients included and the fact that they are single center experiences. The Korean Laparoscopic Study Group (KLASS) has conducted a large randomized controlled trials for patients with stage I gastric cancer. An initial report of this trial with 342 patients revealed that there were

no significant differences in demographics. Complication rate was lower in the LAGD (10.5% vs. 14.7% $p = 0.137$) (22). With this initial safety data, the trial continued and an initial report of safety was published in 2015 (23). The primary endpoint of this trial is to evaluate the oncologic feasibility of LADG versus ODG comparing 5-year OS. Secondary goals included 30-day morbidity and surgical mortality. A total of 686 patients in the LADG and 698 in the ODG were evaluated in the modified intention-to-treat analysis and 644 patients in the LADG and 612 in the ODG were evaluated in the per protocol analysis of morbidity and mortality. Study groups were similar in regards to demographic variables, comorbidities and tumor location, TNM and pathological stage. In regards to intraoperative variables, more Billroth-I reconstructions and D2 lymph node dissections were performed in the ODG group. The LADG was associated with decreased blood loss (184.1 ± 53 vs. 139.4 ± 42.7 $p < 0.001$), decreased length of stay (7.7 ± 3.1 vs. 7.9 ± 4.1 $p < 0.001$) and a smaller lymph node yield (40.5 ± 15.3 vs. 43.7 ± 15.7 $p < 0.001$) (23). In the per protocol analysis, the overall complication rate was lower in the laparoscopic group (13.0% vs. 19.9% $p = 0.001$). Significant differences in complication rates were noticed in the wound complication rates. Intra-abdominal complications, including fluid collections and abscesses, intra-abdominal bleeding, anastomotic leakage, obstruction, ileus, stenosis, stasis, pancreatitis cholecystitis and perforation were similar in both groups (7.6% vs. 10.3% $p = 0.095$). Hospital mortality was 0.6% in the LADG vs. 0.3% (4 vs. 2 deaths, $p = 0.0687$). In regards to risk factor analysis, operative approach (OR LADG 0.599 95% CI 0.44–0.813 $p = 0.001$) and number of comorbidities were identified as risk factors for postoperative morbidity.

Laparoscopic assisted gastrectomy for advanced gastric cancer

Retrospective series

Multiple small retrospective series initially evaluated the role of laparoscopic surgery for advanced gastric cancer. Hur (24) reported the outcomes of 26 patients who underwent laparoscopic gastrectomy for advanced gastric cancer and compared their outcomes to 25 patients who underwent open gastrectomy. No differences were noted between the group in regards to complication rate (15.4 vs. 16% $p = 1.0$). The laparoscopic approach was associated with longer operative times (255 vs. 190 minutes ($p < 0.001$)). Estimated blood loss was less in the laparoscopic group (160 mL vs. 215 mL, $p = 0.012$). Importantly, overall survival rate (88.2 vs. 77.2% $p = 0.246$) and disease-free survival rates (71.4% vs. 53.4% $p = 0.757$) were not different. Du (25) reported seventy-eight patients who underwent LADG and ninety who underwent ODG. The complication rate was similar in both groups (7.7 vs. 10%). The reported number of lymph nodes was 23.5 vs. 21. The LADG was associated with a shorter hospital stay.

Guzman (26) retrospectively evaluated 30 patients treated laparoscopically and 48 open in a Western population. The two groups were similar in regards to age, gender and BMI. Nodal status was more frequently positive in the open group, likely related to a selection bias towards open surgery if preoperative workup suggested positive nodes. The groups were similar in regards to the type of surgery, need for additional organ resection and mean number of lymph node harvested (24.4 vs. 28.7 $p = 0.6579$). Surgery was longer in the laparoscopic group (399 vs. 298 minutes < 0.001). EBL was less in the laparoscopic arm

(200 vs. 383 mL, $p = 0.0009$). Length of stay favored the laparoscopic intervention group (7 vs. 10 $p = 0.0009$). The complication and mortality rates were similar between both groups.

Hwang (27) evaluated 47 patients treated with laparoscopy and 83 patients with ODG all with advanced gastric cancer. Groups were similar in regards to gender, age, ASA status and associated illness. The extent of lymph node dissection was similar in both groups ($p = 0.469$). Operative time was longer in the laparoscopic group (255 ± 58 vs. 208 ± 36 $p = <0.001$). Blood loss was less in the LAG (333 ± 89 vs. 440 ± 156 $p = <0.001$). The laparoscopic approach was associated with improved time to ambulation, decreased analgesic use, decreased time to first flatus and faster time to resumption of diet.

A series of large retrospective studies have examined the role of laparoscopic surgery for advanced gastric cancer. Zhao (28) evaluated 346 patients in the LADG group and 313 in the ODG group. The group was similar in regards to age, gender, tumor size, tumor stage, previous abdominal surgery and postoperative adjuvant chemotherapy. LADG was associated with longer operative times (211 ± 56 vs. 204 ± 41 $p = 0.07$), less blood loss (128 ± 85 vs. 301 ± 156 $p = 0.000$). Extent of lymph node dissection, proximal and distal tumor margin, reconstruction method and number of lymph nodes retrieved were similar in both groups. In regards to postoperative variables, LADG was associated with decreased time to first flatus (3 ± 1.4 vs. 3.9 ± 1.7 $p = 0.000$), time to first liquid diet (3.6 ± 0.6 vs. 4.5 ± 1.8 $p = 0.000$) and postoperative hospital stay (7.9 ± 3.6 vs. 10.7 ± 5.8 $p = 0.008$). The overall incidence of postoperative complications was less in the LADG (6.9% vs. 13.1% $p = 0.008$). There was no difference in mortality. Importantly, there was no significant difference in survival reported for both groups (28).

Chen et al in 2012 (29) evaluated 224 patients who underwent LAG and 112 for the OG. The clinicopathological characteristics were similar as well as the number of lymph nodes of harvested (30.6 ± 10 vs. 30.3 ± 8.6 $p = 0.786$). No difference was noted in the incidence of morbidity and mortality. Survival was similar for both groups (91.5% vs. 89.8% $p > 0.05$) (29). Hamabe (30) included 66 patient in the LAG and 101 in the OG. The groups were similar in age and gender with more advanced T stage in the OG group. Kim (31) evaluated 176 matched cases. There were no differences between the groups in regards to clinicopathological parameters. LAG was associated with shorter time to first flatus (3.2 vs. 3.7 days $p < 0.0001$) and shorter hospital stay (7 vs. 10.4 days $p < 0.0001$). Both groups had an 8% incidence in operative-related complications. Bo (32) evaluated 117 patients treated with laparoscopic total gastrectomy and 117 in the open group. Groups were similar in regards to age, BMI, gender, pathologic characteristics and stage distribution ($p = 0.62$). Operation was longer in the laparoscopic group (292 ± 40 vs. 212 ± 47 $p = 0.039$). Intraoperative blood loss was significantly higher in the open group (196 ± 88 vs. 358 ± 158 $p = 0.024$). Postoperative hospital stay was shorter for the laparoscopic group (7.4 ± 2 vs. 10.7 ± 2 $p = 0.047$).

Randomized controlled trials for advanced gastric cancer

In 2011 Cai (33) published the only trial that has been performed for advanced gastric cancer patients. Sixty-one patients were randomized to laparoscopic assisted radical gastrectomy and 62 to open radical gastrectomy. The two study groups were well balanced

in regard to demographic variables such as age, BMI, functional status and concurrent illness. In regards to extent of surgery, the groups were similar when comparing extent of surgery, tumor location, depth of invasion, and TNM stage. The laparoscopic group had longer operative times (270 ± 55 vs. 187 ± 40 minutes $p < 0.0001$) with decreased blood loss. Postoperative morbidity was 12.2% in the laparoscopic group vs. 19.1% in the open group ($p = 0.357$).

Extent of Lymphadenectomy

The extent of lymphadenectomy has been a matter of debate in gastric surgery, and it is important to consider potential added morbidity from extensive dissection and locoregional control balanced with adequate staging. Roberston (34) reported higher perioperative morbidity in the extensive lymphadenectomy group with no survival advantage, favoring less extensive resections. Cuschieri subsequently evaluated 400 patients who underwent D1 versus D2 lymphadenectomy, again with an increase in operative morbidity for the D2 group and no difference in disease-specific survival (35). A large Western trial, the Dutch Gastric Cancer Trial, has brought new insight to the debate. In this trial, 711 patients underwent curative resection and were randomized to D1 vs. D2. The lymph node yield was higher in the D2 group. Morbidity was higher in the D2 group as well. At the time, based on these results initially D2 was not recommended (36). Subsequent long term follow-up from the Dutch trial published at 15 years showed that the gastric cancer specific survival was 48 versus 37% ($p = 0.01$). These results showed that at 15 years, patients in the D2 group had better survival, thus supporting D2 dissection in patients who have acceptable morbidity and mortality risk. In light of emerging data, D2 lymphadenectomy is favored, and this seems to be a topic in which Eastern and Western approaches are harmonizing (37).

With regard to laparoscopic procedures, Cai (33) evaluated laparoscopic assisted D2 radical gastrectomy compared to open procedures in a randomized study. In this trial, 61 patients were assigned to LAG and 62 to ODG. A total of 49 patients underwent D2 lymph node dissection laparoscopically and 47 in the open group. The total number of lymph nodes dissected in both groups was 22 ($p = 0.839$). The estimated mean overall survival was 29.3 months for the LAG (95% CI 26.4 – 32) and 28.9 months for the OG (95% CI 26 – 31.9 months).

Robotic gastrectomy for gastric cancer

Robotic platforms have been increasingly used for the treatment of gastric cancer. Anderson reported an initial experience with robot assisted laparoscopic subtotal gastrectomy with extended lymphadenectomy in 7 patients with gastric cancer (38). In this report, median operative time was 420 minutes without conversions. The median number of harvested nodes was 24 (range 17–90), and there were no postoperative mortalities. In a similar report, Patriti (39) published their initial experience with eight patients. The median lymph node retrieval was 28.1 ± 8.3 . Song (40) described his initial experience with 20 patients. In this study, operative time was longer compared to 20 patients in a contemporary laparoscopic group (230 ± 34 vs. 134 ± 40 minutes $p < 0.001$). There were no conversions in either group. The retrieved number of lymph nodes was similar (35 ± 10 vs. 42.7 ± 14 $p = 0.080$).

Additionally, hospital stay, time to flatus, soft diet start and complication rates were similar in both groups. Robotic gastrectomy has been performed for both subtotal and total gastrectomy. Small retrospective series have suggested similar results to laparoscopic only procedures (41–43).

In a recent meta-analysis, Shen et al (44) evaluated 8 reports with a total of 1875 patients. RAG was associated with longer operative times and decreased EBL when compared to laparoscopic procedures (-28 mL, 95% CI -67.55 to -9.3 $p = 0.05$). There were no significant differences in proximal margin resection status. The distal margin was longer in the robot assisted group, and the number of harvested lymph nodes was similar in the robotic and laparoscopic only groups. Coratti published five-year follow up data on patients initially treated with robotic assisted gastrectomy (45). In this retrospective review, there were 59 distal gastrectomies, 38 total gastrectomies and one proximal gastrectomy with a 7.1% conversion rate. The median follow-up was 46.9 months. Cumulative 5-year overall survival was 73.3% (95% CI: 62.2–84.4). Five-year survival was 100% stage IA, 84.6% for stage IB, 76.9% for stage II and 21.5% for stage III.

Surgical technique

Laparoscopic gastrectomy requires a thorough knowledge of gastric anatomy and its diverse and intricate lymphatic drainage, adequate preoperative and intraoperative planning and most importantly patient selection.

Patient positioning

The patient is placed in the supine position on the operating room table in a split-leg position, with arms tucked to the sides (Figure 1). It is very important to protect pressure points. The use of a footboard allows the patient to be placed in a reverse Trendelenburg. In robot-assisted cases, the patient will be in an approximately 45-degree angle.

Trocar placement

For robot-assisted gastrectomy, the initial port is placed at the umbilicus, approximately 20 cm from the GEJ. Two additional 8mm ports are placed in the left abdomen for the surgeon robotic right hand and assistant robotic port. An additional 12mm port is placed to the right of the umbilicus, which will serve as the surgeons' robotic left hand and also allow for intracorporeal stapling. An additional assistant port can be placed in the right flank. The use of a liver retractor provides exposure, especially at the GEJ. It is important to keep at least 8 cm of distance between ports, to allow for optimal robotic arm movement without clashing.

Omentectomy and initial gastric mobilization

After pneumoperitoneum has been established the cavity is explored for evidence of metastatic disease. The tumor should be localized at this point, and if needed, endoscopy can help identify early lesions not visible during laparoscopy. The omentum is freed from its colonic attachment to the transverse colon, allowing for entry into the lesser sac. The omentum is subsequently mobilized and dissected off the transverse colon. The posterior wall of the stomach is visualized and grasped, with caudal traction (Figure 2). This allows

for the greater curvature to be mobilized, the left gastroepiploic artery to be dissected and ligated. Continued dissection leads to the short gastric vessels which should be carefully controlled.

Division of the proximal duodenum and lymphadenectomy

The dissection is then carried out distally in the stomach along the posterior wall of the stomach, until the gastroduodenal artery is identified. The right gastroepiploic lymphovascular bundle is identified and ligated close to the head of the pancreas (Figure 3). This allows for the proximal duodenum to be mobilized. The right gastroepiploic artery is ligated and lymph nodes from the hepatic artery included in the specimen. The duodenum should be gently handled and transected. The stomach is retracted towards the left upper quadrant.

Division of the distal esophagus

The dissection continues along the hepatic artery lymph nodes until the left gastric lymphovascular bundle is identified and divided with all the nodal tissue in the specimen. This allows the right crus to be exposed, and completion of the GEJ dissection is now achieved. The esophagus is transected and reconstruction proceeds (Figure 4). An end-to-end stapled anastomosis is created using a transoral anvil device. The alimentary limb blind end is opened and stapler device advanced. The esophagojejunostomy is created and the enterotomy closed.

Complications

An important aspect of the management of gastric cancer is the ability of patients to receive systemic treatment. This can be affected by surgical complications. In a recent study Papenfuss et al (46) analyzed the American College of Surgeons National Surgical Quality and Improvement Program database, describing serious morbidity in 23.6 % of patients and 30-day mortality of 4.1 %, which were higher in the total gastrectomy group when compared to the partial gastrectomy (29.3 vs. 19.9 %, $p < 0.001$ and 5.4 vs. 3.4% $p < 0.0015$) respectively. In a recent study by Selby et al. describing complication for patients undergoing total gastrectomy, 68% of patients had at least 1 medical comorbidity (47). The 90-day mortality was 2.9% in 238 patients. The most common adverse event was anemia, and the most common serious event was anastomotic leak, and a readmission rate of 20%. Laparoscopic gastrectomy has been associated with decreased morbidity and importantly an increased likelihood of receiving adjuvant therapy (48), which should be taking into account in the decision making for operative approach.

Conclusion

Multiple randomized trials and large retrospective series suggest that minimally invasive gastrectomy is associated with decreased intraoperative blood loss, shorter time to oral feeds as well as decreased length of hospital stay and importantly decreased morbidity, which can affect ability of patients to receive systemic therapy. In addition, minimally invasive gastrectomy is associated with similar short term oncologic outcomes. Ongoing randomized

trials are evaluating the long term oncologic outcomes of this approach. Robot-assisted gastrectomy offers increased flexibility and range of instrument motion as well as the possibility to use real-time functional imaging intraoperatively. As these tools evolve, minimally invasive gastrectomy will continue to expand in use and indications.

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Figure 1.
Patient position for minimally invasive gastrectomy.

Figure 2.
Exposure of the lesser sac and traction of the posterior wall of the stomach improves visualization and facilitates omentectomy

Figure 3.
Relevant lymph node basins and exposure during minimally invasive gastrectomy

Figure 4.
Esophageal transection and transoral anvil reconstruction for esophagojejunostomy.