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Minimally Invasive Surgery for Gastric Cancer: The Future Standard of Care

Keisuke Koeda · Satoshi Nishizuka · Go Wakabayashi

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Abstract Laparoscopy-assisted distal gastrectomy for gastric cancer was first reported by Kitano et al. in 1991. Laparoscopic wedge resection (LWR) and intragastric mucosal resection (IGMR) were quickly adapted for gastric cancer limited to the mucosal layer and having no risk of lymph node metastasis. Following improvements in endoscopic mucosal resection (EMR) and endoscopic submucosal dissection (ESD), the use of LWR and IGMR for these indications decreased, and patients with gastric cancer, including those with a risk of lymph node metastases, were more likely to be managed with laparoscopic gastrectomy (LG) with lymph node dissection. Many retrospective comparative trials and randomized-controlled trials (RCT) have confirmed that LG is safe and feasible, and that short-term outcomes are better than those of open gastrectomy (OG) in patients with early gastric cancer (EGC). However, these trials did not include a satisfactory number of patients to establish clinical evidence. Thus, additional multicenter randomized-controlled trials are needed to delineate significantly quantifiable differences between LG and OG. As laparoscopic experience has accumulated, the indications for LG have been broadened to include older and overweight patients and those with advanced gastric cancer. Moreover, advanced techniques, such as laparoscopy-assisted total gastrectomy, laparoscopy-assisted proximal gastrectomy, laparoscopy-assisted pylorus-preserving gastrectomy (PPG), and extended lymph node dissection (D2) have been widely performed.

In the near future, sentinel node navigation and robotic surgery will become additional options in minimally invasive surgery (MIS) involving LG. Such developments will improve the quality of life of patients following gastric cancer surgery.

K. Koeda (✉) · S. Nishizuka · G. Wakabayashi
Department of Surgery, Iwate Medical University School of Medicine, 19-1 Uchimaru, Morioka 020-8505, Japan
e-mail: keikoeda@iwate-med.ac.jp

Introduction

Interest in the various aspects of minimally invasive surgery (MIS) rapidly increased following the first report of laparoscopic cholecystectomy in 1989 [1]. Controversy has surrounded whether MIS in cancer patients is comparable to open surgery in terms of oncological adequacy and safety. Minimally invasive surgery has several advantages compared with conventional open surgery, such as less invasiveness and pain, speedier recovery, and better cosmetic results. As surgeons became more experienced in this area and developments continued in laparoscopic surgical instruments, MIS began to be used as curative therapy in cancer patients [2].

In 1994, Kitano et al. presented the first report of laparoscopy-assisted distal gastrectomy for gastric cancer [3]. In 1994, Ohgami et al. reported the first use of laparoscopic wedge resection (LWR) for the treatment of early gastric cancer (EGC) [4]. In LWR, surgeons use an approach to perform a full-thickness resection of the stomach wall with organ preservation. Intragastric mucosal resection (IGMR) enabled mucosal resections of any part of the stomach except the anterior wall [5]. In the beginning, the indications for LWR and IGMR were strictly limited to mucosal gastric cancer with no risk of lymph node metastasis. Minimally invasive surgery for gastric cancer employs function-preserving procedures using either endoscopy or laparoscopy. The use of LWR and IGMR for mucosal cancer appeared to decline following developments in endoscopic mucosal resection (EMR) and endoscopic

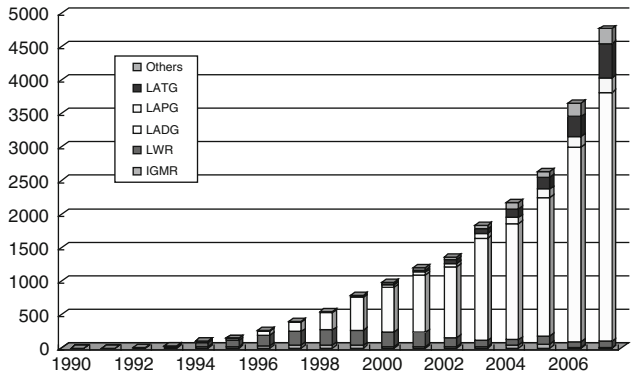

Fig. 1 The numbers of laparoscopic gastrectomies for gastric cancer in Japan [6]. *LATG* laparoscopy-assisted total gastrectomy; *LAPG* laparoscopy-assisted proximal gastrectomy; *LADG* laparoscopy-assisted distal gastrectomy; *LWR* laparoscopic wedge resection; *IGMR* intragastric mucosal resection

submucosal dissection (ESD). However, laparoscopic gastrectomy (LG) has continued to be used, even in early gastric cancer (EGC) patients with a potential risk of lymph node metastasis. This is particularly true in Japan where there is a high prevalence of EGC (Fig. 1) [6]. As laparoscopic techniques and surgical instruments have improved, interest in advanced approaches has grown, among them, extended lymph node dissection and total gastrectomy [7–9]. Multicenter prospective randomized clinical trials to compare short- and long-term outcomes in laparoscopic surgery and open surgery are underway in Korea [10] and Japan. This review summarizes past and current trends in MIS for gastric cancer.

Indications for the use of LG

From EGC to advanced gastric cancer (AGC)

Initially, laparoscopic gastrectomy (LG) was indicated only for EGC patients with a low risk of lymph node metastasis. The Japanese Gastric Cancer Association proposed a clinical guideline for the treatment of gastric cancer in Japan in 2001; the guideline was revised in 2004 [11, 12]. Based on those recommendations, LG is recommended for gastric cancer patients with a preoperative stage Ia (cT1N0M0) diagnosis; patients with stage Ib (cT1N1M0 and cT2N0M0) disease are referred for EMR or ESD. The preoperative stage is determined by endoscopy, endoscopic ultrasound, and abdominal computed tomography. Although a number of institutes adhere to the guideline, LG has also been referred to as a pre-established technique that is still under clinical investigation due to the uncertain quality of lymph node dissection and the lack of long-term data.

The Japanese Gastric Cancer Association's guideline recognizes three types of laparoscopic lymph node dissection: perigastric lymph node dissection (D1 + α), additional lymph node dissection along the common hepatic artery (D1 + β), and extended lymph node dissection (D2). In relation to EGC, the association recommends three optimal lymph node dissection levels. It advocates D1 + α for mucosal cancer not indicated for EMR and for differentiated submucosal cancers less than 1.5 cm in diameter. It recommends D1 + β for submucosal cancer without preoperatively determined lymph node metastasis and for EGC tumors less than 2.0 cm in diameter or with preoperatively determined perigastric lymph node metastasis. The guideline recommends D2 for EGC tumors greater than 2.0 cm in diameter with N1 metastasis; D2 is also approved for advanced gastric cancer (AGC).

A large randomized-controlled European trial failed to prove the efficacy of open gastrectomy (OG) with D2 lymph node dissection due to a high morbidity and mortality rate [13]. However, OG with D2 lymph node dissection is routinely performed for AGC in Asian countries. D2 lymph node dissection has been considered difficult to perform laparoscopically. If an experienced laparoscopic surgeon performs the operation using the standardized procedure, D2 lymph node dissection can be carried out successfully [14]. There have been many recent reports of institutions successfully performing LG with D2 lymph node dissection for AGC and improving both short- and long-term outcomes [6–8, 15–18].

The impact of obesity on LG

Overweight patients are generally thought to have a greater risk of potential complications and require more technically difficult operations than normal weight patients. In OG, obesity is not a risk factor for the survival of patients with gastric cancer, although it is independently predictive of postoperative complications [19]. Various technical disadvantages of LG for obese patients have been reported, including reduced surgical visibility, blood oozing from soft tissues, a dissection plane hindered by adipose tissue, and difficulty with anastomosis. Noshiro et al. previously reported that LG for obese patients resulted in longer operative times, delayed recovery of bowel activity, and a greater rate of extension of the mini-laparotomy incision or conversion to laparotomy [20]. However, other reports have suggested that obesity may not increase operative morbidity following LG for gastric cancer [21–26]. Nevertheless, when a surgeon is relatively inexperienced in the area of LG, a careful approach is required, particularly for male patients with a high body mass index (BMI) [26].

The impact of age on LG

The number of elderly people with gastric cancer has continued to increase, despite the fact that the total number of patients with this type of cancer has reached a plateau [27]. Previous studies have shown that elderly patients who undergo OG tend to have increased morbidity and mortality rates and long hospital stays as a result of co-morbid conditions and decreased functional reserve [28–30]. Minimally invasive surgery may offer substantial advantages to this population in terms of fewer cardiorespiratory complications, shorter hospital stays, and a speedier return to physical activities. Many reports have concluded that LG is a feasible and safe procedure in elderly patients if the patients have been selected carefully and the procedure has been performed by an experienced surgeon [31–36].

Functional preservation in LG

Some institutions have performed laparoscopic proximal gastrectomy for EGC located in the proximal third of the stomach [37, 38]. Partial (distal or proximal), rather than total, gastrectomy was performed due to a previous report of an association between total gastrectomy and significant weight loss caused by insufficient dietary intake [39]. This study also reported that the long-term prognosis of patients who underwent total gastrectomy was significantly worse than that for those who underwent partial gastrectomy.

Pylorus-preserving gastrectomy (PPG) was originally a treatment option for patients with gastric ulcers [40]. However, the procedure is now mostly restricted to patients with EGC located in the distal two-thirds of the stomach [41]. Pylorus-preserving gastrectomy is considered superior to distal gastrectomy followed by Billroth I reconstruction because it largely eliminates postoperative dumping syndrome and the duodenal juice reflux. Following the establishment of laparoscopy-assisted PPG (LAPPG), this procedure has been used in many institutions, especially in Japan and Korea [42, 43]. The selection of LAPPG versus PPG is due to the low incidence of postoperative stasis and adequate lymph node retrieval [44].

Efficacy of LG versus OG in MIS

Retrospective comparative trials

A large number of retrospective comparative trials have compared LG with OG (Table 1) [45–61]. Although most of these trials have been conducted in Japan, many recent studies have been performed in Western countries. In 2000, Adachi et al. reported a comparative study of LG versus OG [45]. They concluded that laparoscopy-assisted distal gastrectomy (LADG) has several advantages over open distal gastrectomy (ODG) for EGC, such as less surgical trauma, fewer instances of impaired nutrition, reduced postoperative pain, rapid return of gastrointestinal function, shorter hospital stays, and no reduction in curability. In another study, the researchers compared laparoscopy-assisted total gastrectomy (LATG) with conventional open total gastrectomy (OTG) [55]. They reported that LATG was successful in 20 patients and that there was no significant difference in operating time between the two groups. However, blood loss was smaller in the LATG group compared with the OTG group. The time to ambulatory status, first flatus, and first oral intake were significantly shorter in the LATG group, as was the length of the postoperative hospital stay. The frequency of analgesics given in the LATG group was lower than that in the OTG group. The authors concluded that LATG is suitable and feasible for EGC and that it has the advantage of a shorter recovery time compared with OTG. Hiki et al. compared LAPPG and conventional PPG (CPPG) with respect to the quality of lymph node dissection and other clinical outcomes [56]. The operative times for the LAPPG procedure (274 ± 6 min) were significantly longer than for the CPPG procedures (259 ± 8 min; $P = 0.047$), although the estimated blood loss with LAPPG (153 ± 13 mL) was not significantly less than that with CPPG (184 ± 13 mL; $p = 0.13$). The incidence of postoperative complications was comparable between the two groups. Postoperative gastric fullness was the most frequent complication in both groups. Analgesics were required 3 days after the operation, and the time to analgesia was shorter in patients who underwent LAPPG. The time to first flatus and start of oral intake was reduced in the LAPPG group compared with the CPPG group; the length of the postoperative hospital stay was also shorter. There was no significant difference between the procedures in terms of the number of lymph nodes retrieved from any of the nodal stations. The authors concluded that clinical outcomes of surgical treatment were comparable between LAPPG and CPPG in terms of station-dependent lymph node dissection. Overall, the intraoperative findings revealed significant differences in terms of operative time and intraoperative blood loss in the LG group. In relation to short-term outcomes, the LG group experienced less postoperative pain, fewer instances of postoperative morbidity, lower mortality rates, and shorter hospital stays. These findings suggest that LG may be considered as MIS for gastric cancer.

Postoperative complications after LG

Concerns remain that the complexity of the LG procedure may increase the rate of unexpected complications.

Table 1 Retrospective comparative trials comparing laparoscopic gastrectomy (LG) and open gastrectomy (OG) (>20 patients in each group)

Study (year)	Type of gastrectomy	No. of patients	Operative time, min	Blood loss, ml	Conversion to OG (%)	No. of resected LN	Morbidity, %	Mortality, %	Hospital stay, days	References
Adachi et al. (2000)	LADG/ODG	49/53	246/228	158/302[a]	0	15/19	8/21	0/0	18/23[a]	[45]
Shimizu et al. (2000)	LADG/ODG	21/31	299/212[a]	273/350	4.8	14/18	19/13	0/0	29/41	[46]
Yano et al. (2001)	LADG/ODG	24/35	220/210	108/296[a]	0	19/24	4/11	0/0	21/29[a]	[48]
Tanimura et al. (2003)	LADG/ODG	160/100	232/184[a]	121/469[a]	–	31/30	–	0/0	12/23[a]	[51]
Naka et al. (2005)	LADG/ODG	20/22	289/145[a]	106/261[a]	0	10/12	–	0/0	18/26[a]	[52]
Noshiro et al. (2005)	LADG/ODG	37/31	320/277[a]	163/488[a]	0	43/41	5/13	0/0	14/20[a]	[53]
Kim et al. (2005)	LADG/ODG	71/76	250/181[a]	–	2.8	23/27[a]	17/17	1.4/1.3	9/11[a]	[54]
Hiki et al. (2006)	LAPPG/CPPG	72/37	279/259[a]	153/184	0	32/29	28/38	0/0	18/29[a]	[56]
Lee et al. (2006)	LADG/ODG	136/120	158/150[a]	49/126[a]	0	31/40[a]	8/12.5	0/0.8	8/11	[58]
Ikenaga et al. (2006)	LADG/ODG	47/33	273/218[a]	167/196	0	37/43	–	–	–	[59]
Strong et al. (2009)	LDG/ODG	30/30	270/126[a]	200/150	–	–	26/43	0/0	5/7[a]	[60]
Orsenigo et al. (2010)	LAG/OG	109/269	272/230[a]	170/372[a]	15.6	31/27[a]	26/19.3[a]	2/1.4	13/15	[61]

LADG laparoscopy-assisted distal gastrectomy, *ODG* open distal gastrectomy, *LAPPG* laparoscopy-assisted pylorus-preserving gastrctomy, *CPPG* conventional pylorus-preserving gastrectomy, *LDG* laparoscopic distal gastrectomy, *LAG* laparoscopy-assisted gastrectomy, *OG* open gastrectomy

[a] Statistically significant

According to a nationwide survey conducted by the Japanese Society for Endoscopic Surgery in 2008 [6], the incidence of intraoperative and postoperative complications with LADG were 1.7% and 8.2%, respectively; in LATG, they were 2.7% and 17.8%, respectively. The rates of conversions to open surgery were 1.3% with LADG and 2.1% with LATG. The most common intraoperative and postoperative complications were bleeding and anastomotic-related problems (leakage, stricture, and stasis). The results suggest that the complication rate is gradually decreasing and that it has reached a plateau in LADG. However, problems remain with LATG, especially in relation to the anastomotic technique. In another study, Park et al. retrospectively reviewed postoperative complications in 300 consecutive patients who had undergone LG for gastric cancer [62]. They reported that 20.3% suffered postoperative complications, including wound infection (7%), anastomotic-related problems (5.3%), and bleeding (4%). The 30-day mortality rate was 0.7%. They concluded that LG could be performed with acceptable perioperative complication rates and that both the surgeon's experience and careful patient selection determined optimal patient outcomes. Kunisaki et al. analyzed predictive factors for surgical complications of LG in terms of BMI and visceral fat area (VFA) [63]. In 152 patients, the conversion to open surgery for uncontrollable bleeding was 5.9% (9/152); postoperative complications were 6.9% (7/101) among males and 1.9% (1/51) among females. The study indicated that a high BMI and greater VFA independently predicted the conversion to open surgery and postoperative complications. The authors emphasized that caution should be exercised in relation to the use of LG to prevent surgical complications in men with a high VFA. Obama et al. compared surgical outcomes in 138 consecutive patients with gastric cancer who had undergone LG with peripancreatic lymphadenectomy with outcomes in 95 consecutive OG cases [64]. The overall postoperative morbidity rates were 15% in the LG group and 20% in the OG group. The rates of grade B and C postoperative pancreatic fistula (criteria of the International Study Group on Pancreatic Fistula) were 7% in the LG group and 2% in the OG group, with no statistical difference. The authors stressed that care must be taken not to damage the pancreas when performing LG with peripancreatic lymphadenectomy.

Table 2 Long-term outcomes after LG for gastric cancer

Study (year)	Kitano et al. [65] (2007)	Hwang et al. [66] (2009)	Song et al. [68] (2010)	Lee et al. [69] (2010)
No. of patients	1,294	197	1,485	601
Period	1994–2003	1998–2007	1998–2005	2000–2009
Indication	EGC	EGC, cT2N0M0	EGC, AGC	EGC, cT2N0-1M0
Median follow-up, months	36	45	41	35.9
Survival rate				
Stage				
Ia	99.8	100	98.6	94.2
Ib	98.7	96.4	–	87.4
IIa	85.7	87.5	86.0	80.8
IIb	–	–	–	69.6
IIIa	–	16.7	44.7	–
IIIb	–	100	–	–
IV	–	100	50.0	–

EGC early gastric cancer, *AGC* advance gastric cancer

Long-term outcomes

Although there is solid evidence on the short-term efficacy of LG for EGC, there is little information on the procedure's long-term efficacy. In 2007, the Japanese Laparoscopic Surgery Study Group reported a multicenter study of oncological outcomes following LG for EGC in Japan [65]. Of 1,294 patients who underwent LG, the 5-year disease-free survival rate was 99.8% in stage IA, 98.7% in stage IB, and 85.7% in stage II with a median follow-up of 36 months. In a single-center study of 197 patients who underwent LG, Hwang et al. reported that the actual 3-year disease-free survival rates for EGC and AGC were 98.8% and 79.1%, respectively [66]. Lee et al. analyzed long-term outcomes in 106 patients who underwent LG with pathological confirmation of AGC [67]. They reported 32 total gastrectomies and 74 distal gastrectomies with D2 lymphadenectomy. The overall and disease-free survival rates were 81.4% and 72.4%, respectively, with a median follow-up of 21.5 months. Song et al. reviewed a retrospective multicenter study (Korean Laparoscopic Gastrointestinal Surgery Study Group) to assess the timing and patterns of disease recurrence [68]. In a 41-month follow-up, the incidence of disease recurrence was 1.6% in patients with EGC and 13.4% in patients with AGC. Advanced T-classification and lymph node metastasis were risk factors for disease recurrence. The authors concluded that LG showed satisfactory long-term oncological outcomes similar to those of OG. In a single-center study, Lee et al. reported on the long-term oncological outcomes of 601 patients who underwent LG [69]. They recommended that LG should be used for all gastric cancers up to preoperative stage T2N1. In patients of stage IA, the 5-year overall and disease-free survival rates were 94.2% and 89.9%, respectively. In patients with stage IB disease, they were 87.4% and 82.7%, respectively; in stage IIA, they were 80.8% and 70.7%, respectively; and in stage IIB, they were 69.6% and 63.1%, respectively. The authors suggested that LG for EGC is acceptable in terms of surgical quality, as well as long-term oncological outcomes; hence, it should be considered as the primary treatment in patients with EGC (Table 2).

Randomized controlled trial (RCT) comparing LG with OG

To date, seven randomized controlled trials have compared LG with OG for gastric cancer. In all the trials, LADG was compared with ODG (Table 3) [10, 70–75]. Six of the trials enrolled only patients with clinically diagnosed EGC. One of the trials reported a 5-year follow-up of 59 patients with EGC or AGC; 29 of the patients underwent open subtotal gastrectomy, and 30 patients underwent laparoscopic resection [70]. The authors found that the LG group experienced a longer operative duration, decreased blood loss, shorter time to resumption of oral intake, and earlier discharge from hospital. The mean numbers of resected lymph nodes were approximately the same in both groups. Postoperative mortality rates were 6.7% and 3.3% in the OG and LG group, respectively. The morbidity rate in the OG group was 27.6% and 26.7% in the LG group. Five-year overall and disease-free survival rates were 55.7% and 54.8%, respectively, in the OG group and 58.9% and 57.3%, respectively, in the LG group. None of the parameters studied were significantly different between groups. The authors concluded that laparoscopic radical subtotal gastrectomy for distal gastric cancer is a feasible and safe oncological procedure supported by short- and

Table 3 Randomized control trials comparing LG and OG

Study (year)	Type of gastrectomy	Indication	No. of patients	Operative time, min	Blood loss, ml	Conversion to OG, %	No. of resected LN	Morbidity, %	Mortality, %	Hospital stay, days	Reference
Kitano et al. (2002)	LADG/ ODG	EGC	14/14	227/171[a]	117/ 258[a]	0	20/25	14/29	0/0	18/16	[71]
Fujii et al. (2003)	LADG/ ODG	EGC	10/10	226/180[a]	134/206	0	–	20/20	0/0	–	[72]
Hayashi et al. (2005)	LADG/ ODG	EGC	14/14	378/235[a]	327/ 489[a]	0	28/27	22/57	0/0	12/18[a]	[73]
Huscher et al. (2005)	LADG/ ODG	EGC, AGC	30/29	196/168	229/ 391[a]	0	30/33	23/28	3/6	10/15[a]	[70]
Lee et al. (2005)	LADG/ ODG	EGC	24/23	319/190[a]	336/294	0	32/38	13/43	0/0	11/17	[74]
Kim et al. (2008)	LADG/ ODG	EGC	82/82	252/171[a]	112/ 267[a]	1.2	39/45[a]	0/5	0/0	7/9[a]	[75]
Kim et al. (2008)	LADG/ ODG	EGC	179/161	–	109/ 200[a]	0	–	12/15	1.1/0	–	[10]
Meta-analysis											
Chen et al. (2009)	LADG/ ODG	EGC	323/306	MD 86.6[a]	MD – 108.3[a]	–	MD –4.8	RR 0.61[a]	RD 0.01	MD –2.0[a]	[76]

LN lymph nodes, *MD* mean difference, *RR* risk ratio, *RD* risk difference

[a] Statistically significant

long-term results similar to those obtained with an open surgery. Chen et al. reported a meta-analysis of the six trials of LG and OG in patients (629) with a clinical diagnosis of EGC [76]. Comparing LADG with ODG, less postoperative early morbidity (risk ratio = 0.61; $P = 0.01$), similar mortality (risk difference = 0.01; $P = 0.32$), prolonged operative time (mean difference [MD] = 86.64 min; $P < 0.00001$), decreased intraoperative blood loss (MD = −108.33 ml; $P = 0.001$), decreased numbers of dissected lymph nodes (MD = −4.88; $P < 0.00001$), forward time to oral intake (MD = −0.48 d; $P = 0.32$), and shortened hospital stays (MD = −2.03 d; $P = 0.14$). The authors concluded that LADG could offer EGC patients a slight benefit in terms of decreased intraoperative blood loss and postoperative morbidity rates; however, it could also increase the operative time and decrease the number of dissected lymph nodes.

Large multicenter randomized controlled trials are still required to delineate significantly quantifiable differences between LG and OG. The KLASS Trial of 342 patients so far has demonstrated reduced morbidity and mortality [10]. However, this trial is ongoing and has yet to determine whether there is a difference in overall survival between the two groups. Currently, the Gastric Cancer Surgical Study Group of the Japan Clinical Oncology Group is conducting a multi-institutional prospective randomized controlled phase III trial (JCOG 0912). This study has been registered with Japan's University Hospital Medical Information Network (UMIN) Clinical Trial Registry (number: UMIN000003319). Separate phase III studies of LG for AGC are also underway to evaluate perspectives on the role of LG in MIS.

Perspectives of LG—pursuing a more minimally invasive surgery

Other investigations of LG have been reported in the context of improving patients' quality of life (QOL). Yamada et al. investigated the efficacy of preserving the celiac branch of the vagus nerve following LADG [77]. They concluded that preservation of the celiac branch of the vagus nerve was associated with a decrease in dumping syndrome and residual foods in the remnant stomach.

Totally laparoscopic gastrectomy represents the final step in the evolution of laparoscopy-assisted gastrectomy. In their review, Katsios et al. noted that modern totally laparoscopic gastrectomy is the most promising approach for improving the short-term QOL of patients with resectable gastric cancer [78]. One of the main advantages of totally laparoscopic gastrectomy is the reduction in the length of the surgical incision. The smaller incision lowers the risk of postoperative infection, hernia, and pain. The technical complexities of intracorporeal reconstruction also impinge on totally laparoscopic gastrectomy. In a report on operative techniques in intracorporeal reconstruction

following laparoscopic distal gastrectomy (LDG), Kanaya et al. described a method for Billroth I anastomosis after LDG that employs only endoscopic linear staplers [79]. In another study, Takaori et al. described the use of intracorporeal Roux-en-Y anastomosis with linear staplers in which gastrojejunostomy was carried out by "functional end-to-end anastomosis" between the residual stomach and the jejunum [80]. Ikeda et al. reported a retrospective analysis aimed at determining the potential advantages of totally laparoscopic distal gastrectomy (TLDG); 24 patients underwent LADG and 56 patients underwent TLDG [81]. Mean blood loss was significantly lower in the TLDG group than in the LADG group. The patients in the TLDG group also recovered earlier and, thus, they had a significantly shorter postoperative hospital stay. The authors concluded that TLDG has several advantages compared with LADG, including small wound size, less invasiveness, secure ablation, and safe anastomosis, and that these advantages are independent of the patient's constitution and the cancer site.

A new treatment concept has been introduced for EGC based on the location and pathological findings of sentinel lymph nodes (SN). In the near future, laparoscopic wedge resection for SN-negative superficial gastric cancer will be an option, in addition to MIS [82, 83]. A combination of ESD and SN mapping is another potential option for superficial cancer; this less-invasive approach would improve patients' QOL in terms of preserving the whole stomach [84].

Robotic surgery may also begin to be exploited alongside conventional laparoscopic surgery. The technical feasibility, effectiveness, and safety of robot-assisted gastrectomy with lymphadenectomy using the da Vinci system have already been demonstrated [85, 86]. The use of robotics offers the surgeon improved dexterity, with an internal articulated endoscopic "wrist" that allows 7 degrees of freedom, including tremor filtering, motion scaling, and stereoscopic vision. In Asian countries, da Vinci robot systems have already been introduced, and a number of leading hospitals have incorporated the da Vinci system in LG with lymph node dissection over a period of time.

Conclusions

Since its introduction in 1991, the importance of laparoscopic gastrectomy for MIS in gastric cancer has been recognized worldwide. The use of LG is expected to grow with continuous innovative developments. However, before LG can be adopted for use in a greater range of clinical applications, several issues need to be resolved. In particular, attention needs to focus on patients with serosa-positive gastric cancer. The results of ongoing RCTs will shed light on the utility of laparoscopic gastrectomy in the next 10 years. We believe that laparoscopic gastrectomy represents an important type of MIS that can maximize patients' QOL following gastric cancer surgery.

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References

1. Dubois F, Berthelot G, Levard H (1989) Cholecystectomy by coelioscopy. Presse Med 18:980–982
2. Weeks JC, Nelson H, Gelber S et al (2002) Short-term quality-of-life outcomes following laparoscopic-assisted colectomy vs open colectomy for colon cancer: a randomized trial. JAMA 287:321–328
3. Kitano S, Iso Y, Moriyama M et al (1994) Laparoscopy-assisted Billroth I gastrectomy. Surg Laparosc Endosc 4:146–148
4. Ohgami M, Kumai K, Otani Y et al (1994) Laparoscopic wedge resection of the stomach for early gastric cancer using a lesion-lifting method. Dig Surg 11:64–67
5. Ohashi S (1995) Laparoscopic intraluminal (intragastric) surgery for early gastric cancer. Surg Endosc 9:169–171
6. Japan Society for Endoscopic Surgery (2008) Nationwide survey on endoscopic surgery in Japan. J Jpn Soc Endosc Surg 13:499–611 (in Japanese)
7. Kawamura H, Hommma S, Yokota R et al (2008) Inspection of safety and accuracy of D2 lymph node dissection in laparoscopy-assisted distal gastrectomy. World J Surg 32:2366–2370
8. Shinohara T, Kanaya S, Taniguchi K et al (2009) Laparoscopic total gastrectomy with D2 lymph node dissection for gastric cancer. Arch Surg 144:1138–1142
9. Sakuramoto S, Kikuchi S, Futawatari N et al (2009) Laparoscopy-assisted pancreas- and spleen-preserving total gastrectomy for gastric cancer as compared with open total gastrectomy. Surg Endosc 23:2416–2423
10. Kim HH, Hyung WJ, Cho GS et al (2010) Morbidity and mortality of laparoscopic gastrectomy versus open gastrectomy for gastric cancer. An interim report—a phase III multicenter, prospective, randomized trial (KLASS Trial). Ann Surg 251:417–420
11. The Japanese Gastric Cancer Association (2001) Guidelines for the treatment of gastric cancer. Kanehara, Tokyo
12. The Japanese Gastric Cancer Association (2004) Guidelines for the treatment of gastric cancer. Kanehara, Tokyo
13. Hartgrink HH, van de Velde CJ, Putter H et al (2004) Extended lymph node dissection for gastric cancer: who may benefit? Final results of the randomized Dutch Gastric Cancer Group trial. J Clin Oncol 22:2069–2077
14. Tokunaga M, Hiki N, Fukunaga T et al (2009) Laparoscopy-assisted distal gastrectomy with D2 lymph node dissection following standardization—a preliminary study. J Gastrointest Surg 13:1058–1063
15. Guzman EA, Pigazzi A, Lee B et al (2009) Totally laparoscopic gastric resection with extended lymphadenectomy for gastric adenocarcinoma. Ann Surg Oncol 16:2218–2223
16. Pugliese R, Maggioni D, Sansonna F et al (2010) Subtotal gastrectomy with D2 dissection by minimally invasive surgery for distal adenocarcinoma of the stomach: results and 5-year survival. Surg Endosc 24:2594–2602
17. Lee SW, Nomura E, Bouras G et al (2010) Long-term oncologic outcomes from laparoscopic gastrectomy for gastric cancer: a

single-center experience of 601 consecutive resections. J Am Coll Surg 211:33–40
18. Hyang JL, Wei HB, Zheng ZH et al (2010) Laparoscopy-assisted D2 radical distal gastrectomy for advanced gastric cancer. Dig Surg 27:291–296
19. Ojima T, Iwahashi M, Nakamori M et al (2009) Influence of overweight on patients with gastric cancer after undergoing curative gastrectomy. Arch Surg 144:351–358
20. Noshiro H, Shimizu S, Nagai E et al (2003) Laparoscopy-assisted distal gastrectomy for early gastric cancer. Is it beneficial for patient of heavier weight? Ann Surg 238:680–685
21. Kim KH, Kim MC, Jung GJ et al (2006) The impact of obesity on LADG for early gastric cancer. Gastric Cancer 9:303–307
22. Shim JH, Song KY, Kim SN et al (2009) Laparoscopy-assisted distal gastrectomy for overweight patients in the Asian population. Surg Today 39:481–486
23. Makino H, Kunisaki C, Izumisawa Y et al (2010) Effect of obesity on laparoscopy-assisted distal gastrectomy compared with open distal gastrectomy for gastric cancer. J Surg Oncol 102:141–147
24. Ohno T, Mochiki E, Ando H et al (2010) The benefits of laparoscopically assisted distal gastrectomy for obese patients. Surg Endosc 24:2770–2775
25. Hiki N, Fukunaga T, Yamaguchi T et al (2009) Increased fat content and body shape have little effect on the accuracy of lymph node retrieval and blood loss in laparoscopic distal gastrectomy for gastric cancer. J Gastrointest Surg 13:626–633
26. Lee HJ, Kim HH, Kim MC et al (2009) The impact of a high body mass index on laparoscopy assisted gastrectomy for gastric cancer. Surg Endosc 23:2473–2479
27. Kitamura K, Yamaguchi T, Taniguchi H et al (1996) Clinicopathological characteristics of gastric cancer in the elderly. Br J Cancer 73:798–802
28. Wu CW, Hsieh MC, Lo SS et al (1995) Morbidity and mortality after radical gastrectomy for patients with carcinoma of the stomach. J Am Coll Surg 181:26–32
29. Eguchi T, Fujii M, Takayama T et al (2003) Mortality for gastric cancer in elderly patients. J Surg Oncol 84:132–136
30. Bittner R, Butters M, Ulrich M et al (1996) Total gastrectomy. Updated operative mortality and long-term survival with particular reference to patients older than 70 years of age. Ann Surg 224:37–42
31. Yasuda K, Sonoda K, Shiroshita H et al (2004) Laparoscopically assisted distal gastrectomy for early gastric cancer in the elderly. Br J Surg 91:1061–1065
32. Mochiki E, Ohno T, Kamiyama Y et al (2005) Laparoscopy-assisted gastrectomy for early gastric cancer in young and elderly patients. World J Surg 29:1585–1591
33. Tokunaga M, Hiki N, Fukunaga T et al (2008) Does age matter in the indication for laparoscopy-assisted gastrectomy? J Gastrointest Surg 12:1502–1507
34. Kunisaki C, Makino H, Takagawa R et al (2009) Efficacy of laparoscopy-assisted distal gastrectomy for gastric cancer in the elderly. Surg Endosc 23:377–383
35. Hwang SH, Park DJ, Jee YS et al (2009) Risk factors for operative complications in elderly patients during laparoscopy-assisted gastrectomy. J Am Coll Surg 208:186–192
36. Cho GS, Kim W, Kim HH et al (2009) Multicentre study of the safety of laparoscopic subtotal gastrectomy for gastric cancer in the elderly. Br J Surg 96:1437–1442
37. Tanimura S, Higashino M, Fukunaga Y et al (2006) Laparoscopic gastrectomy with regional lymph node dissection for upper gastric cancer. Br J Surg 94:204–207
38. Matsui H, Okamoto Y, Nabeshima K et al (2009) Endoscopy-assisted gastric resection: a safe and reliable procedure for tumor clearance during laparoscopic high distal or proximal gastrectomy. Surg Endosc 23:1146–1149
39. Ogoshi K, Okamoto Y, Nabeshima K et al (2005) Focus on the conditions of resection and reconstruction in gastric cancer. What extent of resection and what kind of reconstruction provide the best outcomes for gastric cancer patients? Digestion 71:213–224
40. Maki T, Shiratori T, Hatafuku T et al (1967) Pylorus-preserving gastrectomy as an improved operation for gastric ulcer. Surgery 61:838–845
41. Park DJ, Lee HJ, Jung HC et al (2008) Clinical outcome of pylorus-preserving gastrectomy in gastric cancer in comparison with conventional distal gastrectomy with Billroth I anastomosis. World J Surg 32:1029–1036
42. Shinohara H, Sonoda T, Niki M et al (2002) Laparoscopically-assisted pylorus-preserving gastrectomy with preservation of the vagus nerve. Eur J Surg 168:55–58
43. Hiki N, Kaminishi M (2005) Pylorus-preserving gastrectomy in gastric cancer surgery—open and laparoscopic approaches. Langenbecks Arch Surg 390:442–447
44. Nunobe S, Hiki N, Fukunaga T et al (2007) Laparoscopy-assisted pylorus-preserving gastrectomy: preservation of vagus nerve and infrapyloric blood flow induces less stasis. World J Surg 31:2335–2340
45. Adachi Y, Shiraishi N, Shiromizu A et al (2000) Laparoscopy-assisted Billroth I gastrectomy compared with conventional open gastrectomy. Arch Surg 135:806–809
46. Shimizu S, Uchiyama A, Mizumoto K et al (2000) Laparoscopically assisted distal gastrectomy for early gastric cancer. Is it superior to open surgery? Surg Endosc 14:27–31
47. Reyes CD, Weber KJ, Gagner M et al (2001) Laparoscopic vs. open gastrectomy. Surg Endosc 15:928–931
48. Yano H, Monden T, Kinuta M et al (2001) The usefulness of laparoscopy-assisted distal gastrectomy in comparison with that of open distal gastrectomy for early gastric cancer. Gastric Cancer 4:93–97
49. Migoh S, Hasuda K, Nakashima K et al (2003) The benefit of laparoscopy-assisted distal gastrectomy compared with conventional open distal gastrectomy: a case-matched control study. Hepatogastroenterology 50:2251–2254
50. Weber KJ, Reyes CD, Gagner M et al (2003) Comparison of laparoscopic and open gastrectomy for malignant disease. Surg Endosc 17:968–971
51. Tanimura S, Higashino M, Fukunaga Y et al (2003) Laparoscopic distal gastrectomy with regional lymph node dissection for gastric cancer. Surg Endosc 17:758–762
52. Naka T, Ishikura T, Shibata S et al (2005) Laparoscopy-assisted and open distal gastrectomies for early gastric banker at a general hospital in Japan. Hepatogastroenterology 52:293–297
53. Noshiro H, Nagai E, Shimizu S et al (2005) Laparoscopically assisted distal gastrectomy with standard radical lymph node dissection for gastric cancer. Surg Endosc 19:1592–1596
54. Kim MC, Kim KH, Kim HH et al (2005) Comparison of laparoscopy-assisted by conventional open distal gastrectomy and extra-perigastric lymph node dissection in early gastric cancer. J Surg Oncol 91:90–94
55. Usui S, Yoshida T, Ito K et al (2005) Laparoscopy-assisted total gastrectomy for early gastric cancer: comparison with conventional open total gastrectomy. Laparosc Endosc Percutan Tech 15:309–314
56. Hiki N, Shimoyama S, Yamaguchi H et al (2006) Laparoscopy-assisted pylorus-preserving gastrectomy with quality controlled lymph node dissection in gastric cancer operation. J Am Coll Surg 203:162–169
57. Verela JE, Hiyashi M, Nguyen T et al (2006) Comparison of laparoscopic and open gastrectomy for gastric cancer. Am J Surg 192:837–842

58. Lee SI, Choi YS, Park DJ et al (2006) Comparative study of laparoscopy-assisted distal gastrectomy and open distal gastrectomy. J Am Coll Surg 202:874–880
59. Ikenaga N, Nishihara K, Iwashita T et al (2006) Long-term quality of life after laparoscopically assisted distal gastrectomy for gastric cancer. J Laparoendosc Adv Surg Tech A 16:119–123
60. Strong VE, Devaud N, Allen PJ et al (2009) Laparoscopic versus open subtotal gastrectomy for adenocarcinoma: a case-control study. Ann Surg Oncol 16:1507–1513
61. Orsenigo E, Palo SD, Tamburini A et al (2010) Laparoscopy-assisted gastrectomy versus open gastrectomy for gastric cancer: a mono institutional Western center experience. Surg Endosc 25:140–145
62. Park JM, Jin SH, Lee SR et al (2008) Complications with laparoscopically assisted gastrectomy: multivariate analysis of 300 consecutive cases. Surg Endosc 22:2133–2139
63. Kunisaki C, Makino H, Takagawa R et al (2009) Predictive factors for surgical complications of laparoscopy-assisted distal gastrectomy for gastric cancer. Surg Endosc 23:2085–2093
64. Obama K, Okabe H, Hosogi H et al (2010) Feasibility of laparoscopic gastrectomy with radical lymph node dissection for gastric cancer: from a viewpoint of pancreas-related complications. Surgery 149:14–21
65. Kitano S, Shiraishi N, Uyama I et al (2007) A multicenter study on oncologic outcome of laparoscopic gastrectomy for early cancer in Japan. Ann Surg 245:68–72
66. Hwang SH, Park DJ, Jee YS et al (2009) Actual 3-year survival after laparoscopy-assisted gastrectomy for gastric cancer. Arch Surg 144:559–564
67. Lee J, Kim W (2009) Long-term outcomes after laparoscopy-assisted gastrectomy for advanced gastric cancer: analysis of consecutive 106 experiences. J Surg Oncol 100:693–698
68. Song J, Lee HJ, Cho GS et al (2010) Recurrence following laparoscopy-assisted gastrectomy for gastric cancer: a multicenter retrospective analysis of 1, 417 patients. Ann Surg Oncol 17:1777–1786
69. Lee SW, Nomura E, Bouras G et al (2010) Long-term oncologic outcomes from laparoscopic gastrectomy for gastric cancer: a single-center experience of 601 consecutive resections. J Am Coll Surg 211:33–40
70. Huscher CG, Mingoli A, Sgarzini G et al (2005) Laparoscopic versus open subtotal gastrectomy for distal gastric cancer. Five-year results of a randomized prospective trial. Ann Surg 241:232–237
71. Kitano S, Shiraishi N, Fujii K et al (2002) A randomized controlled trial comparing open vs laparoscopy-assisted distal gastrectomy for the treatment of early gastric cancer: an interim report. Surgery 131:s306–s311
72. Fujii K, Sonoda K, Izumi K et al (2003) T lymphocyte subsets and Th1/Th2 balance after laparoscopy-assisted distal gastrectomy. Surg Endosc 17:1440–1444
73. Hayashi H, Ochiai T, Shimada H et al (2005) Prospective randomized study of open vs laparoscopy-assisted distal gastrectomy with extraperigastric lymph node dissection for early gastric cancer. Surg Endosc 19:1172–1176
74. Lee JH, Han HS, Lee JH (2005) A prospective randomized study comparing open vs laparoscopy-assisted distal gastrectomy in early gastric cancer. Surg Endosc 19:168–173
75. Kim YW, Baik YH, Yun YH et al (2008) Improved quality of life outcomes after laparoscopy-assisted distal gastrectomy for early gastric cancer: results of a prospective randomized clinical trial. Ann Surg 248:721–727
76. Chen XZ, Hu JK, Yang K et al (2009) Short-term evaluation of laparoscopy-assisted distal gastrectomy for predictive early gastric cancer: a meta-analysis of randomized controlled trials. Surg Laparosc Endosc Percutan Tech 19:277–284
77. Yamada H, Kojima K, Inokuchi M et al (2010) Efficacy of celiac branch preservation in Roux-en-Y reconstruction after laparoscopy-assisted distal gastrectomy. Surgery 149:22–28
78. Katsios CG, Baltogiannis G, Roukos DH (2010) Laparoscopic surgery for gastric cancer: comparative-effectiveness research and future trends. Expert Rev Anticancer Ther 10:473–476
79. Kanaya S, Gomi T, Momoi H et al (2002) Delta-shaped anastomosis in totally laparoscopic Billroth-I gastrectomy: new technique of intra-abdominal gastroduodenostomy. J Am Coll Surg 195:284–287
80. Takaori K, Nomura E, Mabuchi H et al (2005) A secure technique of intra-corporeal Roux-Y reconstruction after laparoscopic distal gastrectomy. Am J Surg 189:178–183
81. Ikeda O, Sakaguchi Y, Aoki Y et al (2009) Advantages of totally laparoscopic distal gastrectomy over laparoscopically assisted distal gastrectomy for gastric cancer. Surg Endosc 23:2374–2379
82. Kitagawa Y, Ohgami M, Fujii H et al (2001) Laparoscopic detection of sentinel lymph nodes in gastrointestinal cancer: a novel and minimally invasive approach. Ann Surg Oncol 8:86–89
83. Kitagawa Y, Kitano S, Kubota T et al (2005) Minimally invasive surgery for gastric cancer—toward a confluence of two major streams: a review. Gastric Cancer 8:103–110
84. Abe N, Mori T, Takeuchi H et al (2005) Laparoscopic lymph node dissection after endoscopic submucosal dissection: a novel and minimally invasive approach to treating early-stage gastric cancer. Am J Surg 19:496–503
85. Patriti A, Ceccarelli G, Bellochi R et al (2008) Robot-assisted laparoscopic total and partial gastric resection with D2 lymph node dissection for adenocarcinoma. Surg Endosc 22:2753–2760
86. Song J, Oh SJ, Kang WH et al (2009) Robot-assisted gastrectomy with lymph node dissection for gastric cancer: lessons learned from an initial 100 consecutive procedures. Ann Surg 249: 927–932