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Review Article

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Single-incision Laparoscopic Gastrectomy for Gastric Cancer

Yoontaek Lee [1], **Hyung-Ho Kim** [1,2]

[1]Department of Surgery, Seoul National University Bundang Hospital, Seongnam, Korea
[2]Department of Surgery, Seoul National University College of Medicine, Seoul, Korea

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Correspondence to
Hyung-Ho Kim
Department of Surgery, Seoul National University Bundang Hospital, 82 Gumi-ro 173-beon-gil, Bundang-gu, Seongnam 13620, Korea.
Tel: +82-31-787-7099
Fax: +82-31-787-4078
E-mail: hhkim@snubh.org

ORCID iDs
Yoontaek Lee
https://orcid.org/0000-0003-2643-2007
Hyung-Ho Kim
https://orcid.org/0000-0002-8916-0048

Author Contributions
Conceptualization: K.H.H.; Data curation: L.Y.; Formal analysis: L.Y.; Methodology: K.H.H.; Supervision: K.H.H.; Writing - original draft: L.Y.; Writing - review & editing: K.H.H.

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ABSTRACT

The implementation of national cancer screening has increased the detection rates of early gastric cancer (EGC) in Korea. Since the successful introduction of laparoscopic gastrectomy for gastric cancer in the early 1990s, this technique has demonstrated improved short-term outcomes without compromising long-term oncologic results. It is associated with reduced pain, shorter hospitalization, reduced morbidity rates, better cosmetic outcomes, and equivalent mortality rates as those for open surgery. Laparoscopic gastrectomy improves patients' quality of life (QOL) and provides favorable prognosis. Single-incision laparoscopic gastrectomy (SILG) is one extremely minimally invasive method, theoretically offering improved cosmetic results, less postoperative pain, and earlier recovery after surgery than conventional multiport laparoscopic gastrectomy. In this context, SILG is thought to be an optimal method to promote and maximize patients' QOL in the acute postoperative phase. However, the technical difficulties of this procedure have limited its use. Since the first report describing single-incision distal gastrectomy in 2011, only 16 studies to date have evaluated SILG. Most of these studies have focused on the technical feasibility and safety of SILG because its long-term outcomes have not been reported. This article reviews the advantages and limitations of SILG.

Keywords: Stomach neoplasms; Laparoscopy; Gastrectomy

INTRODUCTION

Gastric cancer is the second most common cancer in Korea. Early gastric cancer (EGC) accounts for more than 60% of cases, due to biannual endoscopic examinations sponsored by the government as a national cancer screening program in Korea. This early detection of gastric cancer facilitated the adoption of minimally invasive techniques for the treatment of gastric cancer. Laparoscopic gastrectomy has been demonstrated to improve patients' quality of life (QOL), resulting in reduced pain and blood loss, earlier postoperative recovery, and shorter hospital stay. Advances in instrumentation and the accumulation of laparoscopic experience have led to the development of laparoscopic techniques that are less invasive, but technically demanding. The ultimate goal of minimally invasive surgery is to provide painless and scarless surgery. There have been many attempts to achieve these purposes since the first laparoscopic cholecystectomy [1-3].

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The peroral transgastric approach to the peritoneal cavity in a porcine model was the first type of natural orifice transluminal endoscopic surgery (NOTES). Since then, this scarless method has been applied to various types of human surgery. However, current instruments and equipment are still inadequate to perform NOTES easily, and its routine application is limited by difficulties including sterility, infection control, tissue manipulation, and safety of access closure. Additionally, expanding its indications beyond benign disease has been limited until recently. The problems encountered with NOTES have led to the introduction of single-incision laparoscopic surgery (SILS), which is regarded as a transitional stage from conventional laparoscopic surgery to NOTES. SILS is increasingly being used to treat EGC. This approach offers excellent cosmetic results because scarring is concealed in the umbilicus.

Although many articles have been published concerning single-incision cholecystectomy or nephrectomy; only few reports have been published regarding single-incision laparoscopic gastrectomy (SILG) thus far because it is technically difficult to perform and there are concerns regarding oncologic safety [4]. However, from the technical viewpoint, most types of laparoscopic gastrectomy can be reproduced using a single-incision technique, even total gastrectomy [4]. Here, we describe in detail the techniques of SILG and review the advantages and limitations of this technique.

HISTORY

Since the first report of single-incision distal gastrectomy (SIDG) in 2011[5], only 16 articles have been published on SILG, mostly from Korea and Japan (**Tables 1** and **2**). However, the first SIDG was not pure SILG, as an assistant inserted 2 additional 2-mm trocars. Needlescopic surgery is a type of modified laparoscopic surgery, which uses needlescopic instruments with external diameters of 2–3 mm [6]. Needlescopic surgery has not been widely adopted for common procedures because of the weakness of the instruments, including easy bending of the shaft, weak grasping power, and small jaw size [7]. However, new, recently introduced needlescopic instruments have more rigid grasping power and less bending of the shaft. In the early period of SILS, needlescopic instruments were used

Table 1. Published reports on single-incision gastrectomy

Author	Year	Type of surgery	Patients	Length of incision (cm)	Additional port	Product of single port	OT (min)	EBL (mL)	LNs
Omori et al. [5]	2011	Distal	7	2.5	Two 2 mm ports	Conventional trocar	344	25	67
Park et al. [8]	2012	Distal	2	2.5	One 2 mm port	OCTO	275	85	32
Kong et al. [30]	2012	Distal	4	2–3	No	Conventional trocar	280	162	16
Omori et al. [31]	2012	Distal	20	2.5	Two 2 mm ports	SILS	NA	NA	NA
Ahn et al. [10]	2014	Distal	22	2.5	No	Gloveport	175	NA	NA
Omori et al. [32]	2014	Distal	45	2.5–3	No	EZ access	236	NA	NA
Ahn et al. [18]	2014	Distal	50	2.5	No	Gloveport	144	50	52
Ahn et al. [20]	2014	Distal	14	2.5	No	Gloveport	NA	NA	61.3
Suh et al. [11]	2015	Distal	11	2.5	No	Gloveport	214	NA	NA
Kim et al. [33]	2015	Distal	30	3–3.5	No	GelPort	122	103	40
Kim et al. [17]	2016	Distal	48	3–3.5	No	GelPort	135	101	35
Omori et al. [27]	2016	Distal	90	2.5–3	No	EZ access	261	44	60
Ahn et al. [12]	2014	Total	2	2.5	No	Gloveport	190	85	77
Ertem et al. [34]	2013	Total	1	3.5	No	OCTO	282	NA	34
Ahn et al. [35]	2015	Total	4	2.5	No	Gloveport	206	53	55
Lee et al. [13]	2016	Proximal	1	2.5	No	Gloveport	350	NA	22

Manufacturer information is follow as: OCTO (DalimSurgNET, Seoul, Korea), SILS (Covidien, Dublin, Ireland), Gloveport (Nelis, Bucheon, Korea), EZ access (Hakko, Nagano, Japan), GelPort (Applied Medical, Rancho Santa Margarita, CA, USA).
OT= operation time; EBL= estimated blood loss; LNs= numbers of retrieved lymph nodes; SILS = single-incision laparoscopic surgery; NA= not applicable.

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Table 2. Postoperative complication according to Clavien-Dindo classification

Complications	Omori et al. [5] (n=7)	Ahn et al. [10] (n=22)	Omori et al. [32] (n=45)	Ahn et al. [18] (n=50)	Kim et al. [17] (n=48)	Omori et al. [27] (n=90)
Grade I						
Wound	2	0	1	2	0	0
Delayed gastric emptying	1	1	1	0	2	0
Ileus	0	0	0	0	2	0
Fever	0	0	0	1	0	0
Atelectasis	0	0	0	1	0	0
Grade II						
Wound	0	0	0	0	2	1
Delayed gastric emptying	0	0	0	0	0	1
Ileus	0	0	0	0	1	0
Pseudomembranous colitis	0	0	0	1	0	0
Stenosis	0	0	0	0	2	0
Others	0	0	0	0	0	1
Grade III						
Intra-abdominal fluid collection	0	0	0	1	0	0
Intestinal obstruction	0	0	0	0	1	0
Cholecystitis	0	0	0	0	0	1
Overall complications	3 (42.9)	1 (4.5)	2 (4.4)	6 (12)	10 (20.8)	4 (4.4)

Values are presented as number (%). Six studies that reported postoperative complications according to the Clavien-Dindo classification are included in this table.

for safety and to reduce operation times, indicating that needlescopic surgery may have an important role in expanding indications for SILS.

Two patients subsequently underwent SIDG with only one additional 2-mm assistant port [8]. Pure SIDG without any additional ports was performed later in 2013 by Ahn et al. [9]. Pure SIDG for intracorporeal uncut Roux-en-Y gastrojejunostomy, accompanied by unaided stapling closure for reconstruction, has also been described previously [10,11]. Recently, single-incision total gastrectomy and single-incision proximal gastrectomy for tumors of the upper one-third of the stomach have also been reported [12,13].

ADVANTAGES

Operative treatment for gastric cancer was developed beginning with open procedures and progressing to minimally invasive surgery, which included laparoscopy-assisted approaches, all laparoscopic techniques, robotic procedures, and SILS, in order of development. QOL after surgery has become an important factor in cancer treatment, because cancer as well as its treatment may have an impact on surgical outcomes and patient wellbeing [14].

SILS has the potential benefits of maximum reduction of postoperative pain and improvement in cosmetic outcomes; however, most studies have evaluated colon and gallbladder surgery. By contrast, there are few reports on the use of SILS in gastric surgery. Single-incision colectomy compared with multiport surgery revealed reduced intraoperative blood loss, earlier recovery of bowel function, and shorter hospitalization in systemic reviews and meta-analysis studies [15]. The SPOCC trial, a multi-center, double-blinded, randomized controlled trial, reported that single-port cholecystectomy revealed significantly improved cosmetic outcomes and body image scores compared to those following conventional surgery [16].

There are several reports regarding pain after SILG. Results are variable and depend on the number of ports used. Kim et al. [17] reported that postoperative pain scores were

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not statistically different between SILG and reduced-port gastrectomy at day 1 (4.1 vs. 4.0; P=0.666), day 3 (3.4 vs. 3.3; P=0.500), and day 5 (2.8 vs. 2.8; P=0.130) after surgery. Ahn et al. [18] reported that pure SIDG was associated with significantly reduced intraoperative blood loss (50.5±31.5 vs. 87.5±79.6 mL; P=0.007) and reduced C-reactive protein levels (4.57±6.26 vs. 8.51±5.25 mg/L; P=0.008) on postoperative day 5 compared to conventional, multiport, totally laparoscopic gastrectomy with a similar mean operative time (144.5±35.4 vs. 140.3±36.3 minutes; P=0.561). They also reported that SIDG was associated with significantly reduced maximum postoperative pain measured by a visual analog scale on the day of surgery (6.11±1.42 vs. 6.93±1.47; P=0.015) and postoperative day 1 (4.55±1.04 vs. 5.49±1.39; P<0.001) and reduced requirement for parenteral analgesics (0.77±1.00 vs. 1.40±1.04; P=0.020), indicating that postoperative pain was more tolerable in SIDG. The numerical rating scale assessment of scarring was significantly greater, indicating improved cosmetic outcomes in the pure SIDG group (9.00±0.70 vs. 6.09±1.09; P<0.001).

LIMITATIONS

The major limitations of SILS are the clashing of instruments and difficulty visualizing the surgical field. Instruments and cameras are introduced together through one umbilical incision. Moreover, the direction of movement and alignment of instrument and camera are along the same axis. This could cause loss of triangulation and "sword-fighting" of the instruments. Additionally, the assistant cannot help to create surgical space. Several techniques and advancements have been introduced to solve these problems. First, a flexible scope could provide optimal visualization of the surgical field, reducing interference due to the movement of instruments [19]. Second, different lengths of each instrument may also decrease clashing and allow for proper traction. Third, changing the patient's position could provide natural retraction of organs. Although the reverse Trendelenburg and right-side-down position is generally used, the Trendelenburg and left-down position could help to expose the surgical field using gravity to approach the infrapyloric area. Fourth, gauze placed between surgical planes and organs could keep the surgical field clean by absorbing fluid and blood. Also, it could provide small, but sufficient surgical space for dissection.

Another difficulty with SILS is suprapancreatic lymph node dissection, because the dissection plane is at a 90° angle to the axis of instrumentation. Specifically, it is most difficult to access the lymph node 11p station because 11p is far behind the vertebra and seated deep in the retroperitoneum. This limitation could be solved by using the mid-pancreas mobilization method, which involves detaching the mid-pancreas from the white line of Toldt, and inserting gauze to expose the suprapancreatic lymph nodes [20]. The flexible scope also provides a downward view of the suprapancreatic area, enabling suprapancreatic lymph node dissection.

ONCOLOGICAL SAFETY

The main purpose of minimally invasive surgery is to minimize surgical trauma and improve QOL without affecting oncologic safety. Laparoscopic gastrectomy has gained popularity based on evidence from prospective, randomized, controlled trials and meta-analyses demonstrating similar oncological outcomes between laparoscopic and open procedures [2,21].

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In the same context, operative and pathologic data of SILS have shown oncologic safety and feasibility, although data on long-term outcomes remain lacking [22,23] SILG is rarely used for gastric cancer treatment due to the complexity of the procedure, especially systemic lymphadenectomy, and the steep learning curve [24]. There are several studies that have compared retrieved lymph node numbers. Lee et al. [25] reported that the number of obtained lymph nodes in SIDG vs. conventional multiport laparoscopic distal gastrectomy was not statistically different in a porcine survival model. Kim et al. [17] reported that there was no difference in surgical outcomes, including lymph node number and resection margin, between SILG and reduced-port gastrectomy. Ahn et al. [18] reported that the mean lymph node numbers in SIDG vs. multiport laparoscopic distal gastrectomy were not significantly different (51.7±16.3 vs. 52.4±17.9; P=0.836).

Taken together, these studies suggest that the oncologic outcomes of SILG, indirectly estimated by lymph node resection number, are comparable to those of conventional multiport laparoscopic surgery. However, lymph node dissection in these studies was limited (D1+). For generalization of SILG, it is necessary that D2 lymphadenectomy is feasible. For D2 lymph node dissection, it is mandatory that the splenic vein and artery and portal vein are exposed for 11p and 12a lymphadenectomy, respectively [26]. From a practical perspective, 12a lymph node dissection may not be overly difficult because it is not deeply seated and the direction of instrumentation for dissection is parallel to the lateral surface of the portal vein. However, 11p lymph node dissection is technically challenging, even in conventional multiport laparoscopic gastrectomy, because it is deeply located in the retroperitoneum and the direction of instrumentation is perpendicular to the splenic vessels. In addition, the splenic vessels sometimes run unexpectedly and tortuously. Nevertheless, Omori et al. [27] reported that SIDG with D2 dissection vs. multiport laparoscopic distal gastrectomy showed low intraoperative blood loss (44.8 vs. 119.2 mL; P=0.001), similar mean operation times, similar mean numbers of lymph nodes retrieved (60.8±23.0 vs. 59.2±21.4; P=0.710), and similar 5-year overall survival (93.7% vs. 87.6%; P=0.689) and recurrence-free survival (90.0% vs. 87.6%; P=0.958) rates. Surprisingly, Ahn et al. [20] reported that SIDG with D2 lymphadenectomy was technically feasible using the midpancreas mobilization method, even without an assistant and scopist, a technique termed solo single-incision gastrectomy.

SURGICAL TECHNIQUES FOR SILG

Lymph node dissection

The patient was placed in a supine position with the legs apart and in the reverse Trendelenburg position. The operator and scope operator sat between the legs of the patient. A 2.5–3-cm longitudinal umbilical incision was made on the umbilicus alone, and a commercialized 4-channel single-port trocar (Gloveport®; Nelis, Bucheon, Korea) was inserted through the umbilical incision (**Fig. 1**). CO_2 of the pneumoperitoneum was maintained below 13 mmHg. A 10-mm 3-dimensional (D) or 2-D flexible laparoscope was introduced into the peritoneal cavity for visualization. The falciform ligament and the left lobe of the liver were retracted by a modified combined suture technique using 2-0 polypropylene sutures on a straight needle (Prolene®; Ethicon, Somerville, NJ, USA) and 5-mm hemoclips (Weck®; Teleflex, Morrisville, NC, USA) [28]. The lymph nodes were dissected and the stomach was transected as in conventional multiport laparoscopic gastrectomy. However, the most apparent difference and most difficult segment of SILG was the retraction method to expose

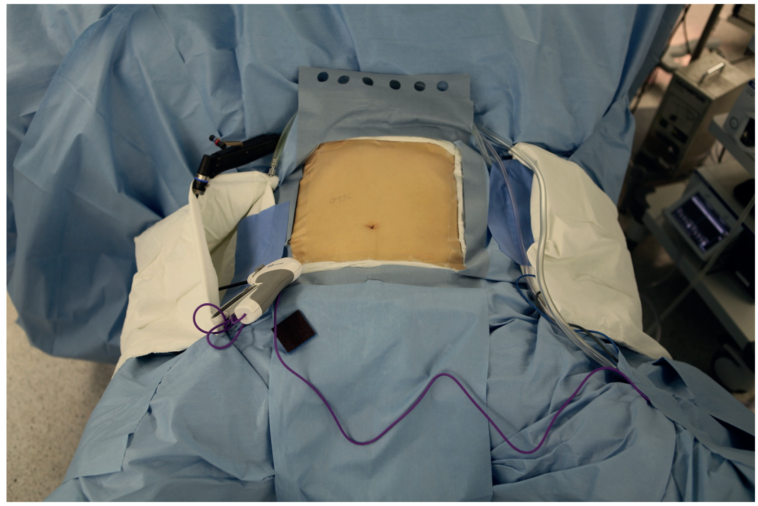

Fig. 1. The position in SILG. The patient was placed in a supine position with the legs apart and in the reverse Trendelenburg position. The pouches for laparoscopic instruments were attached on both sides of the patients. The monitors were placed on the cranial side of the patient.
SILG = single-incision laparoscopic gastrectomy.

the surgical field without an assistant. To expose the surgical field, the patient's position was changed frequently from the Trendelenburg to the reverse Trendelenburg position and by tilting from the right to the left side, thereby using gravity for natural retraction. Additionally, gauze was used to retract tissue and to absorb fluid and blood, thus keeping the operation field clean and dry (**Fig. 2**). Placing gauze between tissues and organs was an atraumatic method of constructing a surgical space. Partial omentectomy was initiated from the middle region of the omentum in a cephalic direction, approximately 3 to 4 cm from the gastroepiploic arcade. To prevent omental infarction, the left gastroepiploic vessels were ligated distal to the omental branch. The right-side omentum was dissected first until the duodenum was exposed. This could facilitate more precise dividing of the fusion fascia to separate the mesocolon from the mesogastrium. After detaching the mesocolon from the mesogastrium, we could easily expose the right gastrocolic trunk, pancreas head, and basin of lymph node station 6. The common technique to remove lymph node station 6 is to proceed with dissection from the gastroepiploic

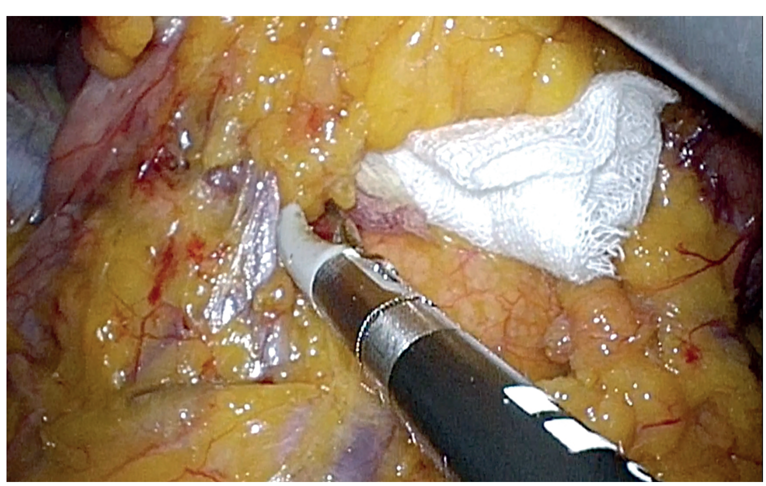

Fig. 2. Placing gauze between the pancreas and antrum of the stomach to construct surgical space and to absorb fluid and blood excreted during the procedure.

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vessels to the duodenum. The right gastroepiploic vein was divided above the junction of the anterior superior pancreatic vein, and the artery was divided to avoid injuring the gastroduodenal and anterior superior pancreatic arteries. The basin, including the infrapyloric vessels and lymph node 6, was cleared from the pancreas head and duodenum. Another method of dissecting lymph node 6 is in a retrograde fashion. With this method, the infrapyloric vessels and soft tissue were initially dissected from the duodenum and pancreas and then the right gastroepiploic vessels were controlled. The space between the duodenum and the basin, including the right gastroepiploic vessels and lymph node station 6, was first dissected, and then detached from the pancreas head to the pylorus. After clearing the duodenum and pancreatic head, the right gastroepiploic vessels and infrapyloric vessels could be skeletonized individually without substantial bleeding. The advantage of this method is reduced bleeding from the soft tissue, including the infrapyloric vessels and lymphatics, especially in obese patients. After dissecting lymph node station 6, gauze was placed in the space between the duodenum and pancreas to protect vessels and organs during supraduodenal vessel dissection. For precise dissection, we always incised the visceral peritoneum first, because all vessels and lymph nodes are encompassed by peritoneum [29]. The small supraduodenal vessels were divided and the peritoneum of the hepatoduodenal ligament was incised along with the proper hepatic artery to expose the right gastric vessel, enabling dissection of lymph node station 5. After dividing the right gastric artery at its origin, the duodenum was transected 2 cm distal to the pylorus using the purple cartilage of the laparoscopic linear stapler (Endo GIA®; Medtronic, Minneapolis, MN, USA). Before initiating the suprapancreatic lymph node dissection, the transected stomach was flipped and placed in the left subdiaphragmatic space and gauze was inserted below the caudate lobe to provide sufficient surgical view and avoid injury of the great vessels. Then, node dissection was initiated with incision of the peritoneum between the pancreas and common hepatic artery. This incision of the visceral peritoneum was extended to the proximal half of the splenic artery. This is useful to provide safe and bloodless exposure of the suprapancreatic and celiac axis. Lymph node stations 8a (common hepatic artery) and 9 (right side of the celiac axis) were dissected, and in some cases, lymph node 12a (anterolateral portion of the portal vein) was dissected if necessary. The left gastric artery and coronary vein were isolated and divided individually at the root of the celiac axis for dissection of lymph node stations 9 and 7. The proximal half of the splenic artery was isolated for dissection of lymph node station 11p. Lymph node station 1 (distal esophagus and cardia) and the upper part of station 3 (reduced curvature of the high and mid-body) were cleared, and two-thirds of the distal stomach were transected from the reduced to the greater curvature using the purple cartilage of a laparoscopic linear stapler (Endo GIA®; Medtronic). The celiac branch of the vagus nerve could be preserved if needed. For this procedure, the left gastric artery was skeletonized and divided at the distal portion of the innervation of the celiac branch of the vagus nerve, simultaneously preserving the left hepatic artery branching from the left gastric artery. The specimen was extracted through umbilical incision without any extension or retrieval bag because the wound was already protected by the port itself [10].

RECONSTRUCTION OF BOWEL CONTINUITY

The reestablishment of bowel continuity after resection is as difficult as the resection itself in SILG. However, there are several reports of an anastomotic method in SILG. Intracorporeal uncut Roux-en-Y gastrojejunostomy after distal gastrectomy and modified semi-loop reconstruction after total gastrectomy have been described for SILG [10,12]. For uncut Roux-en-Y gastrojejunostomy, jejunojejunostomy and uncut stapling to close the afferent limb was

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first performed extracorporeally through the umbilical incision in the usual manner. Next, gastrojejunostomy was performed intracorporeally in an antecolic and antiperistaltic fashion. In detail, a small opening was created at the end of the stapling line on the side of the stomach with greater curvature and at the jejunum, 20 cm from the ligament of Treitz. The cartridge of the linear stapler was introduced into the jejunum first, followed by insertion of the anvil into the stomach. After firing a staple, the stapling line was carefully checked to prevent delayed bleeding. The common entry opening was closed with a linear stapler. The unaided stapling closure of the common entry hole was previously described [10]. In the first step, 2 stay sutures were placed at either end of the stapling line of the common entry hole (i.e., a far-side stay suture was placed on the anterior wall and a near-side stay suture on the posterior wall). The thread of the near-side stay suture was pulled out of the body through the left lower channel of the single port for traction, whereas the far-side stay suture was handled by the grasper and pushed to adjust the stapling line. The balance between pulling and pushing of the 2 stay sutures enabled the horizontal alignment of the common entry hole, through which the laparoscopic linear stapler could be easily and safely applied to close the common entry hall through this adjustment using 2 stay sutures. Alternatively, the common entry hole could be closed by a laparoscopic suture technique using barbered thread. Similarly, intracorporeal side-to-side jejunojejunostomy could be performed in the same fashion as the extracorporeal technique. Finally, the afferent loop was closed 5 cm distal from the jejunojejunostomy and 2 cm proximal from the gastrojejunostomy using a no-knife linear stapler (ENDOPATH® ETS45NK; Ethicon), resulting in complete diversion of bile from the remnant stomach to the proximal jejunum. The mesenteric defect of the jejunojejunostomy and Peterson's space should be closed by a non-absorbable monofilament suture to prevent internal hernia.

The procedure for delta-shaped gastroduodenostomy (unaided delta-shaped anastomosis) was also described [11]. First, a traction suture was added to the posterior wall of the small entry hole of the remnant stomach and pulled out of the body through the left lower channel of an umbilical port. Another stay suture for traction was applied at the entry hole of the duodenal stump, which was also pulled out of the body through a right lower channel of the port. The cartridge of the 45-mm linear stapler was inserted into the remnant stomach, whereas the anvil site of the stapler was introduced into the duodenal stump. After performing side-to-side posteroposterior gastroduodenostomy, the common entry hole could be closed by unaided stapling techniques described above.

The common entry hole was closed temporarily by 3 stitches. The near-side stay suture, mostly the lower-site stitch, was pulled out of the body through the right lower channel of the single port for traction. The far-side stay suture was used for adjusting the alignment of the entry hole to the stapler. Finally, the common entry hole could be safely closed using a 60-mm linear stapler.

It was not necessary to place a drainage tube if the operation field was clean without technical break during the procedure.

CONCLUSIONS

SILG for EGC is technically feasible and reproducible. However, up to now, this procedure was considered to confer no proven advantages over other techniques, except for cosmetic results. Moreover, the learning curve is steeper than that of conventional multiport

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laparoscopic gastrectomy. It is more technically challenging, for both the operator and the surgical team. Caution should be applied in using SILG, especially for patients with advanced stage disease and in those for whom surgery is difficult.

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