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Integrating minimally invasive bariatric surgery with lessons from gastric cancer surgery

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Laparoscopic procedures in bariatric surgery are evolving to enhance cosmetic outcomes and minimize postoperative complications. This study demonstrates the results of bariatric surgery achieved through the application of surgical techniques derived from gastric cancer surgery. Several surgical techniques from gastric cancer surgery were implemented in bariatric surgery, including: (1) V-shaped liver retraction, (2) Reduced port surgery, (3) Intraoperative endoscopy and (4) Multi-degree-of-freedom articulating device. A single surgeon, with experience in over 1000 gastric cancer surgeries, performed consecutive bariatric surgeries starting from the initial case. The study analyzed short-term results, including operation details, postoperative complications, outcomes of weight loss, and the learning curve. A total 94 consecutive laparoscopic sleeve gastrectomy cases were performed from 2019 to 2022. The mean age of 94 patients was 35.9 ± 9.7 years, with 58 (61.7%) being female. The mean body mass index (BMI) was 40.9 ± 6.2. Type 2 diabetes was prevalent in 46.8% of the patients. On average, 3.3 ± 0.5 trocars were used per surgery. The mean estimated blood loss and hospital stay after surgery were 20.1 ± 36.3 cc and 3.3 ± 0.6 days, respectively. There were no complications reported for postoperative leakage, bleeding, or passage disturbance, and no mortality occurred. At 12 months, the mean percentage total weight loss (%TWL) and excess BMI loss (%EBMIL) were 28.5% and 79.7%, respectively. The mean operation times was 109.5 ± 27.4 min, with a plateau observed at around the 30th case. Bariatric surgery can be effectively performed by a gastric cancer expert surgeon using techniques derived from gastric cancer surgery.

Keywords Bariatric surgery, Laparoscopy, Minimally invasive surgical procedures, Stomach neoplasms

Bariatric surgery encompasses gastric division or resection and small bowel manipulation[1]. Therefore, while a few hepatobiliary surgeons or colorectal surgeons perform bariatric surgery, majority are conducted by gastrointestinal surgeons[2]. These surgeons also commonly perform anti-reflux surgery, esophageal cancer surgery, gastric ulcer surgery, gastric cancer surgery, and small bowel disease surgery[3–5]. The choice of major procedures for gastrointestinal surgeons often depends on the prevalence of diseases in their respective countries.

Since gastric cancer is a prevalent malignancy in Korea, with it ranking third in terms of prevalence as of 2020, treatments for gastric cancer have been developed extensively over time, and treatment guidelines, including surgical protocols, have been well-established[6–8]. Consequently, the primary focus of many gastrointestinal surgeons in Korea has been on gastric cancer. With the launch of the Korea National insurance for bariatric surgery in 2019, obese patients who met the insurance criteria began seeking bariatric surgery[9]. As a result, many expert surgeons in gastric cancer started actively performing bariatric surgeries, leading to a rapid increase in the number of such surgeries in Korea[10]. Subsequently, several techniques derived from gastric cancer surgery have been spontaneously applied to bariatric surgery.

In this study, we provide a detailed exploration of the techniques derived from gastric cancer surgery that have been applied to bariatric procedures. We aim to assess the progress in the minimally invasive approach to bariatric surgery and evaluate the effectiveness of surgical outcomes by incorporating expertise from gastric cancer surgery.

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Methods

Techniques from gastric cancers

We introduce four techniques which are currently used in gastric cancer surgery. These techniques were applied to all bariatric surgeries of this study.

V-shaped liver retraction

Liver retraction is crucial for securing the visual field around the stomach during surgery. While the Nathanson retractor is commonly used in bariatric surgeries, it may leave a scar or require the use of a trocar[11,12]. In contrast, V-shaped liver retraction is a simpler, less invasive, and less harmful technique employed during laparoscopic gastric cancer surgery[13,14].

The liver was lifted using a polypropylene monofilament, a straight taper needle, and two plastic surgical clips arranged in a V-shape. The procedure involved making a hole in the pars condensa of the hepatogastric ligament. Subsequently, a straight taper needle was inserted next to the falciform ligament under direct visualization of the abdominal cavity using the camera. The needle was then extracted back through the abdominal wall to the opposite side. Two plastic surgical clips were utilized to fix the thread at the upper part of the pars condensa. The thread was secured with a surgical device, resembling a mosquito clamp, on the epigastrium. Upon completion of the surgery, the surgical clips were removed (Fig. 1).

Reduced port surgery

All bariatric surgeries began with three ports. A 15 mm trocar was positioned at the umbilicus in all patients, primarily for the operator's right-hand device or camera. A 5 mm trocar was placed in the right lower quadrant (RLQ) area for the operator's left-hand device, while a 12 mm trocar was positioned in the left lower quadrant (LLQ) mainly for the camera or intermittent stapler insertion. This three-port setup involved two individuals: the operator and the scopist. This type of reduced port surgery is also known as "Deut" surgery[15–17].

During the operation, the patient was placed in the reverse-Trendelenburg position, with the operator standing on the right side and the scopist positioned to the left of the patient. If an optimal visual field could not be achieved with three ports, a 5 mm trocar was added in the left upper quadrant (LUQ) area, which was then used by the scopist's right hand (Fig. 2).

Intraoperative endoscopy

During sleeve gastrectomy, the endoscope was employed as a bougie for gastric resection. The standard endoscope used had a diameter of 9.8 mm, with a working channel size of 2.8 mm (GIF-Q260, Olympus, Japan), equivalent to approximately 30 French (Fr) in diameter. Typically, an early 30 Fr-sized bougie is utilized in sleeve gastrectomy[18,19]. However, in our procedure, we opted to use the standard endoscope to calibrate gastric volume instead.

In addition to calibrating gastric volume, intraoperative endoscopy (IOE) served another important role in confirming surgical status, particularly regarding stapling conditions, to prevent operative complications such as leakage and stricture[20,21]. The procedure details are as follows:

After dissecting the greater curvature and performing the first stapling approximately 4 cm proximal to the pylorus, we introduced the 30 Fr-gauge endoscope (Fig. 3A, B). Upon completion of gastric resection and insertion of the endoscope, an endoscopic examination was performed. Notably, the staple lines, lumen at the angle level, and the remnant fundus were examined for bleeding and patency, and air leaks were assessed (Fig. 3C).

Multi-degree-of-freedom articulating device

In the reduced port approach, a flexible instrument with articulation has been adopted to overcome maneuverability restrictions[22]. Specifically, a new device with multi-degree-of-freedom (DOF) articulation, known as the ArtiSential® device (LivsMed, Seongnam, Korea), was utilized for manipulating organs during the dissection of the upper third of the stomach and the left crus muscle area[23]. These anatomical regions are situated far from the RLQ trocar site for the left hand of the operator and are crucial for precisely locating the angle of His during the final stapling. The ArtiSential® device, with its specialized features, proved to be effective in enhancing maneuverability and precision in these challenging areas (Fig. 4).

Patients and collective data

The patients who underwent sleeve gastrectomy consecutively for morbid obesity from January 2019 to April 2023 at Seoul St. Mary's Hospital were enrolled in this study. All surgeries were performed by a single surgeon (H.H. Lee) with extensive experience in gastric cancer surgery, having performed over 1300 cases, but no prior experience in bariatric surgery.

The patients underwent preoperative evaluation by a multidisciplinary committee consisting of an endocrinologist, dietician, psychiatrist, and surgeon. Additionally, an upper endoscopy to rule out Helicobacter pylori infection and an abdominal computed tomography (CT) were performed. Co-morbidities considered included obstructive sleep apnea(OSA), type 2 diabetes (T2D), hyperlipidemia (HLD), hypertension (HTN), and gastroesophageal reflux disease (GERD).

Upper gastrointestinal series were routinely conducted on postoperative day 1 to detect gastric leak or stenosis. Patients were initiated on a liquid diet on postoperative day 2. Thirty-day postoperative morbidity and later surgical complications (from 30 days to 12 months postoperatively), such as stricture, was assessed using the Clavien-Dindo classification[24].

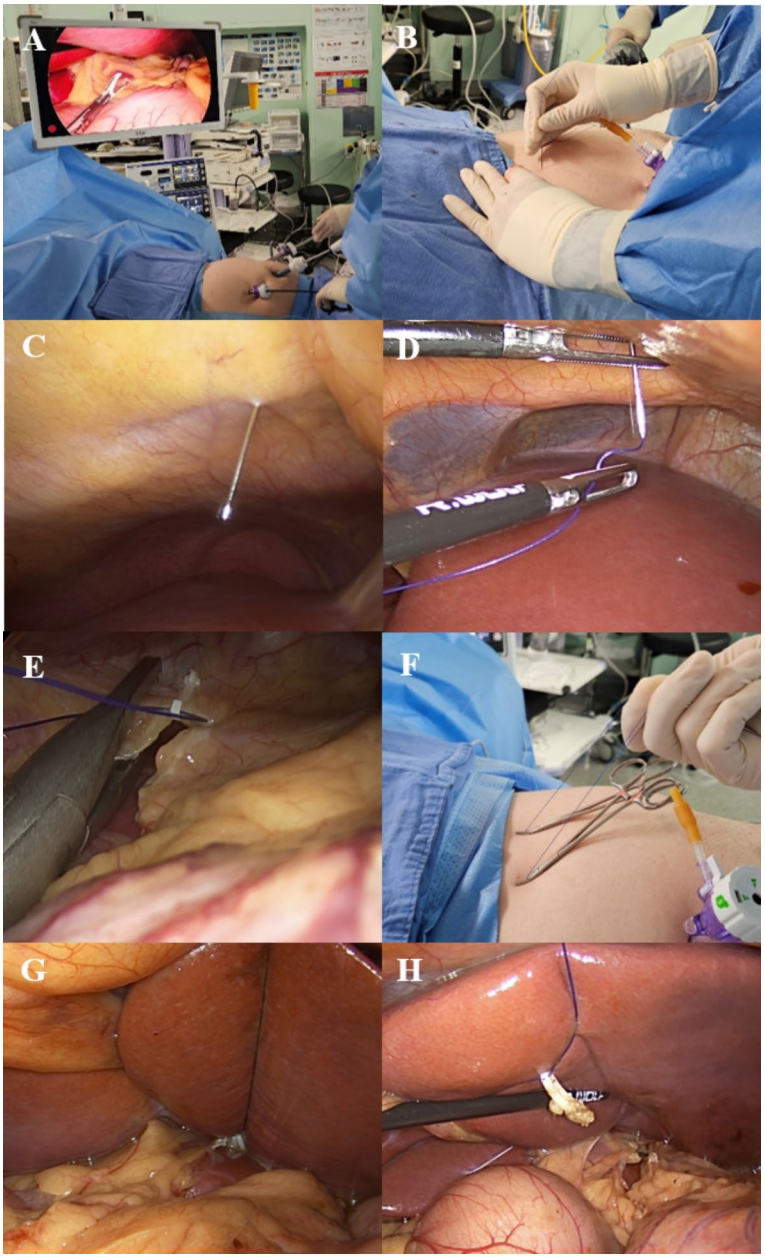

Fig. 1. V-shaped liver retraction. (**A**) Making a hole in the pars condensa, (**B**) Insertion of straight needle, (**C**) Needle visible on the right side of the falciform ligament., (**D**) Extraction of the needle on the left side of the falciform ligament, (**E**) Fixation of the thread on the pars condensa using surgical clips, (**F**) Holding the thread with clamping devices (**G**) Completion of liver retraction, (**H**) Removal of surgical clips as the final step of the surgery.

Postoperative weight loss was evaluated as % total weight loss (TWL) and % excess BMI loss (EBMIL) at 3, 6, and 12 months.

The study was approved by the Institutional Review Board (IRB) of the Ethics Committee of the College of Medicine, Catholic University of Korea (approval no. KC17RESI0110), and IRB of the College of Medicine, Catholic University of Korea waived the need for obtaining informed consent due to the retrospective nature of the study. Patient records were anonymized and de-identified prior to analysis.

Statistical analysis

Continuous variables were reported as the means ± standard deviations. Categorical variables were characterized using frequencies and percentages. Continuous variables were compared using independent-sample Student's t-test. Postoperative weight loss data were analyzed using nonlinear regressions. Differences were considered statistically significant at a 2-sided P-value of < 0.05. SPSS (ver.24; SPSS, Inc., Chicago, IL, USA) for Windows was used for statistical analysis.

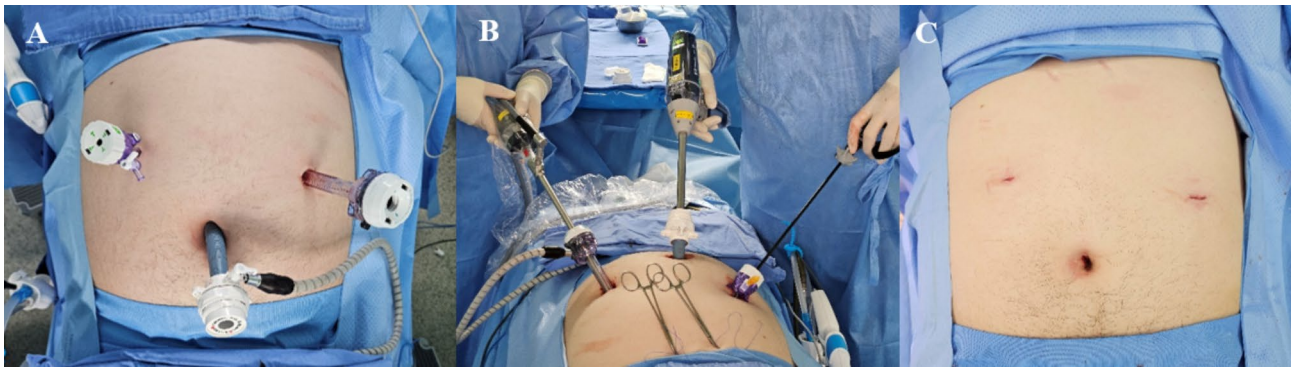

Fig. 2. Reduce port surgery. (**A**) Port positions, (**B**) The operator stands on the right side of the patient, and the scopist stands on the left side of the patient. The linear stapler is inserted via the umbilical port, (**C**) Port wound after completion of the surgery.

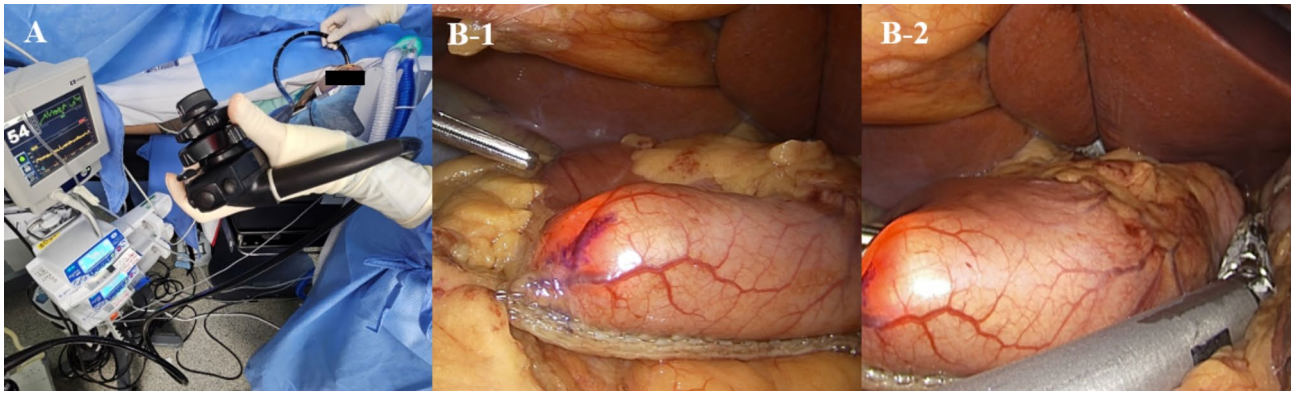

Fig. 3. Intraoperative endoscopy. (**A**) The endoscope is inserted after the first stapling by the surgeon, (**B**) Endoscope functions as a bougie, and subsequent stapling is performed while the bougie is employed, (**C**) After completion of sleeve resection, an endoscopic examination is performed to assess the possibility of the leakage or stenosis.

Results

A total 94 consecutive laparoscopic sleeve gastrectomy cases were included in this study. Among them, three cases involved the simultaneous removal of an adjustable gastric band. Table 1 presents baseline characteristics. The mean age was 35.9 ± 9.7 years, and the number of females was 58 (61.7%). The mean body weight and BMI was 115.8 ± 23.0 kg and 40.9 ± 6.2 kg/m2, respectively. The prevalence of type 2 diabetes, hypertension, dyslipidemia, obstructive sleep apnea, and gastroesophageal reflux disease was 46.8, 56.4, 42.6, 23.4, and 18.1%, respectively.

Table 2 presents perioperative findings. The mean operation times was 109.5 ± 27.4 min, and the mean estimated blood loss (EBL) was 20.1 ± 36.3 cc. The postoperative length of hospital stay was 3.3 ± 0.6 days. There were no intraoperative complications and conversions to open surgery. The mean number of trocars used was 3.3 ± 0.5, with reduced port surgery performed in 69.1% of cases. No surgery-related short or long-term complications such as bleeding, leakage, or stricture were observed. Two patients complained of abdominal pain on postoperative days 16 and 18, respectively, and were diagnosed with venous thromboembolism by abdominal computed tomography. They were successfully treated with anticoagulant agents. One patient visited the emergency room with hematemesis at 4 months postoperatively and was diagnosed with gastric ulcer bleeding with multiple small lesions on endoscopy. The initial hemoglobin level checked in emergency room was 10.6 g/dL and the patient received a blood transfusion (2 units). The lesions completely healed after two months of proton pump inhibitor therapy and did not recur (Table 3).

We divided the patient groups into three phases based on the surgical order and compared perioperative parameters and postoperative outcomes within each period. Significant differences were observed between phase 1 and the other phases in terms of operative time (Phase I *versus* Phase II; $p < 0.001$, Phase I *versus* Phase III; $p < 0.001$) (Table 4; Fig. 5). However, there were no significant differences among the three phases in terms of EBL, postoperative hospital stays, and short- and long-term complication rates (Table 4). At 12 months, mean %TWL and %EBMIL) were 28.5% and 79.7%, respectively. The completion rates of the 1-year follow-up was 50.0% (47/94) (Table 5; Fig. 6).

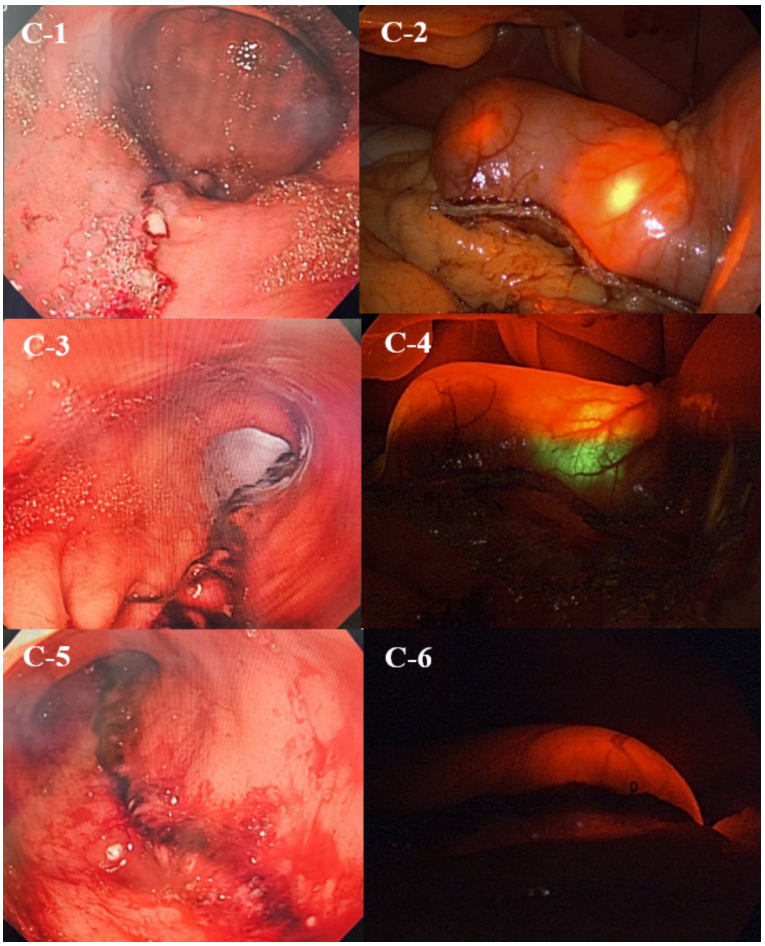

Figure 3. (continued)

Discussion

In gastric cancer surgery, the surgeon should manipulate the perigastric vessels, dissect the tissue around the stomach, resect the stomach and small intestine and anastomose them. Such every procedure during gastric cancer surgery, except lymph node dissection, is almost the same with the things of bariatric surgery[25]. Therefore, it would be natural for a surgeon specialising in stomach cancer to easily adapt to bariatric surgery. However, as the cancer patients usually do not have severe obesity, the different surgical situations such as large intra-abdominal fat, huge fatty liver and thick abdominal wall, which the obese patients have, are difficult hurdles to proceed with the operation. In our experience, we have tried to overcome such situations and perform the operation safely and also improve the operation results by using with basic equipment of bariatric surgery such as long trocar and long-shafted laparoscopic surgical devices plus the surgical technique of gastric cancer surgery.

Using the surgical technique from gastric cancer surgery, our operation results were similar to those of existing previous reports for bariatric surgery, although this report was the initial results of a surgeon who had no prior experience for bariatric surgery. The operation time and estimated blood loss were approximately 100 min and 20 cc, respectively. There were no intraoperative or postoperative complications requiring surgical intervention or reoperation, such as bleeding, leakage and stenosis. In addition, weight loss results were favorable, with a %TWL of approximately 28% at one year postoperatively. These outcomes suggest that incorporating surgical techniques from gastric cancer surgery has a positive impact on our initial operation.

Huge fatty liver is an obvious obstacle that most obese patients have to undergo surgery, and liver retraction is a first step in all types of bariatric surgery. Therefore, the Nathanson retractor is known as an indispensable device for performing bariatric surgery[26]. In gastric cancer surgery, regardless of the size of the liver, the natural structure of the liver covering the upper and middle third of the stomach is also an obstacle to the dissection of the perigastric and peri-celiax lymph nodes and the anastomoses between the small intestine and the remnant stomach or esophagus. As a results, various methods of liver retraction have been invented[11,12,26]. Among them, our technique to tracting the liver using monofilament string fixed to the pars condensa with plastic surgical clips is the most common and safest method to avoid injuring the liver parenchyme during gastric cancer surgery[13,14]. We have used this technique in our bariatric surgery from the very first case and can obtain a clear field of vision around the stomach. In addition, no liver damage was reported, despite the heavy weight of the liver in patients with severe obesity. Because the monofilament with long straight tapered needle was used, the insertion scar in

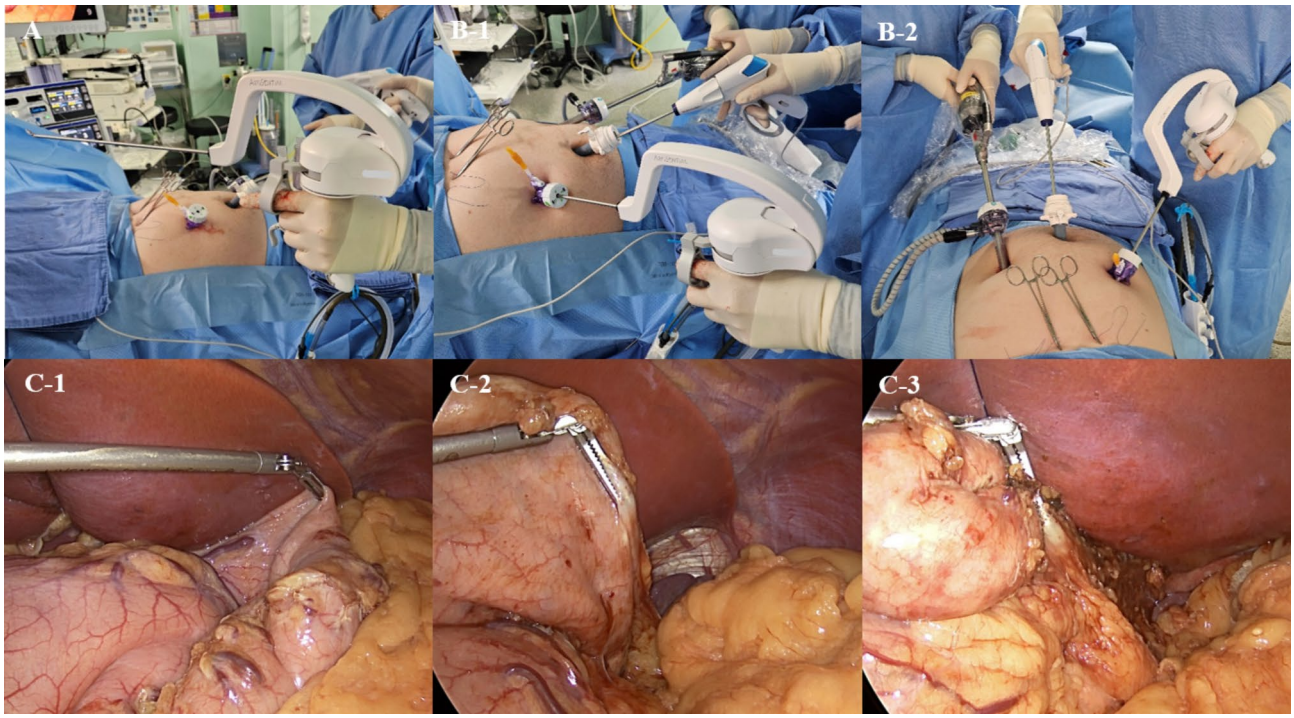

Fig. 4. Multi-degree-of-freedom articulating device. (**A**) The ArtiSential 5® (LivsMed, Seongnam, Korea), Fenestrated forceps, (**B**) This device is used for traction by the operator's left hand, (**C**) The device is utilized for manipulating organs during the dissection of the upper third of the stomach and the left crus muscle area.

Variable	Value ($n=94$)
Age (yr)	35.9 ± 9.7
Gender	
Male (%)	36 (38.3)
Female (%)	58 (61.7)
Preoperative weight (kg)	115.8 ± 23.0
Preoperative BMI (kg/m^2)	40.9 ± 6.2
Type 2 diabetes mellitus (%)	44 (46.8)
Hypertension (%)	53 (56.4)
Hyperlipidemia (%)	40 (42.6)
Obstructive sleep apnea (%)	22 (23.4)
Gastroesophageal reflux disease (%)	17 (18.1)

Table 1. Demographic and anthropometric characteristics of patients. Data given as numbers (%) and mean ± standard deviation.

Variable	Value ($n=94$)
Operation time (min)	109.5 ± 27.4
Estimated blood loss (ml)	20.1 ± 36.3
Length of hospital stay (day)	3.3 ± 0.6
Trocar number	3.3 ± 0.5
Intraoperative complication (%)	0 (0)
Open conversion (%)	0 (0)

Table 2. Operative details. Data given as numbers (%) and mean ± standard deviation.

Variable	Value ($n=94$)	Clavien-Dindo grade
Short-term complication		
Bleeding (%)	0	
Leakage (%)	0	
Ileus (%)	0	
Venous thrombosis (%)	2 (2.1)	II
Diabetic ketoacidosis (%)	1 (1.1)	II
Long-term complication		
Stricture (%)	0	
Gastric ulcer (%)	1 (1.1)	II

Table 3. Short-term (≤ 30 days) and long-term complications. Data given as numbers (%).

Variable	Phase I ($n=32$)	Phase II ($n=31$)	Phase III ($n=31$)	p
Operation time (min)	129.2 ± 27.9	101.2 ± 25.2	97.6 ± 16.2	< 0.001
Estimated blood loss (ml)	25.0 ± 45.3	18.9 ± 36.8	16.2 ± 23.7	0.617
Length of hospital stay (day)	3.2 ± 0.4	3.4 ± 0.7	3.3 ± 0.6	0.358
Short-term complication (%)	2 (6.3)	0 (0.0)	1 (3.2)	0.370
Long-term complication (%)	0 (0.0)	0 (0.0)	1 (3.2)	0.358

Table 4. Perioperative data according to the learning period. Data given as numbers (%) and mean ± standard deviation.

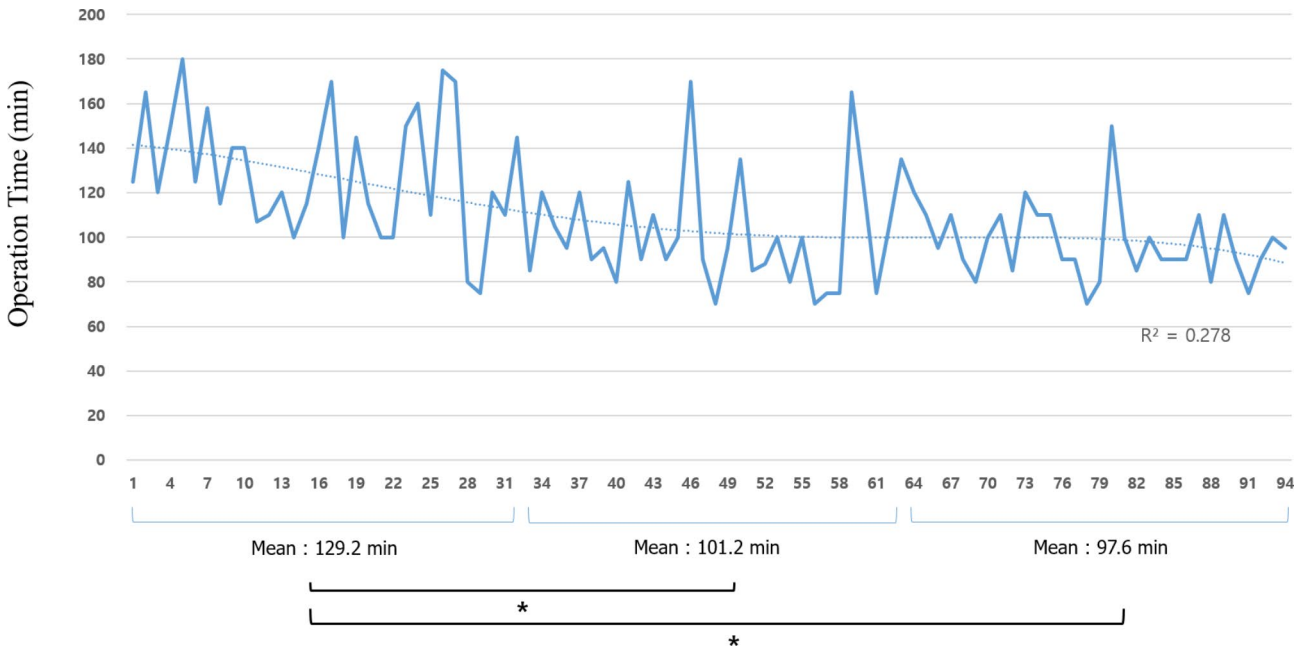

Fig. 5. Changes in operative time. A significant difference was observed between phase 1 and the other phases (phase I *versus* phase II; $p < 0.001$, phase I *versus* phase III; $p < 0.001$).

the epigastric area disappeared in a few days after surgery, and this scarless technique has a strong advantage for the cosmetic aspect, compared to the Nathanson retractor method, which leaves an epigastric scar.

Reduced port laparoscopic approach has been applied to the treatment of cancer surgery to improve the quality of life of patients[27]. Especially in the treatment of early gastric cancer, the reduced port surgery is progressing to decrease the wound scar, postoperative pain and increase the postoperative recovery[28]. In fact, such advances for postoperative period is more required to the bariatric surgery because bariatric surgery has the purpose to improve a physical appearance as well as metabolic diseases. Traditionally, bariatric surgery is performed with at least 5 trocars to overcome the limited intra-abdominal space caused by heavy visceral fat and the long distance between the trocar and the target organ such as the stomach. However, the development of long-

Variable	Preop	3 mo	6 mo	12 mo
Available/Eligible patients (n)	94/94	81/81	60/60	47/47
Weight	115.8 ± 23.0	94.0 ± 19.8	84.9 ± 18.9	82.6 ± 18.7
BMI	40.9 ± 6.2	33.3 ± 5.6	30.2 ± 5.5	29.2 ± 5.5
Change in BW (kg)		22.5 ± 7.4	30.4 ± 11.2	33.6 ± 14.7
Change in BMI (kg/m^2)		7.9 ± 2.3	10.8 ± 3.5	11.8 ± 4.6
% TWL		19.3 ± 4.9	26.3 ± 7.2	28.5 ± 9.1
% EBMIL		54.0 ± 19.6	74.5 ± 28.1	79.7 ± 30.4

Table 5. Weight loss analysis for patients who underwent LSG. Data given as mean ± standard deviation.

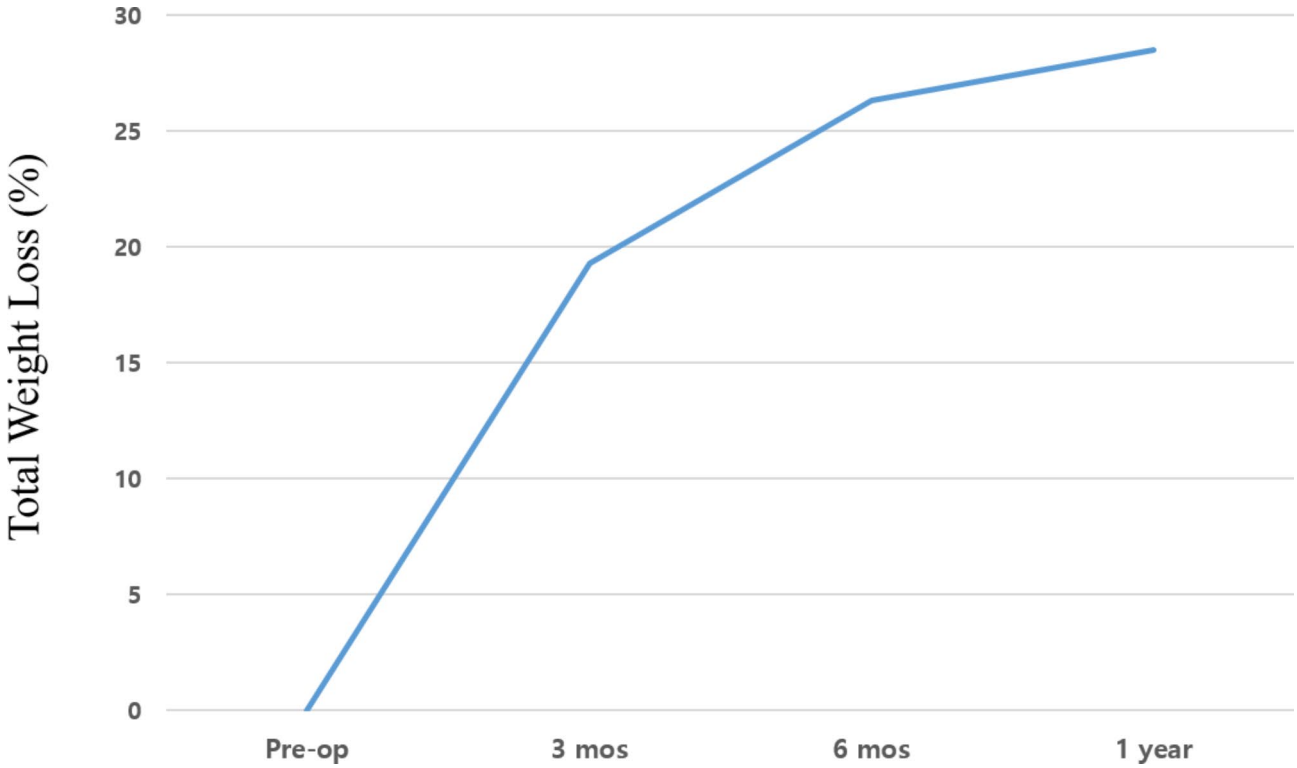

Fig. 6. Changes in the mean percentage total weight loss (%TWL) of patients. At 12 months postoperative, %TWL is reported to be 28.5%.

shafted laparoscopic devices and the accumulated surgical techniques from numerous gastric cancer operations could lead to the application of a reduced port approach in bariatric surgery. Of note, H.H. Lee reported several studies for reduced port surgery for gastric cancer and he is a principal investigator of a multicenter prospective randomized trial for reduced port surgery for early gastric cancer currently being conducted in Korea[15–17,27–29]. Such special experience would make favorable surgical outcomes using reduced port approach, although this report is about initial consecutive cases. During 94 consecutive sleeve gastrectomies, additional trocars had to be inserted in 30.9% of cases during reduced port surgery. The reasons for inserting an additional trocar included the need for effective retraction of a large and heavy liver or to secure a better surgical view, and many of these cases involved male patients with a high BMI. Although no statistical analysis was performed to identify risk factors for the failure of reduced port surgery, it is believed that the success rate of reduced port surgery might be higher in patients with small livers, low BMI, and female sex.

IOE is not a routine part of every gastric cancer operation. In fact, IOE during abdominal surgery presents challenges such as tight spatial constraints and a different axis of entry than normal endoscopes, mainly due to the supine position. In gastric cancer surgery, endoscopy procedure is mainly used for tumor localization or confirmation of anastomosis status[30,31]. As mentioned in the Method section, endoscopy was used as a bougie and to check the stapling line in all our cases. In usual laparoscopic sleeve gastrectomy, orogastric tubes such as a bougie have been used to assess the adequacy of gastric sleeve calibration[32]. However, complications such as esophageal perforation have been reported with a low probability due to its blind and invasive nature[33–35]. In our series, endoscopy played an excellent role as a bougie, demonstrating an optimal sleeve size without the development of stenosis or twisting in short-term results and with favorable weight loss in long-term results.

However, since the diameter of the endoscopic scope is thinner than the 36-40Fr bougie commonly used during sleeve gastrectomy, this difference should be taken into account when using the endoscopic scope for calibration. IOE also proved to be a valuable tool to directly monitor bleeding and leakages at the stapling site without affecting the overall operation time. IOE likely contributed to the low perioperative complications observed in our early experiences.

The ArtiSential® (LivsMed, Seongnam, Korea) is a single-use articulated hand-held laparoscopic device with a multi-DOF level of dexterity and a 360-degree wrist capability of the end effector, similar to that found in surgical robotic systems[36]. This device has a vertical and horizontal joint structure that synchronizes with the user's hand movements, enabling a wider range of surgical procedures compared to straight-fixed laparoscopic instruments, especially when the instrument is at a difficult angle to perform a specific task. It has been used in various types of surgery, both intra-abdominal for benign and malignant conditions[37,38]. However, until now, there have been no reports on the usage of ArtiSential® in the field of bariatric surgery. Based on our experience with its use in gastric cancer surgery, we applied this instrument to the bariatric surgery using a reduced port approach. This study reports good operative outcomes both in the short and long term. To the best of our knowledge, this report is the first to apply the ArtiSential® to the bariatric surgery.

There were a few limitations in this report. First, an accurate analysis for the learning curve of gastric cancer surgeons in bariatric surgery was not calculated. Although we only presented changes in operation time without calculating the learning curve checkpoint, the favorable operative outcomes serve as evidence of the quality of surgery. Second, this study only described the results of sleeve gastrectomy and did not include the results of any bypass surgery. Indeed, sleeve gastrectomy is known as the simplest and most popular procedure among the bariatric surgeries and we applied our integrating minimal invasive methods from experience in gastric cancer treatment to the initial sleeve gastrectomy series. The results of this report will guide the application of our integrating minimal invasive approaches to other types of bariatric surgery. Lastly, the 1-year follow-up rate was relatively low, which may be due to the fact that some patients had not yet reached the 1-year follow-up period at the time of the study results and there was a lack of a management system to ensure consistent follow-up.

In conclusion, integrating minimal invasive procedures, including V-shaped liver retraction, reduced port approach, IOE and the use of a multi-DOF articulating device were successfully applied to the sleeve gastrectomy, resulting in favorable short and long-term outcomes. Gastric cancer surgeons would be able to perform bariatric surgery effectively and safely using specialized techniques derived from gastric cancer surgery.

Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

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Declarations

Competing interests

The authors declare no competing interests.

Etics approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Additional information

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