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Visceral fat area is a better indicator of surgical outcomes after laparoscopic gastrectomy for cancer than the body mass index: a propensity score-matched analysis

Yoshiro Imai[1] · Sang-Woong Lee[1] · Masaru Kawai[2] · Keitaro Tashiro[1] · Satoshi Kawashima[1] · Ryo Tanaka[1] · Kotaro Honda[1] · Kentaro Matsuo[1] · Kazuhisa Uchiyama[1]

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Abstract

Background The number of overweight gastric cancer patients who are undergoing laparoscopic gastrectomy (LG) has increased in Japan. However, the relationship between obesity and surgical outcomes of LG remains unclear. Therefore, this study aimed to evaluate the effect of visceral fat area (VFA) on surgical outcomes of LG for gastric cancer compared to the body mass index (BMI).

Methods This study was a retrospective, cohort study that included 587 patients who underwent LG in our institution between January 2015 and December 2019. The patients were divided into two groups according to VFA (<100 cm^2 and ≥ 100 cm^2) and BMI (<25 kg/m^2 and ≥ 25 kg/m^2) values, respectively. Surgical outcomes and postoperative complications were compared between the low and high groups for each VFA and BMI value. Propensity score matching was used to minimize potential selection bias.

Results After propensity score matching, 144 pairs of patients in the VFA group and 82 pairs of patients in the BMI group were extracted. Operative time ($p=0.003$), intraoperative blood loss ($p=0.0006$), and CRP levels on postoperative day 1 ($p=0.002$) and on postoperative day 3 ($p=0.004$) were significantly higher in the high-VFA group than in the low-VFA group. However, these surgical outcomes were not significantly different between the high-BMI and low-BMI groups. There was no strong correlation between VFA and BMI ($R^2=0.64$). There were no significant differences in postoperative complications between the high and low groups for both VFA and BMI values. On multivariate analysis, high VFA was an independent predictor of operative time, but it was not significantly associated with the incidence of postoperative complications.

Conclusion VFA is a better indicator of longer operative time than BMI. However, increased VFA did not affect postoperative complications.

Keywords Visceral fat area · Laparoscopic gastrectomy · Body mass index · Propensity score matching · Intracorporeally · Surgical outcome

In 1994, Kitano et al. first reported laparoscopic gastrectomy (LG) [1]. Since then, use of LG has been increasing gradually [2–4]. Several randomized trials and meta-analyses have shown the feasibility and surgical safety of LG, along with earlier patient recovery, reduced postoperative pain, and better quality of life after LG than after open gastrectomy (OG) [5–10]. The indications for LG are expanding, including advanced gastric cancer and remnant gastric cancer [11–14].

The number of overweight people in Japan has increased dramatically in recent years, due in part to changes in lifestyle behaviors. Similarly, the number of overweight gastric cancer patients has increased in Japan [15]. Body mass index (BMI) has been commonly used as one of the most reliable indices of obesity because of its simplicity and objectivity. A high BMI is a well-known risk factor for postoperative complications after gastrectomy for gastric cancer [16–20]. However, BMI may not reflect the body fat distribution, that

✉ Sang-Woong Lee
sur079@osaka-med.ac.jp

1 Department of General and Gastroenterological Surgery, Osaka Medical and Pharmaceutical University, 2-7 Daigakumachi, Takatsuki 569-8686, Japan

2 Department of Gastroenterological Surgery, Hirakata City Hospital, Hirakata, Japan

is, BMI does not correlate with visceral fat area (VFA) [21, 22]. Asians have more visceral fat than Caucasians with the same BMI [21]. Several studies have reported that high VFA is more strongly associated with longer operative time and greater intraoperative blood loss, and it is a risk factor for postoperative complications compared to high BMI for OG [23–26]. However, few reports have examined the impact of VFA on laparoscopic procedures. This study aimed to compare the impacts of preoperative VFA and preoperative BMI on outcomes of total laparoscopic resection for cancer.

Materials and methods

Patients

This was a retrospective, cohort study. From January 2015 to December 2019, a total of 587 patients with gastric cancer underwent gastrectomy at Osaka Medical College Hospital, Japan. As per the exclusion criteria, patients who underwent OG or robotic gastrectomy, had macroscopic residual disease following surgery (R2 resection), had simultaneous resection of other organs except for the gallbladder or spleen, or had remnant gastric cancer were excluded. Therefore, data from 409 patients were analyzed in the present study.

Patients' preoperative examinations included upper gastrointestinal endoscopy, abdominal computed tomography (CT), and laboratory tests including tumor markers such as CEA and CA19-9. Gastric cancer diagnoses were based on pathological findings.

Patients' preoperative characteristics, including age, sex, BMI, American Society of Anesthesiologists (ASA) score, pathological stage, and history of diabetes mellitus, antithrombotic therapy, upper abdominal surgery, and neoadjuvant chemotherapy, were retrospectively evaluated from hospital records. Pathological stage was defined by the Japanese classification of gastric carcinoma [27]. The study protocol was approved by the ethics committee of Osaka Medical and Pharmaceutical University Hospital (approval no. 2020-005), which waived the need for informed consent due to the retrospective nature of the study.

Surgical techniques

Lymph node dissection, surgical procedure, and gastric reconstruction were determined according to the Japanese gastric cancer treatment guidelines [28]. Splenectomy was performed when the tumor was located on the greater curvature of the upper third of the stomach. In our institute, almost all resections for gastric cancer were performed laparoscopically regardless of clinical stage, except for clinical trials limited to open surgery procedures and emergency surgery, such as for perforation or acute bleeding. Surgical procedures for gastric cancer consisted of laparoscopic total gastrectomy (LTG), laparoscopic distal gastrectomy (LDG), laparoscopic proximal gastrectomy (LPG), and laparoscopic pylorus-preserving gastrectomy (LPPG). All reconstruction procedures were performed intracorporeally. In LDG, intracorporeal Billroth I reconstruction with a delta-shaped mechanical anastomosis was performed. In cases of a small remnant stomach, reflux esophagitis, or elderly persons, intracorporeal Billroth II, or Roux-en-Y reconstruction was performed [4, 14]. Reconstruction of the esophagojejunostomy following LTG or double-tract LPG, esophagogastrostomy following LPG, gastrogastrostomy following LPPG, and both Billroth I and Billroth II following LDG involved side-to-side anastomosis using a linear stapler with closure of the entry hole using two unidirectional barbed sutures, but Roux-en-Y reconstruction following LDG involved both side-to-side anastomosis and closure of the entry hole using a linear stapler. Details of our procedures have been reported elsewhere [3, 4, 14, 29–31]. All surgeries were performed or supervised by surgeons who had performed more than 500 cases and were certified by the Japan Society for Endoscopic Surgery [32].

Definition of early surgical outcomes and postoperative complications

The primary endpoint was surgical outcomes, including operative time, intraoperative blood loss, number of retrieved lymph nodes, C-reactive protein (CRP) on postoperative day (POD) one or three, number of postoperative hospital days, and first day of flatus.

The secondary endpoint was the incidence of postoperative complications included anastomotic leakage, pancreatic fistula, intra-abdominal abscess, pneumonia, ileus, delayed gastric emptying, wound infection, anastomotic bleeding, hemorrhage, and others determined as grade II or higher complications based on the Clavien–Dindo classification [33]. Pancreatic fistula was diagnosed on the basis of the definitions of the International Study Group on Pancreatic Fistula (ISGPF) [34]. Anastomotic leakage was diagnosed by radiological examination using orally administered contrast media.

Definition of VFA and BMI

Abdominal fat distribution was analyzed on preoperative CT images at the level of the umbilicus [35] (Fig. 1). The Volume Analyzer SYNAPSE VINCENT image analysis system (Fujifilm Medical, Tokyo, Japan) was used to quantify abdominal adipose tissue area and volume. The intraperitoneal area was defined by tracing its contour automatically or manually when it was not correct on the scan. Adipose tissue was determined by setting the attenuation level within

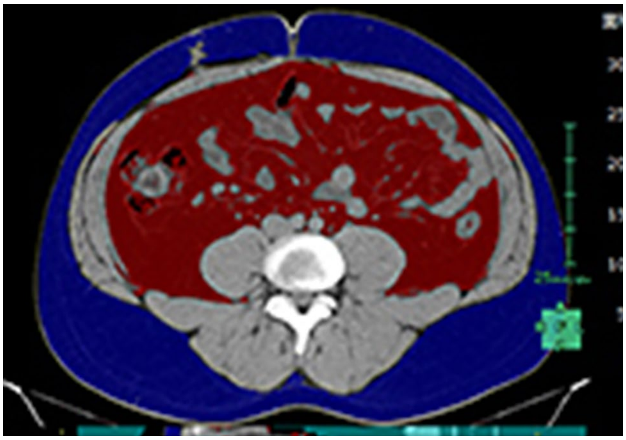

Fig. 1 Visceral fat area at the level of the umbilicus (red field) measured on preoperative computed tomography with the Volume Analyzer SYNAPSE VINCENT image analysis system

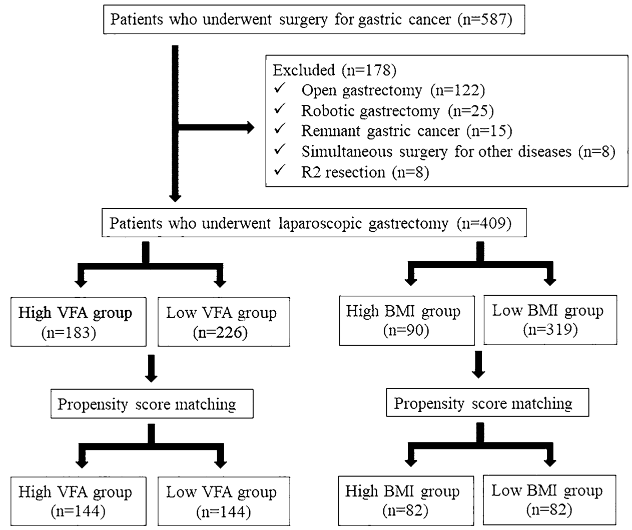

Fig. 2 Flowchart of the patients assessed in this study

the range of − 190 to − 30 Hounsfield units [36]. VFA was quantified automatically by the software. The cutoff value for VFA was set at 100 cm^2. This value is equivalent to that used in Japan for the diagnosis of metabolic syndrome, among other criteria [22]. On the other hand, the cutoff value for BMI was 25 kg/m^2, because it is used in the definition of obesity of the Japan Society for the Study of Obesity [22].

Propensity score matching

Propensity score matching was used to reduce potential bias. Propensity scores were estimated using a logistic regression model with the following 12 factors: age, sex, ASA score, pathological stage, surgical procedure, reconstruction procedure, lymph node dissection, splenectomy, history of diabetes mellitus, anti-thrombotic therapy, upper abdominal surgery, and neoadjuvant chemotherapy. Propensity scores were matched using one-to-one nearest-neighbor matching. A caliper width of 0.2 of the standard deviation of the logit of the propensity score was used.

Statistical analysis

All statistical analyses were performed using JMP pro 15 (ver. 15, SAS Institute, Cary, NC, USA). Continuous variables are presented as means ± standard deviation (SD) and were compared using the Wilcoxon rank-sum test. The Chi-squared test and Fisher's exact probability test were used to compare differences in the categorical variables. Spearman's rank correlation coefficient was used to evaluate relationships between VFA and BMI. Associations of surgical outcomes with the VFA were analyzed using multiple linear regression models. Associations between postoperative complications and the variables were analyzed by logistic regression analysis. A p value of less than 0.05 was considered significant.

Perioperative management

In our institute, the Enhanced Recovery after Surgery (ERAS) protocol has been introduced in perioperative care [37]. The patients took 250 ml of oral carbohydrate solution on the night before surgery and 2 h before anesthesia. On POD 1, patients started walking and were allowed to drink clear fluids. The patients started to ingest a liquid diet on POD 2, after which the diet continued through four daily steps to eventually eating regular food on POD 6. Acetaminophen was administered orally twice daily until POD 5.

Results

Patients' characteristics

The patient selection flowchart is shown in Fig. 2. A total of 587 patients who underwent gastrectomy for gastric cancer were reviewed. Of these, 122 patients who underwent OG, 25 who underwent robotic gastrectomy, 15 who underwent remnant gastrectomy, eight who underwent R2 resection, and eight who underwent simultaneous resection of other organs for other diseases such as colorectal cancer ($n=4$), esophageal cancer ($n=1$), hepatic cancer ($n=2$), and endometrial cancer ($n=1$) were excluded.

Thus, 409 patients who underwent LG were enrolled in this study. In this cohort, 226 patients were in the high-VFA group, and 183 patients were in the low-VFA group. Patients' characteristics according to VFA values are listed in Table 1. There were significant differences in sex, ASA score, and history of upper abdominal surgery. After propensity score matching, data of 144 pairs of patients were extracted. Patients' characteristics after propensity score matching are listed in Table 2, and there were no significant differences.

Similarly, 319 patients constituted the high-BMI group, and 90 patients constituted the low-BMI group. Patients' characteristics according to BMI values are listed in Table 3. There were significant differences in ASA score and history of diabetes mellitus. After propensity score matching, data of 82 pairs of patients were extracted. Patients' characteristics after propensity score matching are listed in Table 4, and there were no significant differences in their background characteristics.

Comparison between high-VFA and low-VFA groups

Table 5 compares the surgical outcomes and postoperative complications between the high-VFA and low-VFA groups. For surgical outcomes, operative time was significantly longer and intraoperative blood loss was significantly higher in the high-VFA group than in the low-VFA group ($p = 0.003$, $p = 0.0006$; respectively). CRP levels on POD 1 and POD 3 were significantly higher in the high-VFA group ($p = 0.001$, $p = 0.004$; respectively). There were no significant differences in the number of retrieved lymph nodes, duration of postoperative hospital days, and first day of flatus between the two groups. Major postoperative complications including anastomotic leakage, pancreatic fistula, intra-abdominal abscess, and pneumonia did not differ between the high-VFA and low-VFA groups.

Correlation between VFA and BMI

Figure 3 shows the correlation between VFA and BMI. VFA and BMI were significantly correlated ($R^2 = 0.64$), but the correlation was not strong. The enrolled patients in this study were divided into 4 subgroups (low VFA/low BMI, high VFA/low BMI, low VFA/high BMI, high VFA/high BMI) (Table 6). The low-VFA/low-BMI group was the most common (50.2%), followed by the high-VFA/low-BMI group (27.8%), high-VFA/high-BMI group (16.8%), and low-VFA/high-BMI group (5.1%).

Comparison between high-BMI and low-BMI groups

Table 7 compares the surgical outcomes and postoperative complications between the high-BMI and low-BMI groups. For surgical outcomes, the first day of flatus was significantly later in the high-BMI group than in the low-BMI

Table 1 Patients' characteristics by VFA group

	Low-VFA group $n = 226$	High-VFA group $n = 183$	*p* value
Age (years)	70 ± 0.7	71.6 ± 0.8	0.64
Sex (male/female)	122 / 104	148 / 35	< 0.0001
BMI (kg/m^2)	21.3 ± 0.1	24.36 ± 0.2	< 0.0001
VFA (cm^2)	56.8 ± 2.2	151.8 ± 2.4	< 0.0001
ASA score			
1 / 2 / 3 / 4	50 / 146 / 29 / 1	20 / 127 / 33 / 1	0.02
pStage			
I / II / III / IV	153 / 35 / 30 / 8	121 / 30 / 29 / 3	0.59
Surgical procedure			
PPG / DG / PG / TG	3 / 180 / 15 / 28	1 / 145 / 21 / 16	0.2
Reconstruction procedure			
GG / BI / BII / EG / DT / RY	3 / 117 / 13 / 14 / 1 / 78	1 / 71 / 23 / 16 / 6 / 66	0.008
Splenectomy [*n* (%)]	5 (2.2)	2 (1.0)	0.46
Lymph node dissection			
D1 / D1 + / D2 / D2 +	15 / 151 / 38 / 22	9 / 128 / 34 / 12	0.55
Preoperative chemotherapy	16 (7.0)	12 (6.5)	0.83
Comorbidity [*n* (%)]			
Diabetes mellitus	43 (19)	44 (24)	0.2
Anti-thrombotic therapy	38 (17)	35 (19.2)	0.6
Upper abdominal surgery	8 (3.5)	20 (10.9)	0.005

BMI body mass index, *VFA* visceral fat area, *ASA* American Society of Anesthesiologists, *PPG* pylorus-preserving gastrectomy, *PG* proximal gastrectomy, *TG* total gastrectomy, *GG* gastrogastrostomy, *BI* Billroth I, *BII* Billroth II, *EG* esophagogastrostomy, *DT* double tract, *RY* Roux-en-Y

Table 2 Patients' characteristics by VFA group after propensity score matching

	Low-VFA group $n=144$	High-VFA group $n=144$	*p* value
Age (years)	71.6 ± 0.84	72.1 ± 0.84	0.66
Sex (male/female)	111 / 33	112 / 32	0.88
BMI (kg/m^2)	21.4 ± 0.2	24.3 ± 0.2	< 0.0001
VFA (cm^2)	60 ± 2.7	147 ± 2.7	< 0.0001
ASA score			
1 / 2 / 3 / 4	19 / 104 / 20 / 1	17 / 103 / 23 / 1	0.95
pStage			
I / II / III / IV	99 / 24 / 20 / 1	95 / 24 / 23 / 2	0.89
Surgical procedure			
PPG / DG / PG / TG	1 / 119 / 11 / 13	1 / 114 / 14 / 15	0.89
Reconstruction procedure			
GG / BI / BII / EG / DT / RY	1 / 68 / 11 / 11 / 53	1 / 64 / 12 / 14 / 14 /51	0.82
Splenectomy [*n* (%)]	1 (0.6)	2 (1.3)	0.56
Lymph node dissection	9 / 99 / 23 / 13	6 / 99 / 29 / 10	0.64
D1 / D1 + / D2 / D2 +	16 (7.0)	12 (6.5)	0.83
Preoperative chemotherapy	8 (5.5)	9 (6.2)	0.8
Comorbidity [*n* (%)]			
Diabetes mellitus	30 (20.8)	33 (22.9)	0.66
Anti-thrombotic therapy	23 (15.9)	26 (18)	0.75
Upper abdominal surgery	8 (5.5)	7 (4.8)	0.79

BMI body mass index, *VFA* visceral fat area, *ASA* American Society of Anesthesiologists, *PPG* pylorus-preserving gastrectomy, *PG* proximal gastrectomy, *TG* total gastrectomy, *GG* gastrogastrostomy, *BI* Billroth I, *BII* Billroth II, *EG* esophagogastrostomy, *DT* double tract, *RY* Roux-en-Y

Table 3 Patients' characteristics by BMI group

	Low-BMI group $n=319$	High-BMI group $n=90$	p value
Age (years)	70.9 ± 11.1	70.3 ± 10.2	0.48
Sex (male/female)	207 / 112	63 / 27	0.36
BMI (kg/m^2)	21.5 ± 2.2	27.2 ± 1.8	< 0.0001
VFA (cm^2)	85.7 ± 49.5	148 ± 58.3	< 0.0001
ASA score			
1 / 2 / 3 / 4	61 / 217 / 40 / 1	9 / 58 / 22 / 1	0.01
pStage			
I / II / III / IV	209 / 55 / 47 / 8	65 / 10 / 12 / 3	0.46
Surgical procedure			
PPG / DG / PG / TG	4 / 250 /28 / 37	0 / 75 / 8 / 7	0.51
Reconstruction procedure			
GG / BI / BII / EG / DT / RY	4 / 153 / 24 / 3 / 25 / 110	0 / 35 / 12 / 4 / 5 / 34	0.05
Splenectomy [*n* (%)]	7 (2.1)	0	0.1
Lymph node dissection			
D1 / D1 + / D2 / D2 +	19 / 215 / 56 / 29	5 / 64 / 16 / 5	0.74
Preoperative chemotherapy	6 (4.4)	6 (4.4)	1
Comorbidity [*n* (%)]			
Diabetes mellitus	59 (18.5)	28 (31.1)	0.009
Anti-thrombotic therapy	55 (17.2)	16 (17.7)	0.87
Upper abdominal surgery	19 (5.9)	9 (10)	0.17

BMI body mass index, *VFA* visceral fat area, *ASA* American Society of Anesthesiologists, *PPG* pylorus-preserving gastrectomy, *PG* proximal gastrectomy, *TG* total gastrectomy, *GG* gastrogastrostomy, *BI* Billroth I, *BII* Billroth II, *EG* esophagogastrostomy, *DT* double tract, *RY* Roux-en-Y

Table 4 Patients' characteristics by BMI group after propensity score matching

	Low-BMI group $n=82$	High-BMI group $n=82$	p value
Age (years)	71.5 ± 11.8	70.9 ± 9.8	0.49
Sex (male/female)	53 / 29	58 / 24	0.4
BMI (kg/m^2)	21.5 ± 2.3	27.2 ± 1.8	< 0.0001
VFA (cm^2)	87.4 ± 47.0	148.9 ± 58.6	< 0.0001
ASA score			
1 / 2 / 3 / 4	11 / 53 / 17 / 1	9 / 56 / 16 / 1	0.95
pStage			
I / II / III / IV	209 / 55 / 47 / 8	65 / 10 / 12 / 3	0.46
Surgical procedure			
PPG / DG / PG / TG	19 / 71 / 5 / 6	19 / 69 / 7 / 6	0.83
Reconstruction procedure			
BI / BII / EG / DT / RY	31 / 10 / 2 / 3 / 36	35 / 10 / 2 / 5 / 30	0.86
Splenectomy [*n* (%)]	2 (2.3)	0	0.15
Lymph node dissection			
D1 / D1 + / D2 / D2 +	5 / 60 / 13 / 4	5 / 57 / 15 / 5	0.95
Preoperative chemotherapy	1 (1.2)	0	0.31
Comorbidity [*n* (%)]			
Diabetes mellitus	19 (23.1)	22 (26.8)	0.58
Anti-thrombotic therapy	21 (25.6)	16 (19.5)	0.35
Upper abdominal surgery	7 (8.4)	8 (9.7)	0.78

BMI body mass index, *VFA* visceral fat area, *ASA* American Society of Anesthesiologists, *PPG* pylorus-preserving gastrectomy, *PG* proximal gastrectomy, *TG* total gastrectomy, *BI* Billroth I, *BII* Billroth II, *EG* esophagogastrostomy, *DT* double tract, *RY* Roux-en-Y

group. Regarding postoperative complications, there were no significant differences between the two groups.

Relationships between VFA or BMI and surgical outcomes

The relationships between surgical outcomes and VFA were investigated by univariate and multivariate analyses. Potential confounding variables with $p < 0.2$ on univariate analysis were included in the multivariate analyses. Independent variables were selected from among age (continuous), sex, VFA (< 100 cm^2 or ≥ 100 cm^2), BMI (< 25 kg/m^2 or ≥ 25 kg/m^2), ASA (≤ 2 or ≥ 3) score, pathological stage (I, II or III, IV), surgical procedure (DG, PG, PPG or TG), reconstruction procedure (Billroth I or other than Billroth I), lymph node dissection (≤ D1 + or ≥ D2), splenectomy (yes or no), history of diabetes mellitus (yes or no), anti-thrombotic therapy (yes or no), upper abdominal surgery (yes or no), and neoadjuvant chemotherapy (yes or no).

The univariate and multivariate analyses of operative time are shown in Table 8. Age, sex, BMI, VFA, pathological stage, surgical procedure, reconstruction procedure, splenectomy, lymph node dissection, and preoperative chemotherapy were included as explanatory variables in the multivariate regression analyses. The VFA was an independent predictor of operative time (regression coefficient (β): 0.11, 95% confidence interval (CI) 3.5–16.27, $p = 0.002$).

The results for intraoperative blood loss are shown in Table 9. Age, BMI, VFA, pathological stage, surgical procedure, reconstruction procedure, splenectomy, lymph node dissection, preoperative chemotherapy, diabetes mellitus, anti-thrombotic therapy, and upper abdominal surgery were included as explanatory variables in the multivariate regression analyses. VFA was not significantly associated with intraoperative blood loss on multivariate analysis (β: 0.01, 95% CI − 5.88 to 8.25, $p = 0.74$).

On the other hand, regarding the BMI, there were no significant relationships with operative time (β: 0.04, 95% CI − 2.94–11.66, $p = 0.24$) and intraoperative blood loss (β: 0.07, 95% CI − 2.19–14.67, $p = 0.14$).

Univariate and multivariate analyses of postoperative complications

The results of univariate and multivariate analyses of postoperative complications are shown in Table 10. Age, sex, VFA, pathological stage, and reconstruction procedures were included as explanatory variables in the multiple logistic regression analyses. VFA was not a risk factor for postoperative complications (odds ratio (OR): 1.407, 95% CI 0.894–2.218, $p = 0.13$).

Table 5 Comparison of surgical outcomes and postoperative complications between the low-VFA group and the high-VFA group

	Low-VFA group *n* = 144	High-VFA group *n* = 144	p value
Surgical outcomes			
Operative time (min)	248 ± 63.8	270 ± 74.8	0.006
Blood loss (ml)	19 ± 31.1	27 ± 47	0.0001
Retrieved nodes	36 ± 14.4	34 ± 13	0.06
CRP (POD 1) (mg/dl)	5.1 ± 2.4	6.1 ± 2.8	0.002
CRP (POD 3) (mg/dl)	9.6 ± 5.8	11.7 ± 6.8	0.004
Hospital days	14.2 ± 10.8	14.1 ± 8.0	0.51
First day of flatus	1.9 ± 0.07	2.1 ± 0.07	0.32
Postoperative complications			
Pancreas-related infection	3 (2.0%)	3 (2.0%)	1
Intra-abdominal abscess	4 (2.7%)	8 (5.6%)	0.23
Anastomotic leakage	6 (4.7%)	5 (3.4%)	0.75
Pneumonia	14 (9.7%)	9 (6.2%)	0.27
Ileus	5 (3.4%)	6 (4.17%)	0.75
Delayed gastric emptying	1 (0.6%)	2 (1.3%)	0.56
Wound infection	5 (3.4%)	4 (2.7%)	0.73
Anastomotic bleeding	2 (1.3%)	1 (0.6%)	0.56
Hemorrhage	0	1 (0.6%)	0.31
Others	11 (7.6%)	11 (7.6%)	1.0

VFA visceral fat area, *CRP* C-reactive protein, *POD* postoperative day

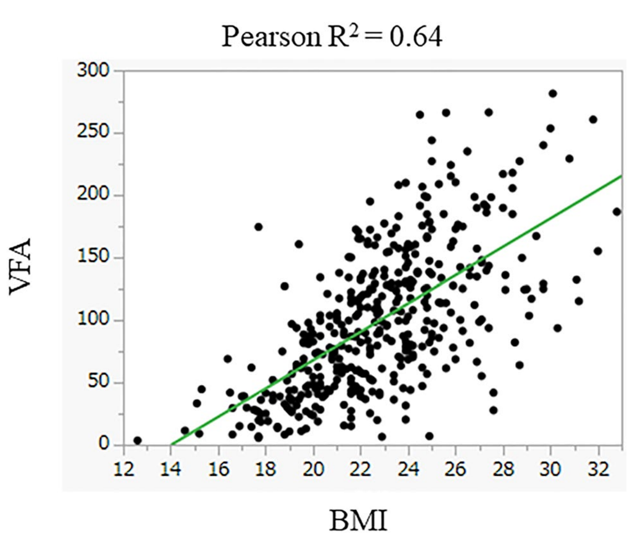

Fig. 3 Correlation between body mass index (BMI) and visceral fat area (VFA)

Table 6 Division of the patients in this study into 4 subgroups by VFA and BMI

	VFA < 100 cm^2	VFA ≥ 100 cm^2
BMI < 25 kg/m^2	205 (50.2%)	114 (27.8%)
BMI ≥ 25 kg/m^2	21 (5.1%)	69 (16.8%)

BMI body mass index, *VFA* visceral fat area

Discussion

The results of the present study showed that high VFA may be more related to longer operative time than high BMI following LG. However, even in patients with high VFA, although operative time was longer, there were no significant differences in postoperative complications compared with low VFA.

In the present study, no similar conclusion was obtained in the BMI group because BMI does not reflect body fat distribution, such as visceral fat and subcutaneous fat. In the present study, VFA and BMI were not strongly correlated. Approximately 30% of enrolled patients had normal BMI (< 25 kg/m^2) but high VFA (≥ 100 cm^2). The effect of visceral fat is stronger than that of subcutaneous fat in laparoscopic surgery.

Some reports showed that, with high VFA, the operative time was significantly longer [38–40], the intraoperative blood loss was significantly increased [39, 40], and the number of retrieved lymph nodes was significantly decreased [38, 41] than with high BMI. However, these reports were derived from a surgical procedure of LDG, not including other gastric resections. There are two reports including surgical procedures besides LDG. Liu et al. reported that VFA better evaluated the operative time and the risk of postoperative complications than BMI [42]. Shin et al. reported that VFA might be a better predictive marker than BMI for operative time and intraoperative blood loss [43]. These reports involved laparoscopic-assisted gastrectomy (LAG) with extracorporeal reconstruction through minilaparotomy. That is, there have been no reports about pure LG. Okabe et al. reported that the incidence of postoperative complications after gastrectomy increased in proportion to the VFA [44]. This report included open and laparoscopic approaches. To the best of our knowledge, the present study was the first evaluate the contributions of VFA and BMI for predicting surgical outcomes and postoperative complications in total LG using propensity score matching.

The reason why patients with high VFA may have difficulty with gastrectomy is that lymph nodes are embedded in thick fat tissue and are hard to distinguish when surrounded by fat, making lymph node dissection difficult. In addition, excessive visceral fat leads to a poor visual operative field, causing vulnerable organization and increased ease

Table 7 Comparison of surgical outcomes and postoperative complications between the low-BMI group and the high-BMI group

	Low-BMI group $n=82$	High-BMI group $n=82$	p value
Surgical outcomes			
Operative time (min)	251 ± 69.5	272 ± 75.4	0.07
Blood loss (ml)	18.9 ± 26.6	40.6 ± 98.2	0.26
Retrieved nodes	34 ± 15.2	33.1 ± 16.8	0.49
CRP (POD 1) (mg/dl)	5.5 ± 2.4	6.1 ± 3.0	0.19
CRP (POD 3) (mg/dl)	10.5 ± 5.9	12.0 ± 6.9	0.11
Hospital days	14.7 ± 11.8	13.3 ± 8.2	0.22
First day of flatus	1.8 ± 0.81	2.2 ± 0.88	0.003
Postoperative complications			
Pancreas-related infection	2 (2.4%)	1 (1.2%)	0.56
Intra-abdominal abscess	5 (6.1%)	1 (1.2%)	0.09
Anastomotic leakage	2 (2.4%)	3 (3.6%)	0.64
Pneumonia	8 (9.7%)	4 (4.8%)	0.36
Ileus	3 (3.6%)	3 (3.6%)	1.0
Delayed gastric emptying	2 (2.4%)	0	0.15
Wound infection	3 (3.6%)	1 (1.2%)	0.31
Anastomotic bleeding	1 (1.2%)	2 (2.4%)	0.56
Hemorrhage	0	1 (1.2%)	0.31
Others	6 (7.3%)	6 (7.3%)	1.0

BMI body mass index, *CRP* C-reactive protein, *POD* postoperative day

of bleeding, naturally leading to longer operative time and increased intraoperative blood loss. However, due to the progress of energy devices such as laparoscopic coagulating shears or vessel sealing systems in recent years, hemostatic ability has improved; so, although intraoperative blood loss has increased significantly, it is considered to be within the acceptable range with high VFA (mean: 27 ml with high VFA). Therefore, high VFA was not an independent risk factor for intraoperative blood loss. In addition, endoscopic images have been sharpened, and the magnifying effect enables the recognition of fat layers and the lymph node dissection along the outermost layer, which refers to the dissectible layer around the artery [45], so that lymph node dissection is possible without decreasing the number of retrieved lymph nodes.

CRP levels on both POD 1 and POD 3 were significantly higher in the high-VFA group than in the low-VFA group. Iida et al. only reported that patients with high VFA have high CRP levels after laparoscopic-assisted gastrectomy compared with low VFA with or without postoperative complications and suggested that visceral fat might promote the postoperative inflammatory response [46]. Fontane et al. reported that interleukin-6 concentrations were significantly higher in the portal vein of obese patients who underwent open gastric bypass surgery and suggested that visceral fat itself is a source of inflammation [47]. The present study showed similar results, but in addition to that consideration, it is also considered that postoperative invasion, such as longer operative time and greater intraoperative blood loss, increases the CRP level. From the clinical perspective, even if the postoperative CRP level is high, if the physical findings are unremarkable, there is no need to start antibiotics or delay oral intake based on suspicion of complications such as infection.

It was interesting that a high VFA had no effect on postoperative complications in the present study. However, several studies have reported that high VFA is more strongly associated with postoperative complications following OG [23–26]. For overweight patients undergoing OG, anastomotic leakage may occur due to the deep surgical field with the high subcutaneous fat that is difficult to anastomose. Furthermore, with LAG as well, the anastomosis is performed through a minilaparotomy made in the epigastrium. There is often difficulty performing the anastomosis in the narrow and restricted space, especially for overweight patients with high subcutaneous fat. However, this effect of high subcutaneous fat is relatively small in total LG with intracorporeal anastomosis. Esophagojejunostomy after LTG is generally a difficult procedure, but it can be performed safely with the recent improvements in the technique of laparoscopic surgery in terms of the incidence of anastomotic leakage (JCOG1401) [48]. With the improvement of the automatic suturing device and the use of barbed sutures, intracorporeal esophagojejunostomy can be performed with greater safety [29]; therefore, high VFA does not lead to an increased risk of anastomotic leakage.

Table 8 Univariate and multivariate analyses for operative time

Variable	Univariate analysis		Multivariate analysis	
	Regression β (95% CI)	p value	Regression β (95% CI)	p value
Age (years)				
Per 1 year	− 0.15 (− 1.77 to − 0.42)	0.001	− 0.12 (− 1.43 to − 0.35)	0.001
Sex				
Male	0.08 (− 0.855 to − 14.83)	0.08	0.07 (− 0.50 to 12.07)	0.07
BMI (kg/m^2)				
≥ 25	0.08 (− 1.40 to 16.54)	0.09	0.04 (− 2.94 to 11.66)	0.24
VFA (cm^2)				
≥ 100	0.15 (4.65 to 19.47)	0.001	0.11 (3.50 to 16.27)	0.002
ASA score				
	0.001 (− 10.14 to 10.39)	0.98		
pStage				
III, IV	0.35 (27.18 to 45.68)	< 0.0001	0.16 (8.07 to 24.99)	0.0001
Surgical procedure				
TG	0.51 (52.92 to 73.61)	< 0.0001	0.31 (28.18 to 49.68)	< 0.0001
Reconstruction procedure				
BI	− 0.4 (− 37.90 to − 24.23)	< 0.0001	− 0.18 (− 20.77 to − 8.18)	< 0.0001
Splenectomy				
Yes	0.29 (58.89 to 113.90)	< 0.0001	0.11 (11.65 to 58.25)	0.003
Lymph node dissection				
≥ D2	0.37 (24.53 to 40.34)	< 0.0001	0.07 (− 1.09 to 14.20)	0.09
Preoperative chemotherapy				
Yes	0.24 (23.17 to 51.80)	< 0.0001	0.12 (7.01 to 30.64)	0.001
Diabetes mellitus				
Yes	− 0.04 (− 13.01 to 5.20)	0.39		
Anti-thrombotic therapy				
Yes	− 0.03 (− 13.52 to 6.16)	0.46		
Upper abdominal surgery				
Yes	0.04 (− 8.44 to 21.08)	0.40		

CI confidence interval, *BMI* body mass index, *VFA* visceral fat area, *ASA* American Society of Anesthesiologists, *TG* total gastrectomy, *BI* Billroth I

The reason why pancreatic fistulas may occur in OG with high VFA is that excessive visceral fat makes it difficult to find the border between the pancreas and lymph nodes, which may result in pancreatic injury during lymph node dissection. However, the border between the pancreas and lymph nodes can be recognized by improving the endoscopic image and the magnifying effect; therefore, as for anastomotic leakage, high VFA does not lead to increased pancreatic fistulas. Similar to VFA, there was no significant difference between the high-BMI and low-BMI groups. High BMI includes obesity, in which there is much subcutaneous fat, not visceral fat. Subcutaneous fat does not increase pancreatic fistulas in laparoscopic surgery.

There were no significant differences in the number of postoperative hospital days for both the VFA and BMI groups. Liu et al. reported that patients with high VFA had longer hospital stays, which indicated that high VFA would delay the postoperative recovery of patients [42]. However, we previously reported that the ERAS protocol shortened the postoperative hospital stay after gastrectomy for gastric cancer [37]; it did not lead to delayed postoperative recovery of patients in both the high-VFA and high-BMI groups. Similarly, there were no significant differences in postoperative complications such as pneumonia, ileus, and delayed gastric emptying. The fact that these complications did not increase may be due to the ERAS protocol. The first day of flatus was only delayed in the high-BMI group, but there is a possibility that postoperative ambulation was less in the high-BMI group than in the low-BMI group. However, it was not enough to lead to postoperative complications such as ileus and longer postoperative hospital stay.

Table 9 Univariate and multivariate analyses for intraoperative blood loss

Variable	Univariate analysis		Multivariate analysis	
	Regression β (95% CI)	p value	Regression β (95% CI)	p value
Age (years)				
Per 1 year	− 0.15 (− 0.15 to 1.05)	0.14	0.06 (− 0.22 to 1.06)	0.2
Sex				
Male	0.03 (− 4.28 to 9.77)	0.44		
BMI (kg/m^2)				
≥ 25	0.08 (− 1.05 to 14.98)	0.08	0.07 (− 2.19 to 14.67)	0.14
VFA (cm^2)				
≥ 100	0.15 (4.65 to 19.47)	0.001	0.01 (− 5.88 to 8.25)	0.74
ASA score				
	0.02 (− 6.97 to 11.37)	0.63		
pStage				
III, IV	0.08 (− 1.29 to 16.34)	0.09	0.008 (− 8.95 to 10.58)	0.86
Surgical procedure				
TG	0.12 (3.11 to 24.46)	0.01	0.07 (− 4.26 to 20.40)	0.19
Reconstruction procedure				
BI	− 0.12 (− 15.46 to − 2.2)	0.009	− 0.03 (− 9.99 to 4.62)	0.47
Splenectomy				
Yes	0.29 (58.89 to 113.90)	< 0.0001	0.09 (− 0.97 to 52.53)	0.05
Lymph node dissection				
≥ D2	0.10 (0.41 to 15.54)	0.03	0.05 (− 4.51 to 13.19)	0.33
Preoperative chemotherapy				
Yes	0.09 (− 0.05 to 26.21)	0.05	0.12 (7.01 to 30.64)	0.25
Diabetes mellitus				
Yes	0.07 (− 2.13 to 14.11)	0.14	0.03 (− 5.06 to 11.31)	0.45
Anti-thrombotic therapy				
Yes	0.06 (− 2.86 to 14.69)	0.18	0.04 (− 4.93 to 13.04)	0.37
Upper abdominal surgery				
Yes	0.16 (8.77 to 34.83)	0.001	0.14 (7.03 to 33.36)	0.002

CI confidence interval, *BMI* body mass index, *VFA* visceral fat area, *ASA* American Society of Anesthesiologists, *TG* total gastrectomy, *BI* Billroth I

There are several limitations to the present study. First, it was performed at a single institution in Japan, and the cutoff value for BMI was 25 kg/m^2 according to the Japan Society for the Study of Obesity [22]. To define obesity, most countries use standards set by the World Health Organization (WHO), which defines overweight as a BMI of more than 25 kg/m^2, and obesity as a BMI of 30 kg/m^2 and above. Those levels are based largely on data from Caucasian populations. About 30% of Americans have a BMI of more than 30 kg/m^2, but only a few Asians, less than 5%, have a BMI of more than 30 kg/m^2. However, whereas a high proportion (30%) of Americans are obese, only 8% have diabetes mellitus, a rate on par with that in Asia [49]. Asians are thought to be prone to metabolic syndrome even with mild obesity. Therefore, it is used in the definition of obesity of the Japan Society for the Study of Obesity [22]. However, a BMI of more than 25 kg/m^2 is very common among Americans, and it would be useful to examine whether there are any differences among overweight, obese, morbidly obese, and super-obese patients. However, even in the present study, only 2% of cases had a BMI of more than 30 kg/m^2, which does not allow proper statistical analysis. Furthermore, Asians are more prone to visceral fat obesity than Caucasians [21]; therefore, the reproducibility of the results requires evaluation in other medical centers and racial groups. Second, there may have been unmeasurable confounding risk factors. However, most major risk factors for surgical outcomes and postoperative complications were included. In addition, men and women should be evaluated separately in order to evaluate the effects of abdominal shape on short-term surgical outcomes. However, dividing the patients by sex would decrease the number of patients in each analysis. In particular, in the present study, the sample size of females

Table 10 Univariate and multivariate analyses for postoperative complications

Variable	Univariate analysis		Multivariate analysis	
	OR (95% CI)	p value	OR (95% CI)	p value
Age (years)				
Per 1 year	1.02 (1.005–1.050)	0.006	1.024 (1.001–1.048)	0.03
Sex				
Male	1.896 (1.183–3.105)	0.007	1.740 (1.055–2.294)	0.02
BMI (kg/m^2)				
≥ 25	1.057 (0.626–1.749)	0.83		
VFA (cm^2)				
≥ 100	1.672 (1.089–2.575)	0.018	1.407 (0.894–2.218)	0.13
ASA score				
	1.230 (0.684–2.159)	0.480		
pStage				
III, IV	1.685 (0.976–2.872)	0.06	1.620 (0.908–2.860)	0.10
Surgical procedure				
TG	1.453 (0.740–2.769)	0.27		
Reconstruction procedure				
BI	0.719 (0.465–1.105)	0.13	0.839 (0.530–1.327)	0.45
Splenectomy				
Yes	0.401 (0.021–2.383)	0.35		
Lymph node dissection				
≥ D2	1.009 (0.615–1.631)	0.96		
Preoperative chemotherapy				
Yes	1.386 (0.598–3.044)	0.43		
Diabetes mellitus				
Yes	0.846 (0.488–1.425)	0.53		
Anti-thrombotic therapy				
Yes	0.946 (0.535–1.670)	0.85		
Upper abdominal surgery				
Yes	0.972 (0.393–2.198)	0.94		

OR odds ratio, *CI* confidence interval, *BMI* body mass index, *VFA* visceral fat area, *ASA* American Society of Anesthesiologists, *TG* total gastrectomy, *BI* Billroth I

was small, they had few complications, and there were no significant differences between two groups. Therefore, we compared and examined the two groups using propensity score-matched analysis so that there would be no difference Thus, we believe that this minimized the effects of unmeasurable confounders. Third, operations were performed or supervised by surgeons certified by the Japan Society for Endoscopic Surgery and well experienced in LG for gastric cancer. Shin et al. reported that VFA accumulation was associated with technical difficulties for surgeons who had performed fewer than 50 cases of LG for gastric cancer [43]. Further retrospective studies are needed to confirm the impact of VFA on outcomes of LG for inexperienced surgeons to show real-world evidence. Fourth, there was no effect on short-term outcomes, and long-term outcomes, including survival rates, could not be addressed. Long-term follow-up is required in future studies. Tan et al. reported that long-term survival following LG was not significantly different between obese patients and non-obese patients [50]. In the present study, lymph node dissection was possible without decreasing the number of retrieved lymph nodes in the high-VFA group, and pathological stage was equivalent between the high-VFA group and the low-VFA group before the propensity score-matched analysis. That is, it is considered that no difference in long-term outcomes could be expected.

Conclusion

In conclusion, VFA is a better indicator of longer operative time than BMI. However, accumulation of VFA did not affect short-term outcomes, except for the duration of surgery.

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Declarations

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References

1. Kitano S, Iso Y, Moriyama M, Sugimachi K (1994) Laparoscopy-assisted Billroth I gastrectomy. Surg Laparosc Endosc 4:146–148
2. Lee SW, Nomura E, Bouras G, Tokuhara T, Tsunemi S, Tanigawa N (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
3. Lee SW, Bouras G, Nomura E, Yoshinaka R, Tokuhara T, Nitta T, Tsunemi S, Tanigawa N (2010) Intracorporeal stapled anastomosis following laparoscopic segmental gastrectomy for gastric cancer: technical report and surgical outcomes. Surg Endosc 24:1774–1780
4. Lee SW, Tanigawa N, Nomura E, Tokuhara T, Kawai M, Yokoyama K, Hiramatsu M, Okuda J, Uchiyama K (2012) Benefits of intracorporeal gastrointestinal anastomosis following laparoscopic distal gastrectomy. World J Surg Oncol 10:267
5. Vinuela EF, Gonen M, Brennan MF, Coit DG, Strong VE (2012) Laparoscopic versus open distal gastrectomy for gastric cancer: a meta-analysis of randomized controlled trials and high-quality nonrandomized studies. Ann Surg 255:446–456
6. Haverkamp L, Brenkman HJ, Seesing MF, Gisbertz SS, van Berge Henegouwen MI, Luyer MD, Nieuwenhuijzen GA, Wijnhoven BP, van Lanschot JJ, de Steur WO, Hartgrink HH, Stoot JH, Hulsewe KW, Spillenaar Bilgen EJ, Rutter JE, Kouwenhoven EA, van Det MJ, van der Peet DL, Daams F, Draaisma WA, Broeders IA, van Stel HF, Lacle MM, Ruurda JP, van Hillegersberg R, group Ls (2015) Laparoscopic versus open gastrectomy for gastric cancer, a multicenter prospectively randomized controlled trial (LOGICA-trial). BMC Cancer 15:556
7. Kim W, Kim HH, Han SU, Kim MC, Hyung WJ, Ryu SW, Cho GS, Kim CY, Yang HK, Park DJ, Song KY, Lee SI, Ryu SY, Lee JH, Lee HJ, Korean Laparo-endoscopic Gastrointestinal Surgery Study G (2016) Decreased morbidity of laparoscopic distal gastrectomy compared with open distal gastrectomy for stage I gastric cancer: short-term outcomes from a multicenter randomized controlled trial (KLASS-01). Ann Surg 263:28–35
8. Hu Y, Ying M, Huang C, Wei H, Jiang Z, Peng X, Hu J, Du X, Wang B, Lin F, Xu J, Dong G, Mou T, Li G, Chinese Laparoscopic Gastrointestinal Surgery Study G (2014) Oncologic outcomes of laparoscopy-assisted gastrectomy for advanced gastric cancer: a large-scale multicenter retrospective cohort study from China. Surg Endosc 28:2048–2056
9. Kitano S, Shiraishi N, Fujii K, Yasuda K, Inomata M, Adachi Y (2002) A randomized controlled trial comparing open vs laparoscopy-assisted distal gastrectomy for the treatment of early gastric cancer: an interim report. Surgery 131:S306-311
10. Katai H, Mizusawa J, Katayama H, Takagi M, Yoshikawa T, Fukagawa T, Terashima M, Misawa K, Teshima S, Koeda K, Nunobe S, Fukushima N, Yasuda T, Asao Y, Fujiwara Y, Sasako M (2017) Short-term surgical outcomes from a phase III study of laparoscopy-assisted versus open distal gastrectomy with nodal dissection for clinical stage IA/IB gastric cancer: Japan Clinical Oncology Group Study JCOG0912. Gastric Cancer 20:699–708
11. Inaki N, Etoh T, Ohyama T, Uchiyama K, Katada N, Koeda K, Yoshida K, Takagane A, Kojima K, Sakuramoto S, Shiraishi N, Kitano S (2015) A multi-institutional, prospective, phase II feasibility study of laparoscopy-assisted distal gastrectomy with D2 lymph node dissection for locally advanced gastric cancer (JLSSG0901). World J Surg 39:2734–2741
12. Ji JF (2019) Chinese standard and milestone of laparoscopic surgery for gastric cancer–comments on the publishing of "standard operation procedure of laparoscopic surgery from CLASS-01 trial." Zhonghua Wei Chang Wai Ke Za Zhi 22:913–915
13. Hyung WJ, Yang HK, Park YK, Lee HJ, An JY, Kim W, Kim HI, Kim HH, Ryu SW, Hur H, Kim MC, Kong SH, Cho GS, Kim JJ, Park DJ, Ryu KW, Kim YW, Kim JW, Lee JH, Han SU, Korean Laparoendoscopic Gastrointestinal Surgery Study G (2020) Long-term outcomes of laparoscopic distal gastrectomy for locally advanced gastric cancer: the KLASS-02-RCT randomized clinical trial. J Clin Oncol 38:3304–3313
14. Lee SW, Kawai M, Tashiro K, Bouras G, Kawashima S, Tanaka R, Nomura E, Uchiyama K (2017) Laparoscopic distal gastrectomy with D2 lymphadenectomy followed by intracorporeal gastroduodenostomy for advanced gastric cancer: technical guide and tips. Transl Gastroenterol Hepatol 2:84
15. Kubo M, Sano T, Fukagawa T, Katai H, Sasako M (2005) Increasing body mass index in Japanese patients with gastric cancer. Gastric Cancer 8:39–41
16. Inagawa S, Adachi S, Oda T, Kawamoto T, Koike N, Fukao K (2000) Effect of fat volume on postoperative complications and survival rate after D2 dissection for gastric cancer. Gastric Cancer 3:141–144
17. Tsujinaka T, Sasako M, Yamamoto S, Sano T, Kurokawa Y, Nashimoto A, Kurita A, Katai H, Shimizu T, Furukawa H, Inoue S, Hiratsuka M, Kinoshita T, Arai K, Yamamura Y, Gastric Cancer Surgery Study Group of Japan Clinical Oncology G (2007) Influence of overweight on surgical complications for gastric cancer: results from a randomized control trial comparing D2 and extended para-aortic D3 lymphadenectomy (JCOG9501). Ann Surg Oncol 14:355–361
18. Ojima T, Iwahashi M, Nakamori M, Nakamura M, Naka T, Ishida K, Ueda K, Katsuda M, Iida T, Tsuji T, Yamaue H (2009) Influence of overweight on patients with gastric cancer after undergoing curative gastrectomy: an analysis of 689 consecutive cases managed by a single center. Arch Surg 144:351–358
19. Dhar DK, Kubota H, Tachibana M, Kotoh T, Tabara H, Masunaga R, Kohno H, Nagasue N (2000) Body mass index determines the success of lymph node dissection and predicts the outcome of gastric carcinoma patients. Oncology 59:18–23
20. Kodera Y, Ito S, Yamamura Y, Mochizuki Y, Fujiwara M, Hibi K, Ito K, Akiyama S, Nakao A (2004) Obesity and outcome of distal gastrectomy with D2 lymphadenectomy for carcinoma. Hepatogastroenterology 51:1225–1228
21. Kadowaki T, Sekikawa A, Murata K, Maegawa H, Takamiya T, Okamura T, El-Saed A, Miyamatsu N, Edmundowicz D, Kita Y, Sutton-Tyrrell K, Kuller LH, Ueshima H (2006) Japanese men have larger areas of visceral adipose tissue than Caucasian men in the same levels of waist circumference in a population-based study. Int J Obesity 30:1163–1165
22. Oda E (2006) New criteria for "obesity disease" in Japan. Circ J 70:150

23. Sugisawa N, Tokunaga M, Tanizawa Y, Bando E, Kawamura T, Terashima M (2012) Intra-abdominal infectious complications following gastrectomy in patients with excessive visceral fat. Gastric Cancer 15:206–212
24. Takeuchi M, Ishii K, Seki H, Yasui N, Sakata M, Shimada A, Matsumoto H (2016) Excessive visceral fat area as a risk factor for early postoperative complications of total gastrectomy for gastric cancer: a retrospective cohort study. BMC Surg 16:54
25. Tokunaga M, Hiki N, Fukunaga T, Ogura T, Miyata S, Yamaguchi T (2009) Effect of individual fat areas on early surgical outcomes after open gastrectomy for gastric cancer. Br J Surg 96:496–500
26. Tanaka K, Miyashiro I, Yano M, Kishi K, Motoori M, Seki Y, Noura S, Ohue M, Yamada T, Ohigashi H, Ishikawa O (2009) Accumulation of excess visceral fat is a risk factor for pancreatic fistula formation after total gastrectomy. Ann Surg Oncol 16:1520–1525
27. Japanese Gastric Cancer A (2011) Japanese classification of gastric carcinoma: 3rd English edition. Gastric Cancer 14**:**101–112
28. Japanese Gastric Cancer A (2020) Japanese gastric cancer treatment guidelines 2018 (5th edition). Gastric Cancer
29. Lee SW, Kawai M, Tashiro K, Kawashima S, Tanaka R, Tanaka K, Nomura E, Uchiyama K (2019) The crossover technique for intracorporeal esophagojejunostomy following laparoscopic total gastrectomy: a simple and safe technique using a linear stapler and two barbed sutures. Surg Endosc Other Interv Tech 33:1386–1393
30. Lee SW, Nomura E, Tokuhara T, Kawai M, Matsuhashi N, Yokoyama K, Fujioka H, Hiramatsu M, Okuda J, Uchiyama K (2011) Laparoscopic technique and initial experience with knotless, unidirectional barbed suture closure for staple-conserving, delta-shaped gastroduodenostomy after distal gastrectomy. J Am Coll Surg 213:e39-45
31. Takaori K, Nomura E, Mabuchi H, Lee SW, Agui T, Miyamoto Y, Iwamoto W, Watanbe H, Tanigawa N (2005) A secure technique of intracorporeal Roux-Y reconstruction after laparoscopic distal gastrectomy. Am J Surg 189:178–183
32. Tanigawa N, Lee SW, Kimura T, Mori T, Uyama I, Nomura E, Okuda J, Konishi F (2011) The endoscopic surgical skill qualification system for gastric surgery in Japan. Asian J Endosc Surg 4:112–115
33. Dindo D, Demartines N, Clavien PA (2004) Classification of surgical complications—a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg 240:205–213
34. Bassi C, Dervenis C, Butturini G, Fingerhut A, Yeo C, Izbicki J, Neoptolemos J, Sarr M, Traverso W, Buchler M, Fist ISGP (2005) Postoperative pancreatic fistula: an international study group (ISGPF) definition. Surgery 138:8–13
35. Sottier D, Petit JM, Guiu S, Hamza S, Benhamiche H, Hillon P, Cercueil JP, Krause D, Guiu B (2013) Quantification of the visceral and subcutaneous fat by computed tomography: interobserver correlation of a single slice technique. Diagn Interv Imaging 94:879–884
36. Mourtzakis M, Prado CM, Lieffers JR, Reiman T, McCargar LJ, Baracos VE (2008) A practical and precise approach to quantification of body composition in cancer patients using computed tomography images acquired during routine care. Appl Physiol Nutr Metab 33:997–1006
37. Tanaka R, Lee SW, Kawai M, Tashiro K, Kawashima S, Kagota S, Honda K, Uchiyama K (2017) Protocol for enhanced recovery after surgery improves short-term outcomes for patients with gastric cancer: a randomized clinical trial. Gastric Cancer 20:861–871
38. Go JE, Kim MC, Kim KH, Oh JY, Kim YM (2015) Effect of visceral fat area on outcomes of laparoscopyassisted distal gastrectomy for gastric cancer: subgroup analysis by gender and parameters of obesity. Ann Surg Treat Res 88:318–324
39. Miyaki A, Imamura K, Kobayashi R, Takami M, Matsumoto J (2013) Impact of visceral fat on laparoscopy-assisted distal gastrectomy. Surgeon 11:76–81
40. Ueda J, Ichimiya H, Okido M, Kato M (2009) The impact of visceral fat accumulation on laparoscopy-assisted distal gastrectomy for early gastric cancer. J Laparoendosc Adv S 19:157–162
41. Yoshikawa K, Shimada M, Kurita N, Iwata T, Nishioka M, Morimoto S, Miyatani T, Komatsu M, Mikami C, Kashihara H (2011) Visceral fat area is superior to body mass index as a predictive factor for risk with laparoscopy-assisted gastrectomy for gastric cancer. Surg Endosc 25:3825–3830
42. Liu Y, Guo D, Niu Z, Wang Y, Fu G, Zhou Y, Xue Q, Jin X, Gong Z (2018) Prediction of the risk of laparoscopy-assisted gastrectomy by comparing visceral fat area and Body Mass Index. Gastroenterol Res Pract 2018:1359626
43. Shin HJ, Son SY, Cui LH, Byun C, Hur H, Lee JH, Kim YC, Han SU, Cho YK (2015) Is there any role of visceral fat area for predicting difficulty of laparoscopic gastrectomy for gastric cancer? J Gastric Cancer 15:151–158
44. Okada K, Nishigori T, Obama K, Tsunoda S, Hida K, Hisamori S, Sakai Y (2019) The incidence of postoperative complications after gastrectomy increases in proportion to the amount of preoperative visceral fat. J Oncol 2019:8404383
45. Kanaya S, Haruta S, Kawamura Y, Yoshimura F, Inaba K, Hiramatsu Y, Ishida Y, Taniguchi K, Isogaki J, Uyama I (2011) Video: laparoscopy distinctive technique for suprapancreatic lymph node dissection: medial approach for laparoscopic gastric cancer surgery. Surg Endosc 25:3928–3929
46. Iida M, Takeda S, Nakagami Y, Kanekiyo S, Nakashima C, Nishiyama M, Yoshida S, Suzuki N, Yoshino S, Nagano H (2020) The effect of the visceral fat area on the predictive accuracy of C-reactive protein for infectious complications after laparoscopy-assisted gastrectomy. Ann Gastroenterol Surg 4:386–395
47. Fontana L, Eagon JC, Trujillo ME, Scherer PE, Klein S (2007) Visceral fat adipokine secretion is associated with systemic inflammation in obese humans. Diabetes 56:1010–1013
48. Katai H, Mizusawa J, Katayama H, Kunisaki C, Sakuramoto S, Inaki N, Kinoshita T, Iwasaki Y, Misawa K, Takiguchi N, Kaji M, Okitsu H, Yoshikawa T, Terashima M, Stomach Cancer Study Group of Japan Clinical Oncology G (2019) Single-arm confirmatory trial of laparoscopy-assisted total or proximal gastrectomy with nodal dissection for clinical stage I gastric cancer: Japan Clinical Oncology Group study JCOG1401. Gastric Cancer 22:999–1008
49. Mandavilli A, Cyranoski D (2004) Asia's big problem. Nat Med 10:325–327
50. Tan J, Zhu SH (2017) Laparoscopic gastrectomy in obese patients with gastric cancer. J Buon 22:410–416

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