Trunk Fat Volume Can Be a Predictor of Short-Term Surgical Outcomes After Gastrectomy: A Retrospective Cohort Study

Shinichiro Shiomi
University of Tokyo

Tetsuro Toriumi
University of Tokyo

Koichi Yagi
University of Tokyo

Raito Asaoka
University of Tokyo

Yasuhiro Okumura
University of Tokyo

Kotaro Wakamatsu
University of Tokyo

Susumu Aikou
University of Tokyo

Hiroharu Yamashita
University of Tokyo

Sachiyo Nomura
University of Tokyo

Yasuyuki Seto (seto-tky@umin.ac.jp)
University of Tokyo

Research Article

Keywords: gastrectomy, obesity, intra-abdominal fat, postoperative complication

DOI: https://doi.org/10.21203/rs.3.rs-156566/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License
Abstract

Background

Obesity can affect postoperative outcomes of gastrectomy. Visceral fat area is superior to body mass index in predicting postoperative complications. However, visceral fat area measurement is time-consuming and is not optimum for clinical use. Meanwhile, trunk fat volume (TFV) can be easily measured via bioelectrical impedance analysis. Hence, this current study aimed to determine the association of trunk fat volume in predicting the occurrence of complications after gastrectomy.

Methods

We retrospectively reviewed patients who underwent curative gastrectomy for gastric cancer between November 2016 and November 2019. The trunk fat volume-to-the ideal amount (%TFV) ratio was obtained using InBody 770 before surgery. The patients were classified into the obese and nonobese groups according to %TFV (TFV-H group, ≥ 150 %; TFV-L group, < 150 %) and body mass index (BMI-H group, ≥ 25 kg/m²; BMI-L group, < 25 kg/m²). We compared the short-term postoperative outcomes (e.g., operative time, blood loss volume, number of resected lymph nodes, and duration of hospital stay) between the obese and nonobese patients. Risk factors for complications were assessed using logistic regression analysis.

Results

In total, 232 patients were included in this study. The TFV-H and BMI-H groups had a significantly longer operative time than the TFV-L (p = 0.022) and BMI-L groups (p = 0.006). Moreover, the TFV-H group had a significantly higher complication rate (p = 0.004) and a lower number of resected lymph nodes (p < 0.001) than the TFV-L group. In univariate analysis, %TFV ≥ 150, total or proximal gastrectomy, and open gastrectomy were found to be potentially associated with higher complication rates with p values < 0.1. Meanwhile, multivariate analysis revealed that %TFV ≥ 150 (OR: 2.73; 95%CI: 1.37–5.46; p = 0.005) and total or proximal gastrectomy (OR: 3.57; 95%CI: 1.79–7.12; p < 0.001) were independently correlated with postoperative morbidity.

Conclusions

%TFV independently affected postoperative complications. Hence, it may be a useful parameter for the evaluation of obesity and a predictor of short-term surgical outcomes after gastrectomy.

Background
Gastric cancer is the fourth most common cancer worldwide [1], and gastrectomy has been considered essential for its curative treatment. Postoperative complications adversely affect the long-term survival of patients with gastric cancer. Therefore, the risk factors of postoperative complications should be identified and postoperative complication rates reduced [2].

Excessive intra-abdominal fat tissue poses difficulties during surgery. Obesity is associated with short-term surgical outcomes, including complications after gastrectomy [3, 4], and is evaluated using several methods. Body mass index (BMI) is the most widely used tool for obesity assessment because it is easy to use, and usually, individuals with BMI > 25 kg/m² are considered obese in Japan [5]. Visceral fat area (VFA), which refers to intra-abdominal fat, is another index used to evaluate obesity. It is measured at the level of the umbilicus on single-slice computed tomography (CT) scan. Recently, several studies have reported that BMI cannot accurately reflect perioperative outcomes, and VFA is more accurate in predicting short-term postoperative outcomes [3, 4, 6–8]. However, measuring VFA is time-consuming, and evaluating each patient for VFA is burdensome for mostly busy clinicians.

Trunk fat volume (TFV), which reflects the fat mass of the body trunk, is another parameter that can be used to evaluate obesity. TFV can be easily measured using bioelectrical impedance analysis (BIA). BIA is a simple method to measure body compositions, including fat mass; this method is increasingly used worldwide because it is non-invasive, cost-effective, and simple to use [9]. Recent studies have shown that body composition measurements can help in evaluating nutrition status after surgery and in predicting surgical outcomes [10]. However, to the best of our knowledge, the relationship between TFV and postoperative outcomes has not been reported in previous studies. Hence, this study aimed to identify the efficacy of TFV in predicting outcomes after gastrectomy.

**Methods**

**Patients**

This was a single institutional retrospective cohort study conducted at the University of Tokyo Hospital. In total, 278 patients underwent gastrectomy for gastric cancer from November 2016 to November 2019. In our institution, preoperative examinations consist of upper gastrointestinal endoscopy with biopsies, CT scans, and laboratory tests. Besides, we routinely measure body composition using BIA preoperatively with written consent. Clinical cancer stage was determined according to the Japanese Classification of Gastric Carcinoma (15th edition) [11]. Treatment strategies were mainly based on Japanese Gastric Cancer treatment guidelines (4th and 5th edition) [12, 13]. Patients who could not undergo curative resection and those who received neoadjuvant chemotherapy were excluded. Study procedures were carried out in accordance with the Declaration of Helsinki. The ethics committee of the faculty of medicine at the University of Tokyo approved this study and waived the requirement for informed consent to this study as anonymized data were used (approval number: 3962).

**Definition of obesity assessed using BMI and TFV**
The patients were divided into obese and nonobese groups according to both BMI and TFV. Patients with BMI $\geq 25 \text{ kg/m}^2$ were classified under the BMI high (BMI-H) group and patients with BMI $< 25 \text{ kg/m}^2$ under the BMI low (BMI-L) group. We obtained the TFV and body fat mass (BFM) using BIA with InBody 770® (InBody Co., Ltd., Seoul, Korea) one or two days before surgery. This tool uses direct segmental multifrequency BIA. It introduces alternating currents into the body and measures impedance, which comprises resistance and reactance. Moreover, it uses eight electrodes and individually measures the impedance of each body part (e.g., the trunk, right and left arms, and right and left legs) at six different frequencies to evaluate body compositions [14, 15]. The accuracy of BIA has been evaluated in several studies, and it is correlated with standard body composition parameters obtained using different modalities, such as dual-energy X-ray absorptiometry, CT scan, and air displacement plethysmography [9, 14, 16, 17]. We classified patients according to TFV in the following manner. First, we calculated the TFV-to-BFM ratios. The median in each sex was defined as an ideal distribution of trunk body fat (% in men and % in women, respectively). Second, we calculated the ideal BFM multiplying the ideal body weight (height$^2 \times 22$ for men and height$^2 \times 21$ for women [18]) by the ideal percentage of body fat (15% for men and 23% for women [19]). Third, we defined the product by multiplying these two components as the ideal TFV. Finally, we calculated the TFV-to-the ideal TFV (%TFV) ratio of each patient. The median TFV-to-BFM ratio of men and women were 0.50 and 0.47, respectively. Following these calculations, we derived the following equations according to sex.

For men:

$$\text{Men : } %\text{TFV} = \frac{\text{TFV}}{(\text{height}^2 \times 21) \times 0.15 \times 0.50}$$

For women:

$$\text{Women : } %\text{TFV} = \frac{\text{TFV}}{(\text{height}^2 \times 22) \times 0.23 \times 0.47}$$

We defined obesity using a %TFV threshold of 150%, and patients with %TFV $\geq 150\%$ and %TFV $< 150\%$ were classified under the high TFV (TFV-H) and low TFV (TFV-L) groups, respectively.

**Surgical procedures**

We performed distal gastrectomy, total gastrectomy, proximal gastrectomy, or pylorus-preserving gastrectomy with radical lymphadenectomy as per the treatment guidelines of the Japanese Gastric Cancer Association [12, 13]. Laparoscopic gastrectomy was used in the preoperative diagnosis of T1-2N0 tumors. Patients who underwent distal or total gastrectomy had Roux-en-Y reconstruction. Esophagogastric anastomosis, jejunal interposition anastomosis, or side overlap esophagogastrostomy that is based on the study of Yamashita [20] was conducted for the reconstruction of proximal gastrectomy. A gastro-gastro anastomosis was established for the reconstruction of pylorus-preserving gastrectomy.

**Evaluation of short-term postoperative outcomes**

We have compared the short-term postoperative outcomes, including operative time, volume of blood loss, number of resected lymph nodes, and duration of hospital stay between the obese and nonobese...
patients. Moreover, the risk factors for complications were assessed. The Clavien–Dindo classification system [21] was used to assess postoperative morbidity. Complications greater than grade 2 were considered as clinically significant and those greater than grade 3a as severe.

**Statistical analysis**

The Pearson's chi-square test or Fisher’s exact test was used in the univariate analysis. Meanwhile, logistic regression was utilized in the multivariate analysis, which was performed using factors with p values < 0.1 in the univariate analysis. The student's t-test or Wilcoxon signed-rank test was utilized for continuous value. P values < 0.05 were considered statistically significant. JMP® 15 (SAS Institute Inc., Cary, NC, the USA) was utilized for all statistical analyses.

**Results**

**Characteristics of the patients**

Of 278 patients, 14 who underwent R1 or R2 resection, and 32 who received neoadjuvant chemotherapy were excluded. Finally, 232 patients were included in our study. The characteristics of the patients are shown in Table 1. In both criteria, obese patients underwent significantly more open gastrectomy and had severer comorbidities. Besides, the TFV-H group had a higher proportion of male patients, early-stage disease, and D1 + dissection, which were not evident in the BMI group. Other properties were comparable between the two groups. A significant correlation was observed between %TFV and BMI (r = 0.784, p < 0.001) (Fig. 1).
Table 1
Characteristics of the patients

|                | TFV-H group (n = 120) | TFV-L group (n = 112) | p value | BMI-H group (n = 50) | BMI-L group (n = 182) | p value |
|----------------|-----------------------|-----------------------|---------|----------------------|-----------------------|---------|
| Sex            | Male                  | 92 (76.7%)            | 67 (59.8%) | 0.006               | 35 (70.0%)            | 124 (68.1%) | 0.865 |
|                | Female                | 28 (23.3%)            | 45 (40.2%) |                     | 15 (30.0%)            | 58 (31.9%)  |       |
| Age (years), (mean ± SD) | 70.1 ± 10.0       | 68.9 ± 12.8            | 0.411  | 66.8 ± 11.8          | 70.3 ± 11.3            | 0.056   |
| %TFV (%), (mean ± SD) | 219.7 ± 54.9         | 94.0 ± 38.5            | < 0.001 | 289.1 ± 68.0         | 152.1 ± 69.1           | < 0.001 |
| BMI (kg/m²), (mean ± SD) | 24.7 ± 3.2          | 20.3 ± 2.6             | < 0.001 | 27.4 ± 3.1           | 21.2 ± 2.4             | < 0.001 |
| Clinical stage | I                     | 102 (85.0%)            | 68 (60.7%) | < 0.001             | 42 (84.0%)            | 123 (70.3%) | 0.204 |
|                | II A                  | 0 (0.0%)               | 7 (6.3%)   |                     | 0 (0.0%)              | 7 (3.9%)    |       |
|                | II B                  | 12 (10.0%)             | 25 (22.3%) |                     | 5 (10.0%)             | 32 (17.6%)  |       |
|                | III                   | 6 (5.0%)               | 12 (10.7%) |                     | 4 (8.0%)              | 15 (8.2%)   |       |
| Open gastrectomy |                       | 24 (20.0%)             | 45 (40.2%) | < 0.001             | 7 (14.0%)             | 62 (34.1%)  | 0.005 |
| Total/proximal gastrectomy |               | 33 (27.5%)             | 22 (19.6%) | 0.160               | 10 (20.0%)            | 45 (24.7%)  | 0.487 |
| LD             | ≤D1+                  | 83 (69.2%)             | 59 (52.7%) | 0.010               | 34 (68.1%)            | 108 (59.3%) | 0.327 |
|                | ≥D2                   | 37 (30.8%)             | 53 (47.3%) |                     | 16 (32.0%)            | 74 (40.7%)  |       |
| CCI            | ≥ 3                   | 12 (10.0%)             | 4 (3.6%)   | 0.054               | 7 (14.0%)             | 9 (5.0%)    | 0.025 |
|                | ≤ 2                   | 108 (90.0%)            | 108 (96.4%)|                     | 43 (86.0%)            | 173 (95.0%) |       |
| Operative history |                     | 28 (23.3%)             | 35 (31.3%) | 0.176               | 9 (18.0%)             | 54 (29.7%)  | 0.111 |

TFV: trunk fat volume; BMI: body mass index; LD: lymph node dissection; CCI: Charlson comorbidity index

Correlation between obesity and short-term outcomes

Table 2 shows the short-term outcomes between the obese and nonobese groups. The TFV-H group required a significantly longer operative time than the TFV-L group (305.1 ± 67.5 min vs 284.9 ± 66.0 min, p = 0.022). Moreover, the TFV-H group had a lower number of resected lymph nodes (33 [IQR 25 to 43] vs
42 [IQR 32 to 52.75, p < 0.001] than the TFV-L group. Although the BMI-H group had a significantly longer operative time than the BMI-L group (321.9 ± 78.5min vs 288.1 ± 62.2 min, p = 0.006), the number of resected lymph nodes did not differ significantly between the two groups. The volume of blood loss and duration of hospital stay were comparable between the two groups in both criteria.

Table 2
Short-term surgical outcomes between the obese and nonobese patients

|                    | TFV-H group (n = 120) | TFV-L group (n = 112) | p value | BMI-H group (n = 50) | BMI-L group (n = 182) | p value |
|--------------------|-----------------------|-----------------------|---------|----------------------|-----------------------|---------|
| Operative time (min), (mean ± SD) | 305.1 ± 67.5          | 284.9 ± 66.0          | 0.022   | 321.9 ± 78.5         | 288.1 ± 62.2          | 0.006   |
| Volume of blood loss¹ (mL), (median [IQR]) | 100 (20–218.75)       | 85 (10–216.25)        | 0.279   | 117.5 (27.5–236.3)   | 75 (10–207.5)         | 0.148   |
| Number of resected LN¹ (median [IQR])   | 33 (25–43)            | 42 (32–52.75)         | < 0.001 | 34 (26–43)           | 38 (29–48)            | 0.112   |
| Duration of hospital stay¹ (day), (median [IQR]) | 9 (8–12)             | 10 (9–13)             | 0.135   | 10 (9–13)            | 10 (9–12)             | 0.358   |

¹ Variables are indicated by median.

SD: standard deviation; IQR: interquartile range; LN: lymph node

Risk factors of postoperative complications

We evaluated the risk factors of postoperative complications. The overall complication rate was 24.6 %. Table 3 shows the results of the univariate and multivariate analyses. In the univariate analysis, %TFV ≥ 150 (32.5 % vs 16.1 %, p = 0.004), total or proximal gastrectomy (47.3 % vs 17.5 %, p < 0.001) and open surgery (31.9% vs 21.5%, p = 0.092) were found to be factors potentially associated with higher complication rates with p values < 0.1. The multivariate analysis revealed that %TFV ≥ 150 (odds ratio [OR]: 2.73; 95% confidence interval [CI]: 1.37–5.46; p = 0.005) and total or proximal gastrectomy (OR: 3.57; 95% CI: 1.79–7.12; p < 0.001) were independently associated with postoperative morbidity.
### Table 3
Risk factors of postoperative complications

|                          | Complications (+) (n = 57) | Complications (-) (n = 175) | Univariate analysis | Multivariate analysis |
|--------------------------|-----------------------------|-----------------------------|---------------------|----------------------|
|                          |                             |                             |                     | Odds ratio (95% CI)   |
|                          |                             |                             |                     | p value              |
| **Sex**                  |                             |                             |                     |                      |
| Male                     | 43 (27.0%)                  | 116 (73.0%)                 | 0.196               |                      |
| Female                   | 14 (19.2%)                  | 59 (80.8%)                  |                     |                      |
| **Age (years)**          |                             |                             |                     |                      |
| ≥65 (172)                | 45 (26.1%)                  | 127 (73.9%)                 | 0.340               |                      |
| <65 (60)                 | 12 (20.0%)                  | 48 (80.0%)                  |                      |                      |
| **BMI (kg/m²)**          |                             |                             |                     |                      |
| ≥25 (50)                 | 13 (26.0%)                  | 37 (74.0%)                  | 0.791               |                      |
| <25 (182)                | 44 (24.2%)                  | 141 (77.5%)                 |                      |                      |
| **%TFV**                 |                             |                             |                     |                      |
| ≥150 (120)               | 39 (32.5%)                  | 81 (67.5%)                  | 0.004               | 2.73 (1.37–5.46)     |
| <150 (112)               | 18 (16.1%)                  | 94 (83.9%)                  |                      | 0.005                |
| **cStage**               |                             |                             |                     |                      |
| IIA/IIB/III (62)         | 39 (22.9%)                  | 131 (77.1%)                 | 0.340               |                      |
| **Surgery**              |                             |                             |                     |                      |
| OP (69)                  | 22 (31.9%)                  | 47 (68.1%)                  | 0.092               | 1.73 (0.84–3.57)     |
| LAP (163)                | 35 (21.5%)                  | 128 (78.5%)                 |                      | 0.137                |
| **Procedure**            |                             |                             |                     |                      |
| TG/PG (55)               | 26 (47.3%)                  | 29 (52.7%)                  | <0.001              | 3.57 (1.79–7.12)     |
| DG/PPG (177)             | 31 (17.5%)                  | 146 (82.5%)                 |                      | P < 0.001            |
| **LD**                   | ≤D1+ (142)                  | 33 (23.2%)                  |                      | 0.555                |
|                         | 109 (76.8%)                 |                             |                      |                      |

**TFV**: trunk fat volume; **BMI**: body mass index; **LD**: lymph node dissection; **CCI**: Charlson comorbidity index; **OP**: open; **LAP**: laparoscopic; **TG**: total gastrectomy; **PPG**: pylorus-preserving gastrectomy; **PG**: proximal gastrectomy
The details of postoperative complications are presented in Table 4. Severe complications were also more common in the TFV-H group than in the TFV-L group although the difference was not significant (10.8% vs 4.5%, p = 0.070). In terms of complications, anastomotic leakage, pancreatic fistula, and pneumonia were more common in the TFV-H group than in the TFV-L group. However, only the occurrence of pancreatic fistula was statistically significant (5.8% vs 0.9%, p = 0.039). Meanwhile, the rate of each complication in the BMI-H group was comparable with that in the BMI-L group.
Table 4
Details of postoperative complications after gastrectomy

| Complications                          | TFV-H group (n = 120) | TFV-L group (n = 112) | p value | BMI-H group (n = 50) | BMI-L group (n = 182) | p value |
|----------------------------------------|-----------------------|-----------------------|---------|----------------------|-----------------------|---------|
| (Clavien–Dindo classification score ≥ 2) | 39 (32.5%)            | 18 (16.1%)            | 0.004   | 13 (26.0%)           | 44 (24.1%)            | 0.791   |
| Severe complications                   | 13 (10.8%)            | 5 (4.5%)              | 0.070   | 4 (8.0%)             | 14 (7.7%)             | 0.943   |
| (Clavien–Dindo classification score ≥ 3a) |                      |                       |         |                      |                       |         |
| Pneumonia                              | 6 (5.0%)              | 1 (0.9%)              | 0.068   | 3 (6.0%)             | 4 (2.2%)              | 0.164   |
| Anastomotic leakage                    | 7 (5.8%)              | 3 (2.7%)              | 0.237   | 2 (4.0%)             | 8 (4.4%)              | 0.902   |
| Pancreatic fistula                     | 7 (5.8%)              | 1 (0.9%)              | 0.039   | 3 (6.0%)             | 5 (2.8%)              | 0.264   |
| Incisional SSI                         | 3 (2.5%)              | 6 (4.5%)              | 0.413   | 1 (2.0%)             | 7 (3.9%)              | 0.526   |
| Anastomotic stenosis                   | 3 (2.5%)              | 0 (0.0%)              | 0.092   | 0 (0.0%)             | 3 (1.7%)              | 0.361   |
| Bleeding                               | 1 (0.8%)              | 1 (0.9%)              | 0.961   | 0 (0.0%)             | 2 (1.1%)              | 0.457   |
| Bowel obstruction                      | 2 (1.7%)              | 0 (0.0%)              | 0.170   | 1 (2.0%)             | 1 (0.6%)              | 0.326   |
| FUO                                    | 2 (1.7%)              | 1 (0.9%)              | 0.602   | 1 (2.0%)             | 2 (1.1%)              | 0.617   |
| Delayed gastric ejection               | 3 (2.5%)              | 3 (2.7%)              | 0.932   | 0 (0.0%)             | 6 (3.3%)              | 0.193   |
| Others                                 | 8 (6.7%)              | 3 (2.7%)              | 0.153   | 2 (4.0%)             | 9 (5.0%)              | 0.781   |

TFV: trunk fat volume; BMI: body mass index; SSI: surgical site infection; FUO: fever of unknown origin

Discussion

This study revealed that obesity evaluated using %TFV and total or proximal gastrectomy was independently associated with postoperative complications. The %TFV may be a better parameter than BMI for the evaluation of the difficulty of gastrectomy and prediction of postoperative complications such as pancreatic fistula. These findings indicate that TFV may help to determine the necessity of drain management or frequent following up of blood tests and X-ray examination in the postoperative period and enable the early detection of each complication.

Excessive visceral fat poses difficulties during surgery, and obesity is associated with unfavorable surgical outcomes, including longer operative time, higher postoperative complication rates, lower number of resected lymph nodes, and prolonged hospital stay [4, 8, 22–24]. BMI is the most commonly
used parameter for the evaluation of obesity. Several studies have shown that a higher BMI is associated with worse surgical outcomes [24, 25]. However, other studies revealed that BMI may not be a predictive factor of postoperative outcomes [3, 6–8]. This finding might be attributed to the fact that BMI is easy to assess. That is, it is calculated using height and weight. However, it does not directly reflect intra-abdominal fat volume [8, 26]. Whether obesity evaluated using BMI can be used to accurately predict operative risks remains controversial. Hence, VFA is used for the evaluation of obesity. It is measured on a cross-sectional CT scan and may directly reflect intra-abdominal fat. Several studies have shown that VFA is more accurate than BMI in predicting postoperative complications [3, 8, 27, 28]. Notably, VFA measurement is time-consuming and might not be suitable for clinical use. Thus, a simpler parameter is preferred in daily use. Besides, VFA is not always ideal as it is measured only on a one-slice CT scan.

In this study, we used %TFV obtained using BIA, which is increasingly used in recent studies [14, 15]. As expected, %TFV was found to be strongly correlated with BMI. However, theoretically, %TFV can only evaluate trunk fat mass, and BMI can assess whole body elements, including muscles and extremities. Therefore, the use of %TFV may be more suitable in predicting any difficulties encountered during surgery. Our results were consistent with this theory. Compared with VFA, %TFV cannot be utilized to distinguish subcutaneous fat from visceral fat, which is considered a disadvantage. However, its simplicity counteracts this detriment in daily clinical practice given that it can predict postoperative outcomes.

Preoperative exercise intervention has been reported to be beneficial, especially in obese patients [29]. When we conduct preoperative interventions, there is a concern about tumor progression, particularly in patients with advanced cancer. However, preoperative wait time up to 90 days has been reported not to affect survival even in cStage I/II gastric cancer patients [30]. Hence, obese patients might have the benefits of fewer complications by preoperative exercise. In this study, %TFV ≥ 150 was an independent risk factor for postoperative complications, and this population might be a good candidate for preoperative intervention, although further study is required for a firm conclusion.

In this study, pancreatic fistula and anastomotic leakage were more common in the TFV-H group than in the TFV-L group and this result was in accordance with that of a previous study [31]. Previous studies have reported the possible causes of poor outcomes among obese patients. High visceral fat may be associated with the misrecognition of anatomy and technical difficulty in achieving a good view of the surgical field. Occasionally, this causes excessive counter traction and over-compression in the pancreas during lymph node dissection [8, 25–28, 31]. These factors result in tissue trauma, a higher volume of blood loss, prolonged operative time, and pancreatic fistula. Excessive tension on the anastomosis site due to thick and heavy mesenteric fat may be a risk factor for anastomotic leakage [22, 27, 32]. In this study, pneumonia was more frequently observed in the TFV-H group, which was consistent with the result of a previous study [33]. Obesity is associated with decreased total lung capacity attributed to high intra-abdominal pressure or excessive subcutaneous fat around the thorax [34]. Difficulty in clearing airway secretions and delayed ambulation may be contributory factors for pulmonary complications, such as atelectasis and pneumonia. However, the number of patients who had each complication was extremely
low in this study, and only the occurrence of pancreatic fistula showed a significant difference. Thus, further investigations should be conducted to accurately identify the occurrence of complications after surgery.

The current study had several limitations. First, this was a retrospective, single-center study. Hence, it was susceptible to selection and cognitive bias. Hence, a larger multicenter study should be performed to obtain a firm conclusion. Second, different surgeons performed gastrectomy during the study period. Hence, the differences in the ability of the surgeons might have affected the results. Although skilled surgeons supervised trainee surgeons who performed gastrectomy, the effect might still be significant. Third, the ideal TFV was derived from the median TFV-to-BFM ratio, which was obtained from data in this study because no previous studies have discussed the ideal distribution of body fat. However, this value should be determined based on the general population. Finally, TFV obtained using BIA represents both subcutaneous and visceral fat. Fat mass is more likely to accumulate in the visceral area in men than in women [6]. The surgical procedure is mainly affected by visceral fat [26], and whether the use of a similar %TFV threshold in both men and women is acceptable has not been confirmed. Thus, further studies should be conducted to identify the ideal threshold for each sex.

Conclusions

%TFV is superior to BMI as a predictive factor for short-term outcomes after gastrectomy. Obesity evaluated using %TFV is an independent risk factor of postoperative complications. Moreover, %TFV may be a useful parameter in the evaluation of obesity and a predictor of postoperative short-term outcomes.

List Of Abbreviations

| Abbreviation | Description                      |
|--------------|----------------------------------|
| BMI          | body mass index                  |
| VFA          | visceral fat area                |
| CT           | computed tomography              |
| TFV          | trunk fat volume                 |
| BIA          | bioelectrical impedance analysis |
| BFM          | body fat mass                    |

Declarations

Ethics approval and consent to participate: This study was conducted in accordance with the Declaration of Helsinki. The ethics committee of the faculty of medicine at the University of Tokyo approved this study and waived the requirement for informed consent to this study as anonymized data were used. All methods were carried out appropriately based on Japanese guidelines of gastric cancer.
Consent for publication: Not applicable.

Availability of data and materials: All data generated or analysed during this study are included in this published article.

Competing interests: The authors declare that they have no competing interests.

Funding: None.

Author’s contributions: Shinichiro Shiomi and Tetsuro Toriumi equally contributed to the conception and design of the research; Shinichiro Shiomi, Tetsuro Toriumi and Raito Asaoka contributed to the acquisition of the data; Shinichiro Shiomi and Tetsuro Toriumi contributed the analysis and interpretation of the data; Shinichiro Shiomi and Tetsuro Toriumi drafted the manuscript. All authors critically revised the manuscript, agree to be fully accountable for ensuring the integrity and accuracy of the work, and read and approved the final manuscript. Yasuyuki Seto finally approved the publication of this research.

Acknowledgements: We would like to thank past and present members of our laboratory for accumulating data for analysis from the early stage of this work.

References

1. Torre LA, Bray F, Siegel RL, Ferlay J, Lortet-Tieulent J, Jemal A. Global cancer statistics, 2012. CA Cancer J Clin 2015;65:87–108
2. Eichelmann AK, Saidi M, Lindner K, Lenschow C, Palmes D, Pascher A, Hummel R. Impact of preoperative risk factors on outcome after gastrectomy. World J Surg Oncol 2020;18:17
3. Yang SJ, Li HR, Zhang WH, Liu K, Zhang DY, Sun LF, Chen XL, Zhao LY, Yang K, Chen ZX, Zhou ZG. Visceral fat area (VFA) Superior to BMI for predicting postoperative complications after radical gastrectomy: a prospective cohort study. J Gastrointest Surg 2020;24:1298–306
4. Ri M, Aikou S, Seto Y. Obesity as a surgical risk factor. Ann Gastroenterol Surg 2018;2:13–21
5. The Examination Committee of Criteria for “Obesity Disease” in Japan, Japan Society for the Study of Obesity. New criteria for “obesity disease” in Japan. Circ J 2002;66: 987–92
6. Miyaki A, Imamura K, Kobayashi R, Takami M, Matsumoto J. Impact of visceral fat on laparoscopy-assisted distal gastrectomy. Surgeon 2013;11:76–81
7. Shin HJ, Son SY, Cui LH, Byun C, Hur H, Lee JH, Kim YC, Han SU, Cho YK. Is there any role of visceral fat area for predicting difficulty of laparoscopic gastrectomy for gastric cancer? J Gastric Cancer. 2015;15:151–58
8. Liu Y, Guo D, Niu Z, Wang Y, Fu G, Zhou Y, Xue Q, Jin X, Gong Z. Prediction of the risk of laparoscopy-assisted gastrectomy by comparing visceral fat area and body mass index. Gastroenterol Res Pract. 2018
9. Sullivan PA, Still CD, Jamieson ST, Dixon CB, Irving BA, Andreacci JL. Evaluation of multi-frequency bioelectrical impedance analysis for the assessment of body composition in individuals with obesity. Obes Sci Pract 2019;5:141–47

10. Mikamori M, Miyamoto A, Asaoka T, Maeda S, Hama N, Yamamoto K, Hirao M, Ikeda M, Sekimoto M, Doki Y, Mori M. Postoperative changes in body composition after pancreaticoduodenectomy using multifrequency bioelectrical impedance analysis. J Gastrointest Surg 2016;20:611–18

11. Japanese Gastric Cancer Association. Japanese Classification of Gastric Carcinoma, the 15th Edition (in Japanese). Tokyo: Kanehara; 2017

12. Japanese Gastric Cancer Association. Japanese gastric cancer treatment guidelines 2018 (5th edition). Gastric Cancer 2020

13. Japanese Gastric Cancer Association. Japanese gastric cancer treatment guidelines 2014 (4th edition). Gastric Cancer 2017

14. Lee SY, Ahn S, Kim YJ, Ji MJ, Kim KM, Choi SH, Jang HC, Lim S. Comparison between dual-energy x-ray absorptiometry and bioelectrical impedance analyses for accuracy in measuring whole body muscle mass and appendicular skeletal muscle mass. Nutrients 2018;10

15. Kyle UG, Bosaeus I, De Lorenzo AD, Deurenberg P, Elia M, Gómez JM, Heitmann BL, Kent-Smith L, Melchior JC, Pirlich M, Scharfetter H. Bioelectrical impedance analysis–part I: review of principles and methods. Clin Nutr 2004;23:1226–43

16. Kim E, Kim S, Won D, Choi M, Lee I, et al. Multifrequency bioelectrical impedance analysis compared with computed tomography for assessment of skeletal muscle mass in primary colorectal malignancy: a predictor of short-term outcome after surgery. Clin Nutr. 2020;35:664-74

17. Ramírez-Vélez R, Tordecilla-Sanders A, Correa-Bautista JE, González-Ruiz K, González-Jiménez E, Triana-Reina HR, García-Hermoso A, Schmidt-RioValle J. Validation of multi-frequency bioelectrical impedance analysis versus dual-energy X-ray absorptiometry to measure body fat percentage in overweight/obese Colombian adults. Am J Hum Biol 2018;30

18. Simopoulos AP. Characteristics of obesity: an overview. Ann N Y Acad Sci. 1987;499:4-13

19. Lohman TG. Advanced in body composition assessment - Current issues in exercise science series. Champaign-IL: Human Kinetics, 1992, pp 80

20. Yamashita Y, Yamamoto A, Tamamori Y, Yoshii M, Nishiguchi Y. Side overlap esophagogastrostomy to prevent reflux after proximal gastrectomy. Gastric Cancer 2017;20:728–35

21. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg 2004;240:205–13

22. Sugisawa N, Tokunaga M, Tanizawa Y, Bando E, Kawamura T, Terashima M. Intra-abdominal infectious complications following gastrectomy in patients with excessive visceral fat. Gastric Cancer 2012;15:206–12

23. Park DJ, Lee HJ, Kim HH, Yang HK, Lee KU, Choe KJ. Predictors of operative morbidity and mortality in gastric cancer surgery. Br J Surg 2005;92:1099–102
24. Dhar DK, Kubota H, Tachibana M, Kotoh T, Tabara H, Masunaga R, Kohno H, Nagasue N. Body mass index determines the success of lymph node dissection and predicts the outcome of gastric carcinoma patients. Oncology 2000;59:18–23

25. Chen K, Pan Y, Zhai ST, Cai JQ, Chen QL, Chen DW, et al. Laparoscopic gastrectomy in obese gastric cancer patients: a comparative study with non-obese patients and evaluation of difference in laparoscopic methods. BMC Gastroenterol. 2017;17:78

26. Tokunaga M, Hiki N, Fukunaga T, Ogura T, Miyata S, Yamaguchi T. Effect of individual fat areas on early surgical outcomes after open gastrectomy for gastric cancer. Br J Surg. 2009;96:496–500

27. Takeuchi M, Ishii K, Seki H, Yasui N, Sakata M, Shimada A, Matsumoto H. Excessive visceral fat area as a risk factor for early postoperative complications of total gastrectomy for gastric cancer: a retrospective cohort study. BMC Surg 2016;16:54

28. Okada K, Nishigori T, Obama K, Tsunoda S, Hida K, Hisamori S, Sakai Y. The incidence of postoperative complications after gastrectomy increases in proportion to the amount of preoperative visceral fat. J Oncol 2019

29. Cho H, Yoshikawa T, Oba MS, Hirabayashi N, Shirai J, Aoyama T, et al. Matched pair analysis to examine the effects of a planned preoperative exercise program in early gastric cancer patients with metabolic syndrome to reduce operative risk: the Adjuvant Exercise for General Elective Surgery (AEGES) study group. Ann Surg Oncol. 2014;21(6):2044-50

30. Furukawa K, Irino T, Makuuchi R, Koseki Y, Nakamura K, Waki Y, et al. Impact of preoperative wait time on survival in patients with clinical stage II/III gastric cancer. Gastric Cancer. 2019;22(4):864-72

31. Wu XS, Wu WG, Li ML, Yang JH, Ding QC, Zhang L, et al. Impact of being overweight on the surgical outcomes of patients with gastric cancer: a meta-analysis. World J Gastroenterol. 2013;19:4596–606

32. Kang KC, Cho GS, Han SU, Kim W, Kim HH, Kim MC, et al. Comparison of Billroth I and Billroth II reconstructions after laparoscopy-assisted distal gastrectomy: a retrospective analysis of large-scale multicenter results from Korea. Surg Endosc. 2011;25:1953–61

33. Kunisaki C, Miyata H, Konno H, et al. Modeling preoperative risk factors for potentially lethal morbidities using a nationwide Japanese web-based database of patients undergoing distal gastrectomy for gastric cancer. Gastric Cancer 2017;20:496–507

34. Watson RA, Pride NB, Thomas EL, Ind PW, Bell JD. Relation between trunk fat volume and reduction of total lung capacity in obese men. J Appl Physiol 2012;112:118–26