BMJ Open

Comparison of visceral fat area measured by CT and bioelectrical impedance analysis in Chinese patients with gastric cancer: a cross-sectional study

Bo Gao,[1] Yu Liu,[2] Chao Ding,[3] Shunli Liu,[4] Xiaotian Chen ,[1] Xiaojie Bian[5]

To cite: Gao B, Liu Y, Ding C, *et al*. Comparison of visceral fat area measured by CT and bioelectrical impedance analysis in Chinese patients with gastric cancer: a cross-sectional study. *BMJ Open* 2020;**10**:e036335. doi:10.1136/bmjopen-2019-036335

► Prepublication history and additional material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2019-036335).

XC and XB contributed equally.

BG and YL are joint first authors.

Received 11 December 2019
Revised 08 April 2020
Accepted 17 June 2020

For numbered affiliations see end of article.

Correspondence to
Dr Xiaotian Chen; xttchen@163.com and Dr Xiaojie Bian; xiaojiebian@hotmail.com

ABSTRACT

Objectives Bioelectrical impedance analysis (BIA) is a simple and inexpensive method to estimate body composition. However, the accuracy of BIA is unknown. We aimed to assess the accuracy of BIA in estimating visceral fat area (VFA) in patients with gastric cancer.

Study design This was a cross-sectional study comparing the accuracy of BIA in estimating VFA with the gold standard method measured by CT. VFA was measured in enrolled patients both by CT and BIA. VFA by CT at umbilical level ≥100 cm^2 was considered as visceral obesity. Reliability between the two methods was assessed by intraclass correlation coefficient (ICC) and consistency was assessed by Bland-Altman method (95% limits of agreement). The area under the receiver operating characteristic curve (AUROC) was used to assess the performance of BIA in diagnosing visceral obesity.

Setting The study was conducted in China.

Participants From 1 January 2017 to 1 December 2018, a total of 157 patients diagnosed with gastric cancer were enrolled.

Results Overall, VFA by CT and BIA in patients was 84.39±46.43 cm^2 and 71.94±22.44 cm^2, respectively. VFA estimated by BIA was positively correlated with VFA measured by CT using Pearson's test (r=0.650, p<0.001). Overall, ICC for the two methods was 0.675. The mean bias between the two measurements was 12.45±36.13 cm^2. The 95% limits of agreement ranged from −58.36 cm^2 to 83.26 cm^2. The cut-off value for diagnosing visceral obesity by BIA was 81 cm^2 (AUROC: 0.822, p<0.001, 95% CI 0.758 to 0.887).

Conclusions VFA measured by BIA showed satisfactory reliability with that measured by CT. However, the absolute values of the two methods were not interchangeable. The cut-off value for VFA by BIA in diagnosing visceral obesity was 81 cm^2 for patients with gastric cancer in the Chinese population.

Strengths and limitations of this study

- ► To our knowledge, this is the first study to assess the accuracy of bioelectrical impedance analysis (BIA) in estimating visceral fat area in patients with gastric cancer in China.
- ► The built-in equations of the BIA instrument will be modified when installed in different regions worldwide, so the single-centre nature of the study, consisting of Chinese population only, made the generalisability of the study limited to the Asian population.
- ► The study used the InBody 720 as BIA instrument, which is a relatively older product than the InBody 770.
- ► The estimation of visceral fat area by BIA was compared with measurement using the gold standard method of CT scan, improving the reliability of the results.
- ► Although the sample size of the study was small, access of data for analyses was strict and could compensate for the bias in some extent.

INTRODUCTION

Gastric cancer is a common type of malignancy worldwide with a high mortality rate.[1] The prevalence of gastric cancer is comparatively higher in Asian than in Western countries.[2] Previous studies suggested that alterations in body composition could affect the outcomes of multiple malignancies.[3–6] The negative effect of sarcopaenia on the prognosis of cancer has reached a consensus.[4–6] In addition, the presence of visceral obesity could cause difficulties in surgical operations, increase postoperative infection rate and reduce the overall survival rate in gastric cancer.[3 7] Go *et al* [7] demonstrated that the presence of visceral obesity in subjects with gastric cancer who had undergone laparoscopy-assisted distal gastrectomy significantly affected the number of retrieved lymph nodes. In addition, visceral fat tissues contain more large adipocytes and androgen receptors than subcutaneous fat tissues and could result in insulin resistance, which is a negative hallmark of tumour progression.[8] Patients with gastric cancer need

postoperative aftercare and individualised nutritional intervention. Measurement of visceral fat area (VFA) and muscle mass plays a role in the formulation of total energy and carbohydrate proportion in dietary instructions. Therefore, it is necessary to measure VFA and screen out visceral obesity in such populations.

Several medical imaging methods have been used to analyse body composition.[9] Among them, CT as a routine imaging examination prior to cancer diagnosis and therapy is accurate and considered the gold standard method for evaluating body composition.[9 10] The area of skeletal muscle and visceral fat tissue examined by CT highly correlates with total body skeletal muscle mass and visceral fat mass.[9–11] However, the use of CT in evaluating body composition has many drawbacks, such as radiation exposure, high expense and the need for specialists in medical imaging, making it not suitable for periodic measurements aftercare. In addition, only a few radiologists in the central cities of China are proficient in using CT to analyse body composition. The bioelectrical impedance analysis (BIA) method is a non-invasive alternative method for body composition evaluation and is widely used in clinical setting.[12] The advantages of BIA lie in its low cost and non-radiation exposure to subjects, making it suitable for repeat monitoring to determine nutrition status. The accuracy of VFA was investigated in a Korean cohort of healthy subjects which revealed that VFA estimated by BIA correlated well with that measured by CT method, but an accurate equation was needed to match that measured by CT.[12] However, the accuracy of BIA is highly dependent on ethnicity and hydration status.[13] Patients with malignancies may have alterations in body composition and hydration status, affecting the performance of BIA in estimating VFA. Moreover, research on validation of its accuracy is limited to Chinese patients. The aim of the present study was to investigate the accuracy of BIA in estimating VFA in subjects with gastric cancer in the Chinese population, as well as to identify the threshold for diagnosing visceral obesity using BIA.

MATERIALS AND METHODS

Patients

From 1 January 2017 to 1 December 2018, patients with a clear diagnosis of gastric cancer either by pathology or radiology admitted to the gastroenterology or general surgery department of Drum Tower Hospital Affiliated to Nanjing University Medical School were prospectively enrolled. Exclusion criteria were patients younger than 18 years or older than 80 years old, with primary tumour that originated from other organs, heart failure, kidney failure, cirrhosis, unmeasurable CT-VFA, use of diuretics or lipid regulation medications, unable to stand still, or patients who refused to undergo CT and BIA. Written consent was obtained from all participants.

Clinical information collection

Patients' clinical information was recorded. Baseline clinical characteristics included age, gender, body weight, body height, body mass index (BMI; defined as body weight in kilogram (kg)/(body height in metres)^2), tumour stage, tumour tissue type and comorbidities. Body weight was measured with the patient wearing thin clothes and to the nearest 0.1 kg. Body height was measured with the patient barefoot and to the nearest 0.1 cm. Body weight and height were measured directly via the InBody 720 instrument at the time of BIA testing. For most patients, body weight and height were measured only once, or were measured in replicate if the trained researcher found the patient was not standing still or standing straight. Tumour stage classification was based on the criteria established by the American Joint Committee on Cancer.[14 15] Neoadjuvant therapy before the study was recorded. Laboratory tests were performed with fasting blood samples when admitted to the hospital. Laboratory parameters included white cell count, haemoglobin level, albumin level, triglyceride level, cholesterol level and C reactive protein level. Tumour markers were also performed once admitted and parameters included carcinoembryonic antigen, carbohydrate antigen 125, carbohydrate antigen 199, carbohydrate antigen 724 and carbohydrate antigen 242.

Body composition assessment by CT

CT scans were performed before treatment. According to previously published method,[10 16] a single slice at umbilical level was selected and the area of different body compositions was analysed using Matlab software (MathWorks, Massachusetts, USA). Different body composition tissue compartments were manually outlined and segmented with different Hounsfield unit (HU) threshold ranges. Tissues with HU ranging from −29 to 150 were considered skeletal muscle and the total skeletal muscle area was calculated. Areas with HU ranging from −150 to −50 were considered visceral fat and the total VFA was calculated. Areas with HU ranging from −190 to −30 were considered subcutaneous fat and the total subcutaneous fat area was calculated.[17 18] CT assessment was performed by two radiologists independently, who were blinded to each other during CT measurement. They were also both blinded to patients' personal information and BIA values. The mean values obtained by the two radiologists were used in the study.

Body composition assessment by BIA

BIA assessment was performed on the same day as with CT scan. An InBody 720 multifrequency BIA instrument (InBody, Seoul, Korea) was used to measure body composition. The method was in accordance with previously described protocol.[10] In brief, patients with fasting condition and empty bladder stand with both arms 45° apart from the body trunk and with both feet bared on the spots of the platform. Total body water, VFA in square centimetre at umbilical level, total fat mass, body

fat percentage, lean body mass, skeletal body mass and fat free mass were estimated and the numeric values of the above parameters were output from the instrument screen. The measurement process was standard and was strictly supervised by an experienced researcher. If the BIA measurement process was not standard or the researcher considered potential mistakes, another measurement by BIA was performed to replace the former result.

Definition of visceral obesity

Based on the Japan Society for the Study of Obesity and the widely accepted criteria in clinics,[7 19] the threshold for visceral obesity was 100 cm^2 at umbilical level measured by CT images. Visceral obesity was defined as patients with VFA at umbilical level ≥100 cm^2.

Statistical analysis

Data analysis was performed using SPSS V.20.0 for Windows and MedCalc V.15.2.2 for Windows (MedCalc Software, Ostend, Belgium). Continuous variables were expressed as mean±SD if data were normally distributed and were compared by independent or paired t-test when appropriate. Skewed distributed data were expressed as median (25th percentile, 75th percentile) and were compared using Mann-Whitney U test. Categorical variables were expressed by number and percentages and were compared using χ^2 test or Fisher's exact test when appropriate. Paired t-test and intraclass correlation coefficient (ICC) for reliability and agreement were applied to compare differences in VFA between CT and BIA. Pearson's correlation coefficient was used to investigate any correlations between these two methods of measurement. Consistency between the two measurements was assessed by Bland-Altman statistical method,[20] with 95% limits of agreements (95% LOA) calculated. Patients with VFA ≥100 cm^2 measured by CT were classified to have visceral obesity. The performance of BIA in estimating VFA to diagnose visceral obesity was assessed by the area under the receiver operating characteristic curve (AUROC). The cut-off value for the VFA estimated by BIA for stratifying visceral obesity was obtained with the maximum Youden index (sensitivity+specificity−1). A two-tailed p value <0.05 was considered statistically significant. Shrout and Fleiss[21] proposed that ICC value ranging from 0.00 to 0.49 be interpreted as poor reliability, from 0.50 to 0.74 as satisfactory, and from 0.75 to 1.00 as excellent reliability.

RESULTS

Baseline characteristics of the study population

A total of 35 patients were excluded from the research, and 157 patients with gastric cancer were finally enrolled, including 48 women and 109 men (online supplementary figure 1). The mean age of the patients was 60.61±11.95 years old. The mean body weight and body height were 61.27±9.14 kg and 162.10±7.07 cm, respectively. Overall the mean BMI was 23.28±2.93 kg/m^2. According to the classification standard of China,[22] 5 patients were underweight (3.2%), 85 patients were within the normal range of BMI (54.1%), 61 patients were overweight (38.9%) and 6 patients were obese (3.8%). The number of patients with gastric cancer tumour stage I, II, III and IV was 48 (30.6%), 31 (19.7%), 49 (31.2%) and 29 (18.5%), respectively. Majority of patients were diagnosed with adenocarcinoma tissue type. The laboratory indicators and demographic characteristics are summarised in table 1.

The ICC between the two radiologists was 0.999. The mean value of VFA measured by CT in all patients was 84.39±46.43 cm^2. There were 65 (41.4%) patients diagnosed with visceral obesity. The VFA estimated by BIA in all patients was 71.94±22.44 cm^2 (table 2).

Comparison of VFA measured by CT (VFA-CT) and estimated by BIA (VFA-BIA) in all patients

The difference in VFA between CT and BIA was statistically significant via paired t-test (p<0.001). There was a mean 14.75% difference (based on CT) between the values of the two methods (table 2). The VFA measured by CT was positively correlated with that estimated by BIA in all patients using Pearson's correlation test (r=0.650, p<0.001) (table 3). The ICC value between VFA-CT and VFA-BIA was 0.675, indicating satisfactory reliability and agreement. With Bland-Altman analysis, the mean bias between the two measurements was 12.45±36.13 cm^2, indicating that BIA underestimated VFA by 12.45±36.13 cm^2 in all patients (table 4, figure 1). In addition, the Bland-Altman plot also showed that the VFA was overestimated in patients with smaller VFA and underestimated in patients with larger VFA (figure 1). The 95% LOA of the bias ranged from −58.36 cm^2 to 83.26 cm^2, indicating that the absolute values of the two measurements were not interchangeable directly and the bias was not clinically acceptable.

Subgroup analysis

The VFA measured by CT was significantly correlated with that estimated by BIA in both women (r=0.559, p<0.001) and men (r=0.714, p<0.001) using Pearson's correlation test. The mean difference of the two methods between genders was not significantly different (5.04±31.57 cm^2 and 15.71±37.64 cm^2, respectively, p=0.088). In both genders, the two methods showed satisfactory reliability (ICC=0.659 and ICC=0.683, respectively). Patients were divided into groups according to median BMI. In both BMI groups, VFA-CT and VFA-BIA were significantly correlated using Pearson's correlation test (r=0.315, p=0.010 in BMI >24 kg/m^2 group; r=0.551, p<0.001 in BMI ≤24 kg/m^2). The mean bias of VFA between the two BMI categories was significantly different (25.50±31.00 cm^2 and 2.99±36.78 cm^2, p<0.001), indicating that BIA largely underestimated VFA in subjects who are overweight or with obesity. The ICC value in the BMI >24 kg/m^2 group was interpreted to be of poor reliability. In both older (>60 years old) and younger (≤60 years old) groups, the two methods showed significant correlation

Table 1 Baseline characteristics

	Overall (N=157)
Age (years)	60.61±11.95
<60 (%)	66 (42.0)
≥60 (%)	91 (58.0)
Gender (male, %)	109 (69.4)
Body weight (kg)	61.27±9.14
Body height (cm)	162.10±7.07
BMI (kg/m^2)	23.28±2.93
<18.5	5 (3.2)
18.50–23.99	85 (54.1)
24–27.99	61 (38.9)
≥28	6 (3.8)
Tumour stage (AJCC)	
I	48 (30.6)
II	31 (19.7)
III	49 (31.2)
IV	29 (18.5)
Tissue type	
Adenocarcinoma	124 (79.0)
Signet ring cell carcinoma	7 (4.5)
Others	11 (7.0)
Unknown	15 (9.5)
Neoadjuvant (yes, %)	2 (1.3)
Diabetes (yes, %)	8 (5.1)
Laboratory	
White cell count (×10^9/L)	5.3 (4.5, 6.25)
Haemoglobin (g/L)	126 (109.5, 139.5)
Albumin (g/L)	38.30±4.18
Triglyceride (mmol/L)	1.18±0.70
Cholesterol (mmol/L)	3.75±0.86
C reactive protein (mg/L)	3.2 (2.5, 4.45)
CEA (ng/mL)	1.12 (0.52, 2.22)
CA125 (ng/mL)	7.2 (4.9, 13.55)
CA199 (ng/mL)	10.43 (6.08, 18.96)
CA724 (ng/mL)	1.84 (1.01, 4.15)
CA242 (ng/mL)	9.97±17.86

Normally distributed variables are expressed as mean±SD.
Skewed variables are expressed as median (25th percentile, 75th percentile).
AJCC, American Joint Committee on Cancer; BMI, body mass index; CA125, carbohydrate antigen 125; CA199, carbohydrate antigen 199; CA242, carbohydrate antigen 242; CA724, carbohydrate antigen 724; CEA, carcinoembryonic antigen.

Table 2 Body composition assessment by CT and BIA in all patients

Body composition assessment	Overall (N=157)
Body composition by CT	
Skeletal muscle mass area (cm^2)	117.32±24.97
Subcutaneous fat mass area (cm^2)	103.56±50.01
Visceral fat area (cm^2)	84.39±46.43
Visceral obesity, n (%)	65 (41.4)
Body composition by BIA	
Total body water (L)	33.43±5.23
Visceral fat area (cm^2)	71.94±22.44
Total fat mass (kg)	16.03±5.12
Body fat percentage (%)	25.83±6.84
Lean body mass (kg)	42.88±6.73
Skeletal muscle mass (kg)	24.86±4.29
Fat free mass (kg)	45.42±7.08

The difference in VFA between CT and BIA was statistically significant (p<0.001) via paired t-test. There was a mean 14.75% difference (based on CT) between the values of the two methods.
BIA, bioelectrical impedance analysis; VFA, visceral fat area.

using Pearson's correlation test (r=0.640, p<0.001; r=0.656, p<0.001, respectively) and satisfactory reliability (ICC=0.668 and ICC=0.678, respectively). Bias between patients in different age groups was not statistically significant (p=0.855). Bias between different tumour stages was not significantly different (p=0.424).

VFA-BIA in diagnosing visceral obesity

VFA ≥100 cm^2 [27 19] measured by CT at umbilical level was adopted as the threshold for diagnosing visceral obesity. The VFA estimated by BIA showed a good to excellent performance in diagnosing visceral obesity in all patients of the present study (AUROC=0.822, p<0.001, 95% CI 0.758 to 0.887), with a sensitivity of 65.6% and a specificity of 88.2% (figure 2). The best cut-off value for VFA-BIA was 81 cm^2, indicating that patients with gastric cancer with VFA larger than 81 cm^2 estimated by BIA should be highly suspected for visceral obesity.

DISCUSSION

The present study revealed that the VFA estimated by BIA significantly correlated with that measured by CT at the umbilical level in patients with gastric cancer in the Chinese population, with satisfactory reliability (ICC=0.675). This was in accordance with a previous Korean study.[12] Lee *et al* [12] compared VFA-CT with VFA-BIA in healthy subjects with wide ranges of age and BMI. The mean bias of VFA between the two methods was 21.4±45.6 cm^2 and tended to increase with BMI. Our study also demonstrated positive correlation of bias with BMI, indicating the drawback of BIA in analysing body composition in subjects who are overweight or obese. This limitation of BIA for obesity has been proposed by several studies.[23–27] Bosaeus *et al* discovered that BIA underestimated total fat mass in overweight

Table 3 Pearson's correlation in VFA measured by CT and BIA

	n	VFA by CT (cm^2)	VFA by BIA (cm^2)	r	P value
Overall	157	84.39±46.43	71.94±22.44	0.650	<0.001
Female	48	85.10±38.04	80.06±22.67	0.559	<0.001
Male	109	84.08±49.84	68.37±21.48	0.714	<0.001
BMI >24 kg/m^2	66	113.57±32.22	88.07±15.24	0.315	0.010
BMI ≤24 kg/m^2	91	63.23±43.70	60.24±19.39	0.551	<0.001
Age ≤60 years	66	84.94±42.66	73.11±20.67	0.640	<0.001
Age >60 years	91	83.99±49.21	71.09±23.71	0.656	<0.001
Stage I	48	86.78±47.18	72.49±21.87	0.671	<0.001
Stage II	31	84.26±36.56	74.53±18.90	0.564	<0.001
Stage III	49	88.15±47.00	70.63±21.15	0.726	<0.001
Stage IV	29	74.22±53.99	70.46±28.97	0.605	0.001

r for Pearson's correlation coefficient.
P value for statistical significance using Pearson's correlation test.
BIA, bioelectrical impedance analysis; BMI, body mass index; VFA, visceral fat area.

and obese women compared with MRI measurement.[24] Neovius *et al*[27] discovered that compared with dual-energy X-ray absorptiometry (DXA), the bias in fat mass increased with degree of adiposity.

CT slice at umbilical level serves as the gold standard for VFA assessment.[7 19] However, the exposure to radiation and the high cost restrict its use for periodic nutritional assessment in clinical settings. Moreover, the need for expertise in medical imaging also restricts its application. In China, the reality is that only a few doctors working in regional central hospitals are proficient in body composition quantification using CT. Body composition assessment is important for these patients with gastric cancer in postoperative aftercare and individualised nutritional intervention. Patients with distinct VFA status require different energy formulation and proportion of macronutrients.[28] Periodic measurement of VFA could provide clues for nutritionists with regard to individualised dietary instructions. Unfortunately, CT for body composition assessment is not applicable to non-central city hospitals in China and is also not suitable for periodic nutritional assessment during follow-up. However, it has clinical value in evaluating the accuracy of BIA in estimating VFA in patients with gastric cancer, as BIA compensates for the shortcomings of CT and is suitable for extensive nutritional screening and monitoring.[11] However, what needs to be clarified is that the principle of BIA instruments is based on electrical property, the impedance of the tissues in the conductive path between the sense electrodes.[9] The quantifications of adipose tissue by BIA

Table 4 correlation coefficient and Bland-Altman analysis of VFA measured by CT and BIA

	n	CT-BIA VFA (cm^2)	P value	ICC	95% LOA
Overall	157	12.45±36.13	–	0.675	−58.36 to 83.26
Female	48	5.04±31.57	0.088	0.659	−56.84 to 66.92
Male	109	15.71±37.64		0.683	−58.06 to 89.48
BMI >24 kg/m^2	66	25.50±31.00	0.000*	0.392	−35.26 to 86.26
BMI ≤24 kg/m^2	91	2.99±36.78		0.580	−69.10 to 75.08
Age ≤60 years	66	11.83±33.45	0.855	0.668	−53.73 to 77.39
Age >60 years	91	12.90±38.13		0.678	−61.83 to 87.63
Stage I	48	14.28±36.32	0.424	0.677	−56.91 to 85.47
Stage II	31	9.73±30.23		0.631	−49.25 to 68.98
Stage III	49	17.51±34.83		0.704	−50.76 to 85.78
Stage IV	29	3.77±43.15		0.670	−80.80 to 88.34

P value for comparison of CT-BIA VFA between subgroups by independent t-test.
*indicated for p<0.05.
BIA, bioelectrical impedance analysis; BMI, body mass index; ICC, intraclass correlation coefficient; 95% LOA, 95% limits of agreement; VFA, visceral fat area.

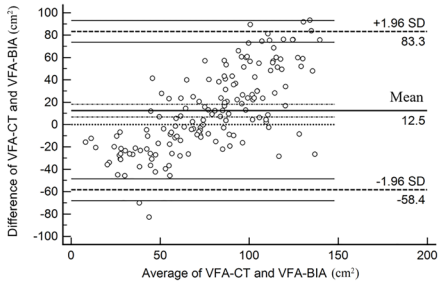

Figure 1 Bland-Altman plot for comparing the two methods. The mean bias between the two measurements was 12.45±36.13 cm^2 (lines of the mean and its 95% CI are shown). 95% limits of agreements ranged from –58.36 cm^2 to 83.26 cm^2 (lines of the mean±1.96 SD and their 95% CI are shown). BIA, bioelectrical impedance analysis; VFA, visceral fat area.

are only estimations rather than direct measurements.[9] Therefore, we still recommend CT as the priority when there are enough professionals and economic conditions permit for routine VFA assessment by CT. Otherwise, BIA could be an alternative. To supplement, the present study only enrolled patients who could stand still and undertake BIA measurement using InBody 720. However, there are many patients with cancer who are too weak to stand, and in this case the InBody S10 designed to measure VFA in supine subjects is a choice.[29] The accuracy of InBody S10 in VFA estimation warrants further investigation.

In recent years, the role of visceral obesity in the progression of cancer and cancer-related comorbidities has been investigated in several studies.[30 31] Ozoya *et al* [30] retrospectively analysed 110 patients with colon cancer and concluded that visceral obesity was associated with metabolic comorbidities and postoperative morbidities. Go *et al* [7] indicated that the presence of visceral obesity

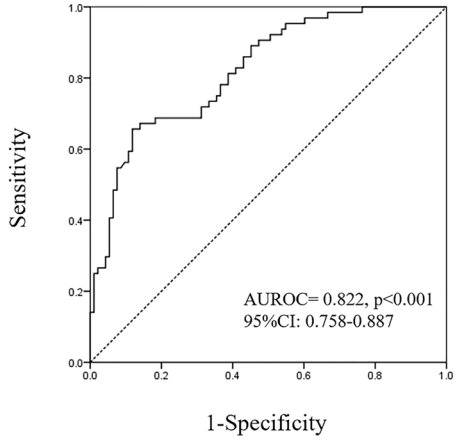

Figure 2 ROC of VFA by BIA in diagnosing visceral obesity in all patients (AUROC=0.822, p<0.001, 95% CI 0.758 to 0.887). The best cut-off value for diagnosing visceral obesity by VFA-BIA was 81 cm^2, with a sensitivity of 65.6% and a specificity of 88.2%. AUROC, area under the receiver operating characteristic curve; BIA, bioelectrical impedance analysis; ROC, receiver operating characteristic curve; VFA, visceral fat area.

could cause technical difficulties during operations and could significantly reduce the number of retrieved lymph nodes, as well as the overall survival in patients with gastric cancer who had undergone laparoscopy-assisted distal gastrectomy. Therefore, visceral obesity should be identified prior to surgery, and operations should be conducted by more experienced surgeons.[7] Preoperative quantification of VFA could help surgeons optimise the selection of patients suitable for laparoscopic approach and take interventions for prophylaxis of surgical incision infection. In addition, the low-grade chronic inflammation produced by excessive visceral fat tissues is considered suitable microenvironment for tumour growth.[30] Growth factors released by visceral fat tissues also mediate in cancer progression.[30–32] Therefore, to reverse visceral obesity state is essential in subjects with gastric cancer. Tumour of gastrointestinal origin apparently affects the digestion and absorption of nutrients. Many patients suffer from weight loss, sarcopaenia or even cachexia after gastrectomy or under tumour-bearing state.[33] The metabolic characteristics and nutritional management are different between patients with distinct body composition.[34] How to provide scientific, accurate and reasonable individualised nutritional support for these patients is a major challenge and difficulty. Some patients with cancer, especially those in the earlier stage, are prone to excessive daily energy intake and with restricted daily physical activity, may consequently develop sarcopaenic obesity. For patients with similar skeletal muscle mass but different VFA status, the total energy and micronutrient proportions required daily will be distinctive,[28] as well as the physical exercise regimen.[35] Therefore, it is essential to identify visceral obesity both prior to surgery and in the aftercare period.

In the present study, the values of the two methods were significantly different by paired t-test (p<0.001), and the mean bias of the two methods was 12.45±36.13 cm^2, with a wide range of 95% LOA, indicating that the absolute values of the two methods were not interchangeable directly. This was in accordance with Lee *et al*'s research.[12] Lee *et al*[12] postulated a formula to predict actual VFA with BIA variables. However, this formula was too complicated in calculation and difficult to implement routinely. In addition, previous formulas were based on healthy subjects with different ethnicities, which were not applicable to Chinese patients with gastric cancer. Therefore, the present study identified a cut-off value of VFA by BIA in diagnosing visceral obesity. The Chinese patients with gastric cancer with VFA exceeding 81 cm^2 by BIA should be highly suspected for visceral obesity. What we need to clarify here is that BIA data are based on certain built-in equations suitable for different ethnicities.[36 37] The equations will be modified when the instruments are installed in different regions worldwide. Therefore, our conclusions were only applicable to the Asian population, especially to the Chinese population, when they take BIA using instruments installed in China.

There were several limitations to the present research. First, the study was conducted in a single centre with a

relatively small sample size and only included patients from China. The conclusions might not be generalised to patients from other regions. A multicentre design study with a larger sample size is warranted to validate our conclusions. Second, the receiver operating characteristic curve result of the present study could distinguish visceral obesity by BIA, but could not directly convert VFA-BIA absolute value to VFA-CT absolute value. It was unable to obtain the exact and accurate value of VFA via BIA. Third, the study design used the InBody 720 as BIA instrument, which is a relatively older product. Further studies to validate the conclusions using the promotion product InBody 770 should be performed.[38]

In conclusion, it is necessary to identify visceral obesity in patients with gastric cancer both prior to surgery and in the aftercare period via body composition analysis. The present study revealed that the VFA measured by CT and BIA showed significant correlation and satisfactory reliability. However, the bias between the two methods was within a wide range, indicating that the absolute values of the two methods were not interchangeable directly. The cut-off value for VFA-BIA in identifying visceral obesity in the present study was 81 cm^2, indicating Chinese patients with gastric cancer with VFA estimated by BIA larger than the threshold should be highly suspected for visceral obesity.

Author affiliations
[1]Department of Clinical Nutrition, Nanjing University Medical School Affiliated Nanjing Drum Tower Hospital, Nanjing, Jiangsu, China
[2]Department of Gynecology and Obstetrics, The affiliated Obstetrics and Gynecology Hospital with Nanjing Medical University; Nanjing Maternity and Child Health Care Hospital, Nanjing, Jiangsu, China
[3]Department of General Surgery, Nanjing University Medical School Affiliated Nanjing Drum Tower Hospital, Nanjing, Jiangsu, China
[4]Department of Radiology, Nanjing University Medical School Affiliated Nanjing Drum Tower Hospital, Nanjing, Jiangsu, China
[5]Department of Pharmacy, Nanjing University Medical School Affiliated Nanjing Drum Tower Hospital, Nanjing, Jiangsu, China

Acknowledgements We acknowledge all patients who participated in the study. We are also grateful to all the staff who helped us with the study.

Contributors BG was responsible for the methodology, data curation, project administration and writing. YL was responsible for the methodology, statistical analysis, data analyses and writing. CD was responsible for data collection. SL was responsible for data curation, project administration and software management. XB was responsible for BIA management and data collection. XC was responsible for study design and manuscript supervision. All authors gave their final approval of the final version of the manuscript.

Funding The research received grant from the National Natural Science Foundation of China (grant number 81700463). The funding was used for data collection and analyses.

Competing interests None declared.

Patient consent for publication Not required.

Ethics approval The observational study was in accordance with the principles of the Declaration of Helsinki and was approved by the Clinical Research Ethics Committee of the Nanjing Drum Tower Hospital (209-173-01).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available with the corresponding author upon reasonable request.

ORCID iD
Xiaotian Chen http://orcid.org/0000-0001-6112-0784

REFERENCES

1 Yoon H, Kim N. Diagnosis and management of high risk group for gastric cancer. *Gut Liver* 2015;9:5–17.
2 Wu H-H, Lin W-chang, Tsai K-W. Advances in molecular biomarkers for gastric cancer: miRNAs as emerging novel cancer markers. *Expert Rev Mol Med* 2014;16:e1.
3 van Dijk DPJ, Bakens MJAM, Coolsen MME, *et al*. Low skeletal muscle radiation attenuation and visceral adiposity are associated with overall survival and surgical site infections in patients with pancreatic cancer. *J Cachexia Sarcopenia Muscle* 2017;8:317–26.
4 Fukushima H, Takemura K, Suzuki H, *et al*. Impact of sarcopenia as a prognostic biomarker of bladder cancer. *Int J Mol Sci* 2018;19:2999.
5 Joglekar S, Nau PN, Mezhir JJ. The impact of sarcopenia on survival and complications in surgical oncology: a review of the current literature. *J Surg Oncol* 2015;112:503–9.
6 Takada H, Kurosaki M, Nakanishi H, *et al*. Impact of pre-sarcopenia in sorafenib treatment for advanced hepatocellular carcinoma. *PLoS One* 2018;13:e0198812.
7 Go J-E, Kim M-C, Kim K-H, *et al*. 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* 2015;88:318–24.
8 Yip C, Dinkel C, Mahajan A, *et al*. Imaging body composition in cancer patients: visceral obesity, sarcopenia and sarcopenic obesity may impact on clinical outcome. *Insights Imaging* 2015;6:489–97.
9 Lemos T, Gallagher D. Current body composition measurement techniques. *Curr Opin Endocrinol Diabetes Obes* 2017;24:310–4.
10 van Vugt JLA, Levolger S, Gharbharan A, *et al*. A comparative study of software programmes for cross-sectional skeletal muscle and adipose tissue measurements on abdominal computed tomography scans of rectal cancer patients. *J Cachexia Sarcopenia Muscle* 2017;8:285–97.
11 Mourtzakis M, Prado CMM, Lieffers JR, *et al*. 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* 2008;33:997–1006.
12 Lee D-H, Park KS, Ahn S, *et al*. Comparison of abdominal visceral adipose tissue area measured by computed tomography with that estimated by bioelectrical impedance analysis method in Korean subjects. *Nutrients* 2015;7:10513–24.
13 Yamada Y, Nishizawa M, Uchiyama T, *et al*. Developing and validating an age-independent equation using multi-frequency bioelectrical impedance analysis for estimation of appendicular skeletal muscle mass and establishing a cutoff for sarcopenia. *Int J Environ Res Public Health* 2017;14:809.
14 Deng J, Zhang R, Pan Y, *et al*. Comparison of the staging of regional lymph nodes using the sixth and seventh editions of the tumor-node-metastasis (TNM) classification system for the evaluation of overall survival in gastric cancer patients: findings of a case-control analysis involving a single institution in China. *Surgery* 2014;156:64–74.
15 Liu J-Y, Peng C-W, Yang X-J, *et al*. The prognosis role of AJCC/UICC 8th edition staging system in gastric cancer, a retrospective analysis. *Am J Transl Res* 2018;10:292–303.
16 Black D, Mackay C, Ramsay G, *et al*. Prognostic value of computed tomography: measured parameters of body composition in primary operable gastrointestinal cancers. *Ann Surg Oncol* 2017;24:2241–51.
17 Zhang Y, Wang JP, Wang XL, *et al*. Computed tomography-quantified body composition predicts short-term outcomes after gastrectomy in gastric cancer. *Curr Oncol* 2018;25:e411–22.
18 Prado CMM, Lieffers JR, McCargar LJ, *et al*. Prevalence and clinical implications of sarcopenic obesity in patients with solid tumours of the respiratory and gastrointestinal tracts: a population-based study. *Lancet Oncol* 2008;9:629–35.
19 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;66:98792.
20 Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986;1:307–10.

21 Shrout PE, Fleiss JL. Intraclass correlations: uses in assessing rater reliability. *Psychol Bull* 1979;86:420–8.
22 Zhu J, Loos RJF, Lu L, *et al*. Associations of genetic risk score with obesity and related traits and the modifying effect of physical activity in a Chinese Han population. *PLoS One* 2014;9:e91442.
23 Ellegård L, Bertz F, Winkvist A, *et al*. Body composition in overweight and obese women postpartum: bioimpedance methods validated by dual energy X-ray absorptiometry and doubly labeled water. *Eur J Clin Nutr* 2016;70:1181–8.
24 Bosaeus M, Karlsson T, Holmäng A, *et al*. Accuracy of quantitative magnetic resonance and eight-electrode bioelectrical impedance analysis in normal weight and obese women. *Clin Nutr* 2014;33:471–7.
25 Pateyjohns IR, Brinkworth GD, Buckley JD, *et al*. Comparison of three bioelectrical impedance methods with DXA in overweight and obese men. *Obesity* 2006;14:2064–70.
26 Panotopoulos G, Ruiz JC, Guy-Grand B, *et al*. Dual X-ray absorptiometry, bioelectrical impedance, and near infrared interactance in obese women. *Med Sci Sports Exerc* 2001;33:665–70.
27 Neovius M, Hemmingsson E, Freyschuss B, *et al*. Bioelectrical impedance underestimates total and truncal fatness in abdominally obese women. *Obesity* 2006;14:1731–8.
28 Koliaki C, Liatis S, Dalamaga M, *et al*. Sarcopenic obesity: epidemiologic evidence, pathophysiology, and therapeutic perspectives. *Curr Obes Rep* 2019;8:458–71.
29 Sukackiene D, Laucyte-Cibulskiene A, Vickiene A, *et al*. Risk stratification for patients awaiting kidney transplantation: role of bioimpedance derived edema index and nutrition status. *Clin Nutr* 2019:33168–1.
30 Ozoya OO, Siegel EM, Srikumar T, *et al*. Quantitative assessment of visceral obesity and postoperative colon cancer outcomes. *J Gastrointest Surg* 2017;21:534–42.
31 Long E, Beales ILP. The role of obesity in oesophageal cancer development. *Therap Adv Gastroenterol* 2014;7:247–68.
32 Sheean PM, Hoskins K, Stolley M. Body composition changes in females treated for breast cancer: a review of the evidence. *Breast Cancer Res Treat* 2012;135:663–80.
33 Choi KM. Sarcopenia and sarcopenic obesity. *Korean J Intern Med* 2016;31:1054–60.
34 Kalinkovich A, Livshits G. Sarcopenic obesity or obese sarcopenia: a cross talk between age-associated adipose tissue and skeletal muscle inflammation as a main mechanism of the pathogenesis. *Ageing Res Rev* 2017;35:200–21.
35 Mooren FC, Krüger K. Exercise, autophagy, and apoptosis. *Prog Mol Biol Transl Sci* 2015;135:407–22.
36 Deurenberg P. Limitations of the bioelectrical impedance method for the assessment of body fat in severe obesity. *Am J Clin Nutr* 1996;64:449S–52.
37 Shafer KJ, Siders WA, Johnson LK, *et al*. Validity of segmental multiple-frequency bioelectrical impedance analysis to estimate body composition of adults across a range of body mass indexes. *Nutrition* 2009;25:25–32.
38 Antonio J, Knafo S, Kenyon M, *et al*. Assessment of the FTO gene polymorphisms (rs1421085, rs17817449 and rs9939609) in exercise-trained men and women: the effects of a 4-week hypocaloric diet. *J Int Soc Sports Nutr* 2019;16:36.