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Effect of visceral fat area on prognosis of patients undergoing radical gastrectomy and construction of nomogram

Zhicheng Huang[1†], Baohua Zheng[1†], Zhiwei Wang[1], Xiaobin Chen[1] and Yu Wang[1*]

Abstract

Background We aim to investigate the impact of visceral fat area (VFA) on the prognosis of patients following radical gastric resection and develop a nomogram prediction model to forecast the prognosis of gastric cancer patients.

Methods We retrospectively analyzed 156 patients who underwent laparoscopic radical gastrectomy for distal gastric cancer in the 900th hospital of the Joint Logistics Support Force from April 2018 to April 2020. We collected the CT image data and clinicopathological data one week prior to the operation and then used software to calculate the VFA, dividing it into two groups: a low VFA group ($n=71$) and a high VFA group ($n=85$). We compared the clinicopathological characteristics and early postoperative complications of the two groups. The Pearson χ^2 test was used to analyze the correlation between body mass index (BMI) and VFA. We used the Kaplan-Meier method to draw the survival curve, analyzed the independent risk factors affecting the prognosis of gastric cancer patients using univariate and multivariate Cox regression models, and established a nomogram model for patient prognosis prediction.

Results The results of CT showed that VFA value was (95.89 ± 41.40) cm^2, and body mass index (BMI) was positively correlated with VFA value ($r=0.291$, $P<0.001$). The ROC curve shows that VFA can predict the prognosis of patients with gastric cancer significantly better than BMI (AUC = 0.826 vs. AUC = 0.707, $P=0.016$). The incidence of incision fat liquefaction, pancreatic fistula, and abdominal infection in the high VFA group was higher than that in the low VFA group ($P<0.05$). We followed up with all patients for 0.5–48.5 months, with a median follow-up time of 30 months. We used the Kaplan-Meier method to draw the survival curve. The results showed that the overall survival rate of patients in the high VFA group was significantly higher than that in the low VFA group ($\chi^2=38.208$, $P<0.001$), and the high BMI group was significantly higher than that in the low BMI group ($\chi^2=29.767$, $P<0.001$). Age, the degree of differentiation, complications after surgery, VFA, ASA grading, and TNM staging were all found to have independent effects on the prognosis of gastric cancer patients (Multivariate Cox regression analysis). Multivariate Cox regression analysis led to the construction of a nomogram prediction model for the total survival of gastric cancer patients. Its internal verification C-index was 0.881 (95% CI: 0.852–0.910), and the calibration chart showed good consistency.

†Zhicheng Huang and Baohua Zheng are co-first authors.

*Correspondence:
Yu Wang
flyfishwang@hotmail.com

Full list of author information is available at the end of the article

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Conclusions Age, differentiation degree, postoperative complications, VFA, ASA grading, and TNM staging are independent influencing factors for the prognosis of patients with gastric cancer. The constructed nomogram has excellent prediction accuracy and is helpful to evaluate the prognosis of patients.

Keywords Gastric cancer, Visceral fat area, Body mass index, Prognosis, Nomogram

Introduction

In recent years, with the continuous improvement of people's living standards, obesity has gradually become a global health problem [1]. Body mass index (BMI) is often used to assess obesity in patients due to its simple calculation, but it only considers weight and height and does not reflect fat distribution. In contrast to their European and American counterparts, Asian individuals tend to accumulate more fat in their abdomens. Foreign scholars first introduced the concept of visceral obesity, based on the distinct fat distribution of obese patients [2]. Visceral fat provides a more accurate assessment of the degree of obesity and the distribution of fat. Relevant research shows that it is more objective and accurate to evaluate the visceral fat area (VFA) measured by CT scanning the umbilical plane (L_4-L_5 plane) [3]. Research clearly links the prognosis of patients with malignant tumors, including gastric cancer, to excessive adipose tissue [4, 5]. As one of the common malignant tumors, gastric cancer ranks fourth and third, respectively, in the incidence and mortality of malignant tumors in China [6, 7]. Patients with gastric cancer still primarily receive surgery, but due to the hidden early and clinical symptoms, most diagnoses occur at a late stage, leading to a poor 5-year survival rate [8]. However, numerous factors influence the prognosis of patients with gastric cancer, leaving no definitive conclusion. Previous studies have suggested that high VFA is often associated with poor postoperative outcomes of colorectal cancer [9, 10]. There are few studies on the relationship between VFA and long-term survival after radical gastrectomy. Furthermore, nomograms, widely used in cancer prognosis [11], provide a visual representation of the probability of clinical events specific to each patient's situation [12]. This study retrospectively analyzed the clinical data of patients undergoing radical gastrectomy, measured the preoperative VFA of patients with gastric cancer based on CT, analyzed the relationship between VFA and the long-term prognosis of patients after radical gastrectomy, and constructed a prognostic nomogram of patients with gastric cancer, which provided a basis for prognosis judgment and individualized treatment.

Materials and methods

Data collection

The clinical and pathological information of 156 patients who had a laparoscopic radical gastrectomy for distal gastric cancer in the 900th hospital of the Joint Logistics Support Force from April 2018 to April 2020 was looked at in the past. This included their age, gender, smoking or drinking habits, complications before the surgery (affecting the respiratory system, circulatory system, digestive system, etc.), the size of the tumor, albumin levels, complications after the surgery, differentiation degree, lymph node metastasis, BMI, VFA, ASA grading, and TNM staging. We define overweight as having a BMI of more than 25 kg/m^2. We followed up patients every six months for the first three years after the operation, including telephone follow-up and outpatient review, and then once a year until April 20, 2024. We set the overall survival time (OS) from the date of operation to the time of death, the last follow-up, or the end of observation.

Inclusion and exclusion criteria

The inclusion criteria are as follows: (1) Patients must have gastric adenocarcinoma confirmed by preoperative pathological examination and laparoscopic distal gastrectomy; (2) No other malignant tumor or distant metastasis occurred; and (3) Patients' general data and follow-up results must be complete.

The exclusion criteria include: (1) Coagulation dysfunction and endocrine diseases prior to the operation; (2) Patients with gastric cancer who underwent a laparotomy during the operation; and (3) Receiving neoadjuvant chemotherapy prior to the operation.

VFA measurement method

All patients underwent a 64-slice spiral CT scan in a supine position on an empty stomach, with a pitch of 0.625, a scanning time of 0.35s, a matrix of 512×512, a tube voltage of 120 kV, a current of 100-200 mA, and a reconstruction thickness of 5 mm. After the scan, upload the scanned image to the PACS system, read the DICOM file of the CT image, select the axial CT image at the $L_{4\text{-}5}$ level, and adjust the fat density threshold to be between 190 and 30 Hu [13]. We used ImageJ, a program created by the American College of Public Health, to draw and measure the outline of the fat area. The CT value of all tissues in the cross section is the sum of pixel areas between −190 and −30 Hu. We then chose the region of interest (ROI) to calculate VFA (VFA = total area of regional fat - subcutaneous fat area (SFA)), which can be seen in Fig. 1. According to the Japanese Obesity Association Standard [14], VFA ≥ 100 cm [2] was defined as visceral obesity, and patients were divided into high VFA group and low VFA group according to this standard.

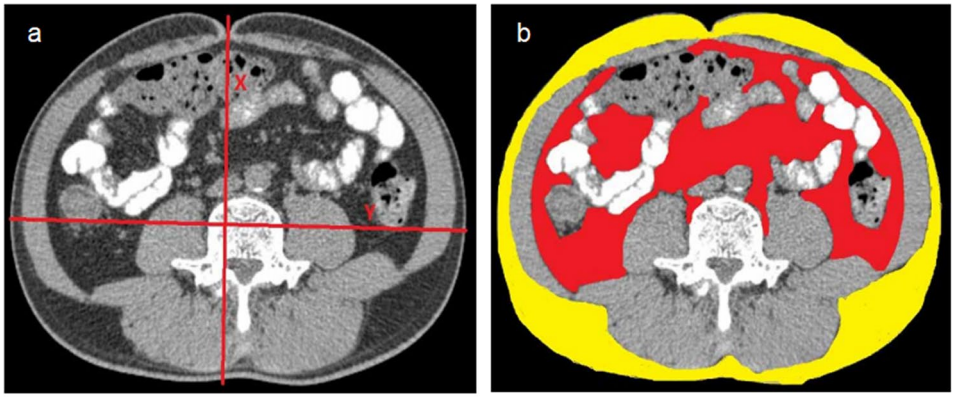

Fig. 1 CT umbilical plane axial position. X: transverse diameter of abdomen, Y: anteroposterior diameter, VFA is red area

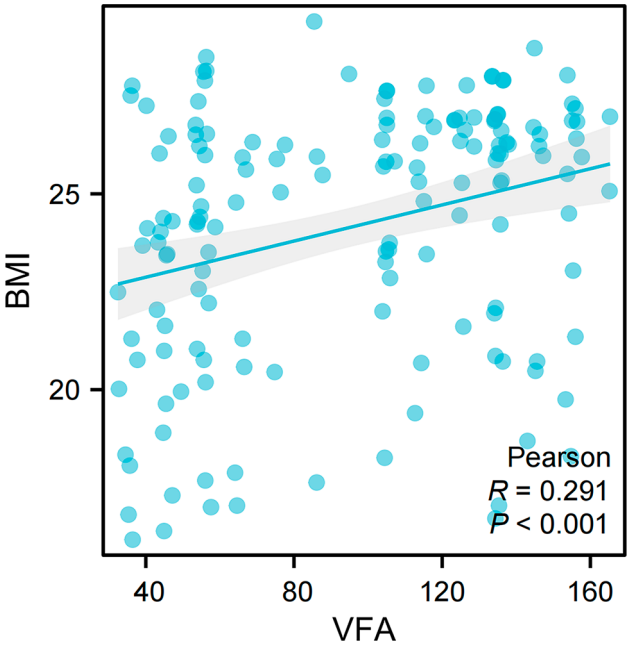

Fig. 2 Correlation analysis between visceral fat area (VFA) and body mass index (BMI)

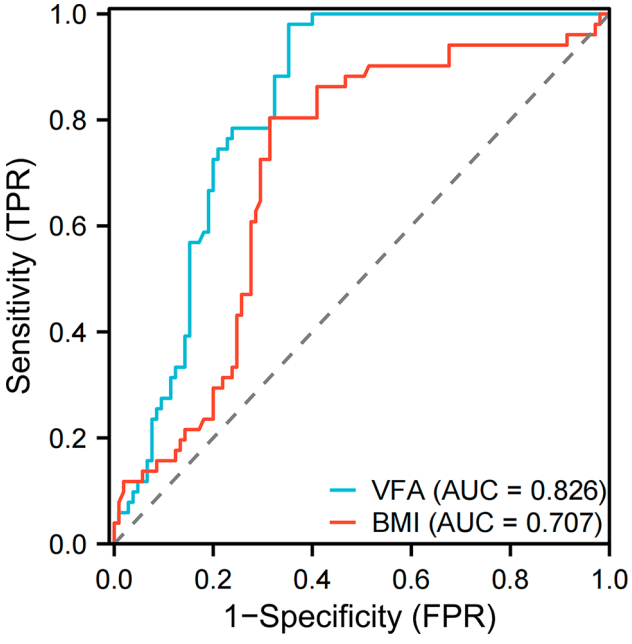

Fig. 3 Comparison of VFA and BMI in predicting the prognosis of patients with gastric cancer

Statistical analysis

We used SPSS 26.0 software and R (version 4.4.0) software for statistical analysis. The count data was expressed in the form of a percentage n (%) and the comparison between groups was made by the χ [2] test or Fisher test ($n<5$). The Pearson χ [2] test was used to analyze the correlation between BMI and VFA. We used the Kaplan-Meier method to calculate OS and draw the survival curve. A log-rank test was used to test the differences between groups. We used univariate and multivariate Cox regression models to analyze the independent risk factors affecting the prognosis of gastric cancer patients and calculated the hazard ratio (HR) and corresponding 95% CI. We constructed and drew a nomogram prediction model using R software (version 4.4.0). We internally verify the model and evaluate its performance using the index of concordance (C-index) and calibration chart. $P<0.05$ is statistically significant.

Results

Comparison of clinical and pathological data of BMI and VFA in different groups

There were 156 patients in total, 33 of whom were female and 123 of whom were male. The age ranged from 31 to 77 years with an average of (57.28 ± 8.85) years. The results of CT showed that VFA was (95.89 ± 41.40) cm^2, and BMI was positively correlated with VFA ($r=0.291$, $P<0.001$, Fig. 2). Figure 3 shows that the ROC curve shows that VFA is a much better predictor of the prognosis of people with gastric cancer than BMI (AUC = 0.826 vs. AUC = 0.707, $P=0.016$). According to the VFA value (100 cm [2]), 85 cases were divided into the visceral

obesity group (high VFA group) (VFA ≥ 100 cm [2]), and 71 cases were divided into the non-visceral obesity group (low VFA group) (VFA < 100 cm [2]). According to the BMI value (25 kg/m^2), 83 cases were divided into hyperrecombination (high BMI group) (BMI ≥ 25 kg/m^2) and 73 cases were non-hyperrecombination (low BMI group) (BMI < 25 kg/m^2). There were significant differences in age, gender, preoperative complications, tumor size, albumin, postoperative complications, lymph node metastasis, ASA grading, and TNM staging between the high VFA group and the low VFA group ($P < 0.05$). There were significant differences in age, preoperative complications, tumor size, albumin, differentiation degree, lymph node metastasis, ASA grading, and TNM staging between the high BMI group and the low BMI group ($P < 0.05$, Table 1).

Comparison of early postoperative complications between high VFA group and low VFA group

There was a clear link between VFA level and the early postoperative complications that happened more often in people with gastric cancer. We discovered that the high VFA group had more incision fat liquefaction, pancreatic fistula, and abdominal infections than the low VFA group

Table 1 Comparison of Clinicopathological Features between Two Groups [n (%)]

Variables	Low VFA group ($n=71$)	High VFA group ($n=85$)	χ^2	*P*	Low BMI group ($n=73$)	High BMI group ($n=83$)	χ^2	*P*
Age (years)			12.839	< 0.001			8.823	0.003
≤ 60	29(40.85)	59(69.41)			32(43.84)	56(67.47)		
> 60	42(59.15)	26(30.5)			41(56.16)	27(32.53)		
Gender							0.048	0.827
Male	61(85.92)	62(72.94)	3.904	0.048	57(78.08)	66(79.52)		
Female	10(14.08)	23(27.06)			16(21.92)	17(20.48)		
Smoking			2.834	0.092			0.834	0.361
Yes	43(60.56)	40(47.06)			37(50.68)	36(43.37)		
None	28(39.44)	45(52.94)			36(49.32)	47(56.63)		
Drinking			1.436	0.231			0.901	0.343
Yes	30(42.25)	28(32.94)			43(58.90)	55(66.27)		
None	41(57.75)	57(67.06)			30(41.10)	28(33.73)		
Preoperative complications			8.766	0.003			5.733	0.017
Yes	22(30.99)	10(11.76)			21(28.77)	11(13.25)		
None	49(69.01)	75(88.24)			52(71.23)	72(86.75)		
Tumor size (cm)			20.512	< 0.001			21.292	< 0.001
≤ 5	32(45.07)	68(80.00)			33(45.21)	67(80.72)		
> 5	39(54.93)	17(20.00)			40(54.79)	16(18.82)		
Albumin (g/L)			8.527	0.003			8.011	0.005
≤ 30	9(12.68)	1(1.18)			9(12.33)	1(1.20)		
> 30	62(87.32)	84(98.82)			64(87.67)	82(98.80)		
Postoperative complications			5.623	0.018			0.105	0.746
Yes	21(29.58)	41(48.24)			30(41.10)	32(38.55)		
None	50(70.42)	44(51.76)			43(58.90)	51(61.15)		
Differentiation degree			2.184	0.139			5.149	0.023
Low differentiation, undifferentiated	28(39.44)	24(28.24)			31(42.47)	21(25.30)		
Moderate and high differentiation	43(60.56)	61(71.76)			42(57.53)	62(74.70)		
Lymph node metastasis			23.586	< 0.001			18.134	< 0.001
Yes	43(60.56)	19(24.66)			42(57.53)	20(24.10)		
None	28(39.44)	66(75.34)			31(42.47)	63(75.90)		
ASA grading			15.250	< 0.001			15.647	< 0.001
I	13(18.31)	17(20.00)			9(12.33)	21(25.30)		
II	39(54.93)	64(75.29)			45(61.64)	58(69.88)		
III	19(26.76)	4(4.71)			19(26.03)	4(4.82)		
TNM staging			34.015	< 0.001			23.644	< 0.001
I	29(40.84)	56(65.88)			34(46.58)	51(61.45)		
II	16(22.54)	28(32.94)			15(20.55)	29(34.94)		
III	26(36.62)	1(1.18)			24(32.87)	3(3.61)		

Table 2 Early postoperative complications of two groups of patients

Postoperative complications	Low VFA group ($n=71$)	High VFA group ($n=85$)	χ^2	P
Incision fat liquefaction	1	8	4.558	0.033
Pancreatic fistula	3	12	4.356	0.037
Anastomotic fistula	2	2	0.033	0.855
Anastomotic bleeding	2	1	0.552	0.458
Lung infection	2	1	0.552	0.458
Urinary tract infection	2	0	2.425	0.119
Abdominal infection	6	17	4.105	0.043
deep venous thrombosis of the legs	3	0	3.662	0.056
Total	21	41	5.623	0.018

($P<0.05$). However, the low VFA group did not have significantly more anastomotic fistula, anastomotic bleeding, lung infections, urinary tract infections, or deep vein thrombosis of the lower limbs ($P>0.05$). See Table 2.

Postoperative survival

All patients were followed up for 0.5–48.5 months, with a median follow-up time of 30 months. Among them, 51 cases died (32.69%) and 105 cases survived (67.31%). The 1-year and 3-year survival rates were 87.2% and 66.7%, respectively. The 1-year and 3-year survival rates of patients with the high VFA group were 97.6% and 85.9%, respectively, while those of patients with the low VFA group were 74.6% and 43.4%, respectively. The overall survival rate of patients with the high VFA group was significantly higher than that of patients with the low VFA group, and the difference was statistically significant ($\chi^2=38.208$, $P<0.001$, Fig. 4a). The 1-year and 3-year survival rates of patients in the high BMI group were 97.6% and 84.7%, respectively, while those of patients in the low BMI group were 75.3% and 47.1%, respectively. The overall survival rate of patients in the high BMI group was significantly higher than that of patients in the low BMI group, and the difference was statistically significant ($\chi^2=29.767$, $P<0.001$, Fig. 4b).

Cox regression analysis of prognostic factors in patients with gastric cancer

In a one-variable Cox regression analysis, the outcomes for gastric cancer patients were affected by their age, tumor size, lymph node metastases, differentiation degree, postoperative complications, albumin, VFA, BMI, ASA grading, and TNM staging ($P<0.05$). The univariate significant indexes were analyzed in a multivariate Cox regression model. The results showed that age, differentiation degree, postoperative complications, VFA, ASA grading, and TNM staging were independent factors affecting the prognosis of patients with gastric cancer ($P<0.05$), as shown in Table 3.

Establishment and verification of nomogram

Six independent prognostic factors (age, differentiation degree, postoperative complications, VFA, ASA grading, and TNM staging) obtained by Cox multivariate analysis were included in the nomogram, and the nomogram model for predicting the 1- and 3-year survival rate after radical gastrectomy was constructed (Fig. 5). The nomogram allows us to obtain the integral of each prognostic factor, and we can draw one down on the total score scale of each integral to determine the 1- and 3-year survival rates of patients. The higher the total score, the worse the prognosis. Its consistency C index is 0.881 (95% CI: 0.852–0.910), which indicates that the model has good

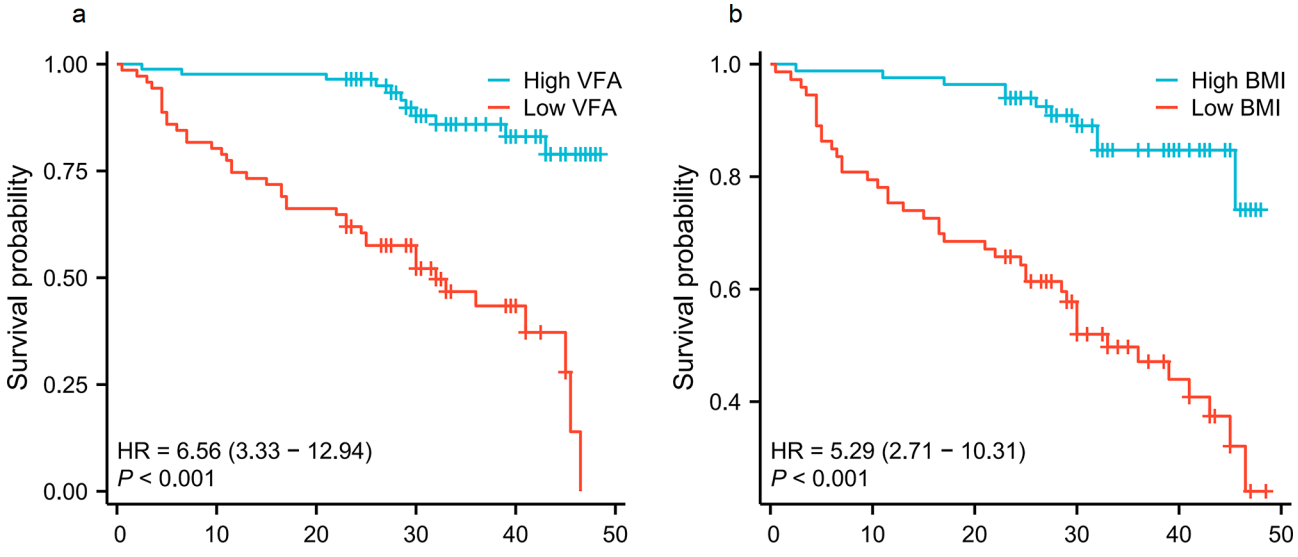

Fig. 4 Survival curve of prognosis of patients with gastric cancer. **a**: VFA, **b**: BMI

Table 3 Univariate and multivariate Cox regression models affecting the survival of patients with gastric cancer

Characteristics	Univariate analysis		Multivariate analysis	
	HR(95%CI)	*P*	HR(95%CI)	*P*
Age (≤ 60 vs. >60)	2.192(1.251 ~ 3.841)	0.006	2.069(1.015 ~ 4.216)	0.045
Gender (male vs. female)	1.436(0.775 ~ 2.658)	0.250		
Smoking (none vs. yes)	1.432(0.825 ~ 2.487)	0.202		
Drinking (none vs. yes)	1.231(0.701 ~ 2.163)	0.469		
Preoperative complications (none vs. yes)	1.794(1.000 ~ 3.219)	0.050		
Tumor size (≤ 5 vs. >5)	1.098(1.013 ~ 1.190)	0.022	1.065(0.910 ~ 1.245)	0.432
Lymph node metastasis (none vs. yes)	8.079(4.131 ~ 15.799)	< 0.001	1.781(0.752 ~ 4.221)	0.190
Differentiation degree (low differentiation, undifferentiated vs. moderate and high differentiation)	0.267(0.152 ~ 0.471)	< 0.001	0.480(0.251 ~ 0.918)	0.027
Postoperative complications (none vs. yes)	2.160(1.219 ~ 3.828)	< 0.001	2.785(1.402 ~ 5.530)	0.003
Albumin (≤ 30 vs. >30)	0.118(0.055 ~ 0.255)	< 0.001	0.528(0.209 ~ 1.335)	0.177
VFA (≤ 100 vs. >100)	0.153(0.078 ~ 0.303)	< 0.001	0.323(0.129 ~ 0.810)	0.016
BMI (≤ 25 vs. >25)	0.190(0.097 ~ 0.371)	< 0.001	0.452(0.200 ~ 1.017)	0.055
ASA grading		< 0.001		< 0.001
I	1		1	
II	1.318(0.560 ~ 3.103)		0.886(0.334 ~ 2.345)	
III	17.677(6.820 ~ 45.813)		5.939(1.650 ~ 21.374)	
TNM staging		< 0.001		0.012
I	1		1	
II	2.557(1.055 ~ 6.201)		1.566(0.555 ~ 4.421)	
III	38.838(17.673 ~ 85.347)		5.724(1.765 ~ 18.562)	

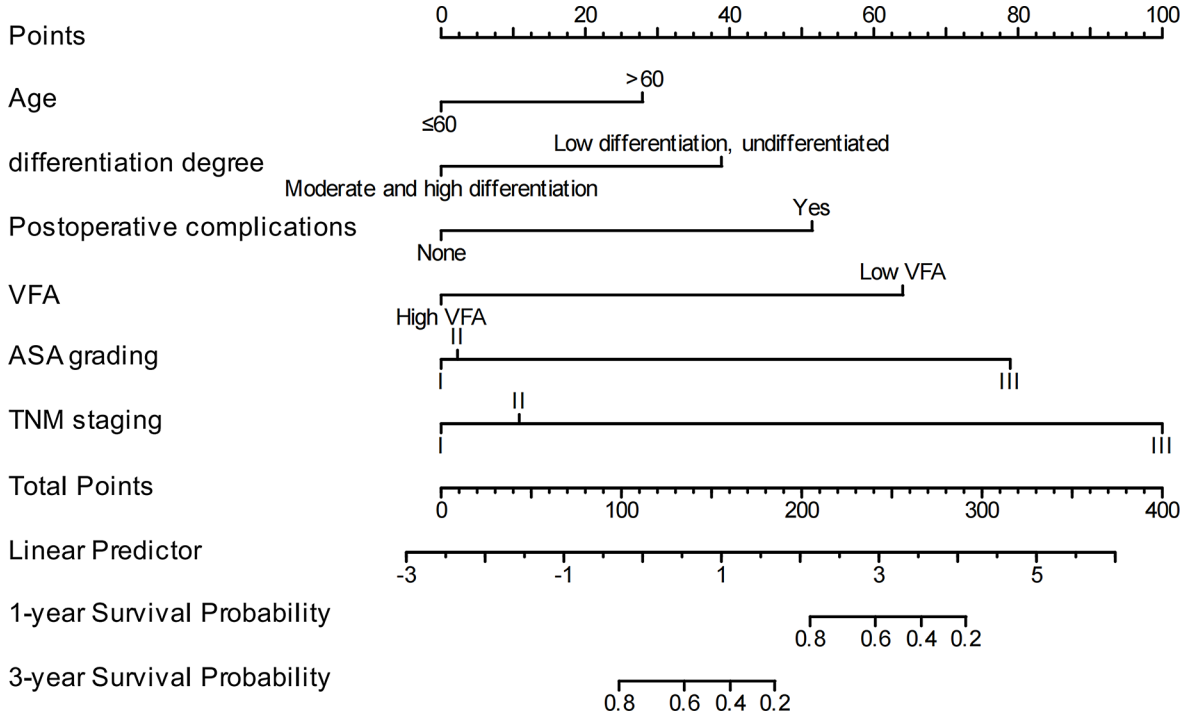

Fig. 5 A nomogram prediction model for prognosis of gastric cancer patients

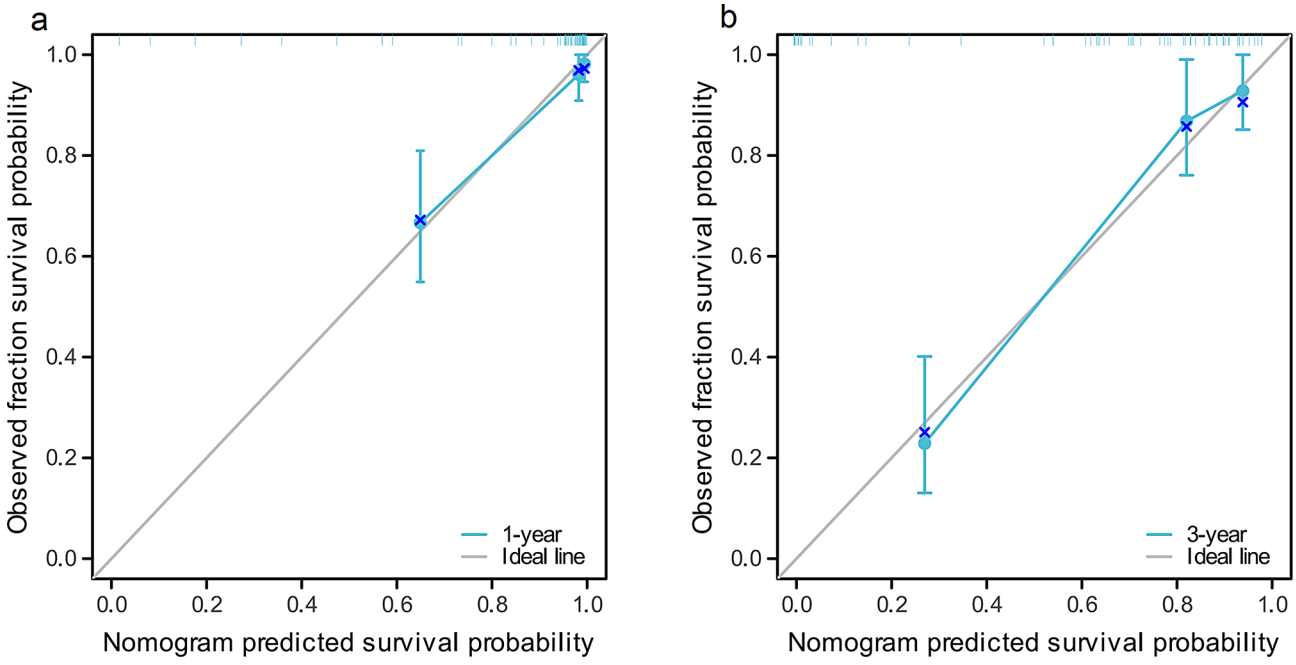

Fig. 6 Calibration curve of nomogram prediction model

prediction accuracy. It shows that the calibration curve (blue line) predicted by the nomogram for one year and three years is close to the gray line of the ideal situation, showing excellent consistency, indicating that the predicted value is in excellent agreement with the actual value (Fig. 6).

Discussion

With the development of the economy and the improvement of people's living standards, the proportion of obese people has obviously increased, which has gradually become a common health problem in the world. Obesity is not only closely related to the occurrence of cardiovascular and cerebrovascular diseases but also to the occurrence and development of tumors, and its epidemiological relationship with many cancers, has been confirmed [15]. A study on the correlation between abdominal fat and prognosis of pancreatic cancer patients [16] showed that patients with more Intra-abdominal fat had poor overall survival rate (OS); It is considered that visceral fat can induce the increase of serum insulin, inflammatory cytokines, angiogenesis factors and oxidative stress markers, and these factors may promote the growth and metastasis of tumors [17]. A retrospective cohort study in 2015 analyzed the relationship between body composition measurement indexes and the prognosis of HCC. By analyzing the body composition indexes such as visceral fat content, subcutaneous fat content, skeletal muscle content and muscle attenuation measured by CT in 1257 HCC patients, it was found that skeletal muscle loss, intramuscular fat deposition and visceral fat can independently predict the prognosis of HCC patients [18]. Another study analyzed the clinical data of 606 HCC patients, and found that the high preoperative visceral fat content was closely related to the poor prognosis after hepatectomy for hepatocellular carcinoma [19]. As for the correlation between colorectal cancer and visceral fat, Moon et al. [20] analyzed the clinical data of 161 patients who underwent radical colorectal cancer resection, and found that the disease-free survival rate of visceral obese patients was significantly reduced. Contrary to these findings, Harada et al. [21] believe that low visceral fat leads to a significant increase in the total mortality of patients with upper digestive tract cancer.

Radical gastrectomy is the main clinical treatment for gastric cancer at present. However, because the early symptoms of patients with gastric cancer are hidden, the detection rate is low, and gastric cancer has the characteristics of high malignancy and easy recurrence and metastasis, its surgical effect is often poor, resulting in a low 5-year survival rate of patients with gastric cancer after operation [22]. Related research also pointed out that obesity is related to the prognosis of patients with gastric cancer. Lee et al. [23] through a large cohort study, the results show that overweight or obese patients with gastric cancer tend to have better prognosis. Similarly, Kim et al. [24] also pointed out that BMI level is obviously related to the prognosis of gastric cancer patients, and the 5-year survival rate of patients with high BMI after gastrectomy is significantly higher than that of patients with normal BMI. However, there is no definite study on the relationship between VFA and long-term

survival after radical gastrectomy. Wang et al. [25] analyzed the clinical data of 859 patients who underwent radical gastrectomy in the First Affiliated Hospital of Wenzhou Medical University from 2009 to 2017. To explore the correlation between VFA and the prognosis of patients with gastric cancer (including OS and DFS). The results showed that compared with patients with low VFA, patients with high VFA had longer operation time, higher incidence of postoperative complications and longer hospital stay ($P<0.05$). while patients with high level VFA had no obvious correlation with the prognosis of gastric cancer patients, and could not be used as a prognostic biomarker of OS or DFS in gastric cancer patients. However, Uchida et al. [26] pointed out that VFA may be a risk factor for poor postoperative prognosis of patients with gastric cancer, and low preoperative skeletal muscle mass index (SMI) combined with visceral obesity is an independent risk factor for postoperative complications, while low VFA combined with low SMI is an important risk factor for OS (HR = 3.033; $P<0.001$) and RFS (HR = 2.144; $P=0.008$) of patients after gastrectomy. In addition, interestingly, a long-term prognosis study of gastrectomy for patients with advanced gastric cancer [27] found that the postoperative complications of patients with gastric cancer with more visceral fat before operation increased significantly, and the patients performed better in overall survival and disease-free survival. This result suggests that there is a phenomenon called "obesity paradox" in patients with advanced gastric cancer, which has also been reported in cardiovascular diseases, respiratory diseases, diabetes and some malignant tumors (lung cancer, gastric cancer, etc.) [28, 29]. The long-term prognosis (survival status) of patients with gastric cancer after operation is not only affected by oncology and nutrition-related factors, but also the baseline status of patients, such as age, complications, TNM staging and tumor differentiation, which is also considered as an important factor affecting the long-term prognosis after operation. In addition, the definition of high VFA is not standardized, and different thresholds of visceral fat area (VFA) (traditional ways to set critical values include searching relevant references, guideline consensus or ROC curve, as well as X-Tile and time ROC considering time factors, etc.) can also lead to different research results. The results of this study showed that the overall survival time of gastric cancer patients in the low VFA group is significantly shortened, the 3-year survival rate was significantly lower than that in high level VFA group (43.4% vs. 85.9%, $P<0.001$), suggesting that excessive visceral fat is beneficial to overall survival after operation. The author mainly considers that a malignant tumor can promote the body to be in a state of high metabolism and accelerate the decomposition of fat, which leads to the malnutrition of patients, and the clinical manifestations are extreme emaciation and low immunity, which leads to a bad prognosis. Excessive visceral fat can reflect a better nutritional level to a certain extent. Visceral obese patients have better nutritional status and greater energy storage in clinic. It can provide energy for the body when the body is in a negative energy balance, and can resist certain adverse risks and is beneficial to cancer patients. Visceral fat volume of patients with advanced tumor is often lower than that of patients with early tumor, which is related to tumor staging to some extent. This is also confirmed by analyzing VFA and TNM staging. In the high VFA group, 84 cases were patients with stage I and II gastric cancer (98.82%), while in the low VFA group, 45 cases were patients with stage I and II gastric cancer (63.38%). Finally, through univariate and multivariate Cox regression analysis, we also confirmed that low VFA level is an independent risk factor for poor prognosis of gastric cancer patients ($P<0.05$). In view of the limited research on the relationship between VFA and long-term survival rate, these results need to be further confirmed by larger-scale research.

For abdominal surgery, the operation difficulty of obese patients, especially those with high VFA, is significantly increased, the operation time is significantly prolonged, and the postoperative complications may increase. In this study, the risk of incision fat liquefaction and pancreatic fistula in patients with high VFA was higher than that in patients with low VFA ($P<0.05$). Studies have shown that [30] patients with visceral fat increase have a blurred surgical field, decreased differentiation between pancreatic tissue and adipose tissue, and unclear tissue boundary, which makes it difficult for operators to judge and may accidentally injure the pancreas and cause pancreatic fistula; in addition, because visceral obesity often exists with subcutaneous fat hypertrophy, it is easy to cause incision fat liquefaction. Fu Guanghua et al. [31] showed that the incidence of pancreatic leakage in patients with visceral obesity gastric cancer increased significantly after operation. Considering the increase of visceral fat can increase the difficulty of anastomosis during operation, affect the blood supply near the anastomosis and the quality of anastomosis, and then increase the risk of postoperative pancreatic leakage. It is consistent with the results of this study. In addition, in this study, the risk of abdominal infection in patients with high VFA is higher than that in patients with low VFA ($P<0.05$), which is consistent with previous research results [32]. Currently, the mechanism of infection remains unclear. The main considerations are as follows: in patients with an increase in visceral fat, it can be difficult to distinguish the boundary between the lesion and adjacent organs and tissues. This uncertainty also affects the surgical anatomical results, making the operation more difficult. Besides, excessive fat can lead to a decrease in adiponectin levels

and hematopoietic function through the TNF-SOCS3-STAT3 axis, and insufficient neutrophil production leads to the aggravation of infection. At the same time, excessive fat accumulation can lead to abnormal production of adipocytokines and infiltration of inflammatory macrophages and other immune cells, which can result in a long-term low-level inflammatory reaction in the body. This, in turn, increases the risk of postoperative infection [33, 34].

Multivariate Cox regression analysis showed that age, differentiation degree, postoperative complications, ASA grading, and TNM staging were all independent factors that affected the prognosis of gastric cancer patients. The literature highlights the clear correlation between age and the mortality rate of gastric cancer. Among the deceased, the proportion of 80-year-olds is twice and four times higher than that of 70-year-olds and 60-year-olds, respectively [35]. Postoperative complications, to a certain extent, reflect the prognosis of patients; that is, the corresponding complications after surgery indicate a poor prognosis, and pancreatic fistula and abdominal hemorrhage can lead to the postoperative death of patients with gastric cancer. Therefore, clinical medical staff should enhance perioperative management and reduce the incidence of postoperative complications, aiming to enhance the prognosis of patients with gastric cancer and boost the overall survival rate [36]. Furthermore, the prognosis of tumor patients closely correlates with the differentiation degree of a tumor. Roshanaei et al. [37] also pointed out that the degree of tumor differentiation is an independent risk factor for the prognosis of gastric cancer patients. The related literature [38] has confirmed that ASA grading is an independent risk factor for the prognosis of patients with gastric cancer. The higher the ASA grading, the greater the risk of death. TNM staging significantly influences the prognosis of gastric cancer patients as a comprehensive index [39]. Finally, we constructed a nomogram model according to the prognostic factors of gastric cancer patients determined by the Cox regression model, and its C-index was 0.881, which indicated that the model had good prediction accuracy. The calibration chart showed that the predicted survival rate was in high agreement with the actual survival rate, showing good consistency, and it could be applied to the medical system to evaluate the prognosis of patients in the future.

There are some limitations in this study. On the one hand, this study is a single-center, retrospective analysis that requires further verification by a larger sample. On the other hand, the sample size of this study is relatively small. Finally, there is no test set available to externally verify the survival model and nomogram. Therefore, in the future, it will be necessary to further expand the sample size, pass multiple centers, and conduct forward-looking research verification so as to further improve the prediction accuracy and popularity of the model.

In a word, high-level VFA can increase the difficulty of operation and increase the risk of fat liquefaction, abdominal infection, and pancreatic fistula after operation. The worse the prognosis, the higher the overall mortality in elderly patients with gastric cancer who have low differentiation, high postoperative complications, low VFA, and high ASA and TNM staging. In addition, the nomogram has high clinical application value, which can directly predict the prognosis of patients with gastric cancer and is conducive to individualized analysis of the prognosis of patients in clinic, providing reference and help for clinical decision-making. By improving risk stratification, the nomogram can help clinicians identify high-risk patients earlier, enabling more tailored treatment plans, closer follow-up, and better-informed decisions regarding interventions.

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Author contributions
Zc H: Designed the research and wrote the paper; Y W: Revised the paper; Zc H, Bh Z and Xb C: Participated in research work; Zc H and Zw W: Collected samples; Zc H and Xb C: Analyzed data and constructed figures; Y W: Responsible for project guidance.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethical approval
Ethical approval was not required in the treatment of the patient in this report.

Informed consent
Informed consent has been received from the subject.

Reserch involving human participants and/or animals
This article does not contain any studies with human participants or animals performed by any of the authors.

Competing interests
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Author details
[1]Department of General Surgery, Fuzhou General Teaching Hospital, Fujian University of Traditional Chinese Medicine, 900th Hospital of Joint Logistics Support Force, Fuzhou 350025, China

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References

1. Zeng Q, Li N, Pan XF, Chen L, Pan A. Clinical management and treatment of obesity in China. Lancet Diabetes Endocrinol. 2021;9(6):393–405. https://doi.org/10.1016/S2213-8587(21)00047-4. Erratum in: Lancet Diabetes Endocrinol. 2021;9(7):e2.
2. Singh D. Adaptive significance of female physical attractiveness: role of waist-to-hip ratio. J Pers Soc Psychol. 1993;65(2):293–307. https://doi.org/10.1037/0022-3514.65.2.293.
3. Sottier D, Petit JM, Guiu S, Hamza S, Benhamiche H, Hillon P, Cercueil JP, Krausé D, Guiu B. Quantification of the visceral and subcutaneous fat by computed tomography: interobserver correlation of a single slice technique. Diagn Interv Imaging. 2013;94(9):879–84. Epub 2013 May 28.
4. Chen X, Chen W, Huang Y, Xu J, Zeng Y, Shi M, Xu L, Zhang W, Zhu G, Mao C, Shen X. A quantified risk-scoring system including the visceral fat area for peritoneal metastasis of gastric cancer. Cancer Manag Res. 2019;11:2903–13. https://doi.org/10.2147/CMAR.S194356.
5. Zhang Y, Wang JP, Wang XL, Tian H, Gao TT, Tang LM, Tian F, Wang JW, Zheng HJ, Zhang L, Gao XJ, Li GL, Wang XY. Computed tomography-quantified body composition predicts short-term outcomes after gastrectomy in gastric cancer. Curr Oncol. 2018;25(5):e411–22. https://doi.org/10.3747/co.25.4014. Epub 2018 Oct 31.
6. Zhu Xiaoxuan L, Haipeng F, Xuegan, et al. Effect of preoperative individualized nutritional support on patients with gastric cancer at nutritional risk [J]. J Lanzhou Univ (Medical Edition). 2022;48(4):30–4. https://doi.org/10.13885/j.issn.1000-2812.2022.04.006.
7. Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, Bray F. Global Cancer Statistics 2020: Globocan estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin. 2021;71(3):209–49. Epub 2021 Feb 4.
8. Zeng H, Chen W, Zheng R, Zhang S, Ji JS, Zou X, Xia C, Sun K, Yang Z, Li H, Wang N, Han R, Liu S, Li H, Mu H, He Y, Xu Y, Fu Z, Zhou Y, Jiang J, Yang Y, Chen J, Wei K, Fan D, Wang J, Fu F, Zhao D, Song G, Chen J, Jiang C, Zhou X, Gu X, Jin F, Li Q, Li Y, Wu T, Yan C, Dong J, Hua Z, Baade P, Bray F, Jemal A, Yu XQ, He J. Changing cancer survival in China during 2003-15: a pooled analysis of 17 population-based cancer registries. Lancet Glob Health. 2018;6(5):e555–67. https://doi.org/10.1016/S2214-109X(18)30127-X.
9. Goulart A, Malheiro N, Rios H, Sousa N, Leão P. Influence of visceral fat in the outcomes of colorectal cancer. Dig Surg. 2019;36(1):33–40. https://doi.org/10.1159/000486143. Epub 2018 Mar 22.
10. Jain R, Austin Pickens C, Fenton JI. The role of the lipidome in obesity-mediated colon cancer risk. J Nutr Biochem. 2018;59:1–9. https://doi.org/10.1016/j.jnutbio.2018.02.015. Epub 2018 Mar 2.
11. Chen J, Wang Y, Shou X, Liu Q, Mei Z. Development and validation of a prognostic nomogram for Takotsubo syndrome patients in the intensive care units: a retrospective cohort study. Sci Rep. 2023;13(1):477. https://doi.org/10.1038/s41598-022-27224-5.
12. Balachandran VP, Gonen M, Smith JJ, DeMatteo RP. Nomograms in oncology: more than meets the eye. Lancet Oncol. 2015;16(4):e173–80. https://doi.org/10.1016/S1470-2045(14)71116-7.
13. Park SW, Lee HL, Doo EY, Lee KN, Jun DW, Lee OY, Han DS, Yoon BC, Choi HS, Lee KH. Visceral obesity predicts fewer lymph node metastases and better overall survival in colon cancer. J Gastrointest Surg. 2015;19(8):1513–21. https://doi.org/10.1007/s11605-015-2834-z. Epub 2015 May 5.
14. Examination Committee of Criteria for. New criteria for 'obesity disease' in Japan. Circ J. 2002;66(11):987–92. https://doi.org/10.1253/circj.66.987.
15. Kaaks R, Kühn T. Epidemiology: obesity and cancer–the evidence is fattening up. Nat Rev Endocrinol. 2014;10(11):644–5. https://doi.org/10.1038/nrendo.2014.168. Epub 2014 Sep 30.
16. Balentine CJ, Enriquez J, Fisher W, Hodges S, Bansal V, Sansgiry S, Petersen NJ, Berger DH. Intra-abdominal fat predicts survival in pancreatic cancer. J Gastrointest Surg. 2010;14(11):1832–7. https://doi.org/10.1007/s11605-010-1297-5. Epub 2010 Aug 20.
17. Pou KM, Massaro JM, Hoffmann U, Vasan RS, Maurovich-Horvat P, Larson MG, Keaney JF Jr, Meigs JB, Lipinska I, Kathiresan S, Murabito JM, O'Donnell CJ, Benjamin EJ, Fox CS. Visceral and subcutaneous adipose tissue volumes are cross-sectionally related to markers of inflammation and oxidative stress: the Framingham Heart Study. Circulation. 2007;116(11):1234–41. https://doi.org/10.1161/CIRCULATIONAHA.107.710509. Epub 2007 Aug 20.
18. Fujiwara N, Nakagawa H, Kudo Y, Tateishi R, Taguri M, Watadani T, Nakagomi R, Kondo M, Nakatsuka T, Minami T, Sato M, Uchino K, Enooku K, Kondo Y, Asaoka Y, Tanaka Y, Ohtomo K, Shiina S, Koike K. Sarcopenia, intramuscular fat deposition, and visceral adiposity independently predict the outcomes of hepatocellular carcinoma. J Hepatol. 2015;63(1):131–40. https://doi.org/10.1016/j.jhep.2015.02.031. Epub 2015 Feb 24.
19. Hamaguchi Y, Kaido T, Okumura S, Kobayashi A, Shirai H, Yao S, Yagi S, Kamo N, Seo S, Taura K, Okajima H, Uemoto S. Preoperative visceral adiposity and muscularity predict poor outcomes after hepatectomy for hepatocellular carcinoma. Liver Cancer. 2019;8(2):92–109. https://doi.org/10.1159/000488779. Epub 2018 Jun 5.
20. Moon HG, Ju YT, Jeong CY, Jung EJ, Lee YJ, Hong SC, Ha WS, Park ST, Choi SK. Visceral obesity may affect oncologic outcome in patients with colorectal cancer. Ann Surg Oncol. 2008;15(7):1918–22. https://doi.org/10.1245/s10434-008-9891-4. Epub 2008 Apr 5.
21. Harada K, Baba Y, Ishimoto T, Kosumi K, Tokunaga R, Izumi D, Ida S, Imamura Y, Iwagami S, Miyamoto Y, Sakamoto Y, Yoshida N, Watanabe M, Baba H. Low visceral fat content is associated with poor prognosis in a database of 507 upper gastrointestinal cancers. Ann Surg Oncol. 2015;22(12):3946–53. https://doi.org/10.1245/s10434-015-4432-4. Epub 2015 Feb 25.
22. Wakahara T, Kanemitsu K, Asari S, Tsuchida S, Ueno N, Toyokawa A, Sasako M. The combined use of drainage amylase concentration and serum C-reactive protein as predictors of pancreas-related complications after elective gastrectomy. Oncology. 2020;98(2):111–6. https://doi.org/10.1159/000503581. Epub 2019 Oct 10.
23. Lee JH, Park B, Joo J, Kook MC, Kim YI, Lee JY, Kim CG, Choi IJ, Eom BW, Yoon HM, Ryu KW, Kim YW, Cho SJ. Body mass index and mortality in patients with gastric cancer: a large cohort study. Gastric Cancer. 2018;21(6):913–24. https://doi.org/10.1007/s10120-018-0818-x. Epub 2018 Apr 12.
24. Kim EY, Jun KH, Kim SY, Chin HM. Body mass index and skeletal muscle index are useful prognostic factors for overall survival after gastrectomy for gastric cancer: Retrospective cohort study. Med (Baltim). 2020;99(47):e23363. https://doi.org/10.1097/MD.0000000000023363.
25. Wang SL, Ma LL, Chen XY, Zhou DL, Li B, Huang DD, Yu Z, Shen X, Zhuang CL. Impact of visceral fat on surgical complications and long-term survival of patients with gastric cancer after radical gastrectomy. Eur J Clin Nutr. 2018;72(3):436–45. https://doi.org/10.1038/s41430-017-0032-7. Epub 2017 Nov 29.
26. Uchida T, Sekine R, Matsuo K, Kigawa G, Umemoto T, Tanaka K. Impact of body fat and muscle quantity on short- and long-term outcome after gastrectomy for cancer. Clin Nutr. 2022;41(7):1467–74. Epub 2022 May 6.
27. Matsui R, Inaki N, Tsuji T, Kokura Y, Momosaki R. Preoperative high visceral fat increases severe complications but improves long-term prognosis after gastrectomy for patients with advanced gastric cancer: a propensity score matching analysis. Nutrients. 2022;14(20):4236. https://doi.org/10.3390/nu14204236.
28. Prado CM, Gonzalez MC, Heymsfield SB. Body composition phenotypes and obesity paradox. Curr Opin Clin Nutr Metab Care. 2015;18(6):535–51. https://doi.org/10.1097/MCO.0000000000000216.
29. Cespedes Feliciano EM, Kroenke CH, Caan BJ. The obesity paradox in cancer: how important is muscle? Annu Rev Nutr. 2018;38:357–79. https://doi.org/10.1146/annurev-nutr-082117-051723. Epub 2018 May 4.
30. Li Jing L, Xuan C. Peri-operative effect of visceral fat on patients undergoing gastrectomy [J]. china J Mod Med. 2017;27(26):83–6. https://doi.org/10.3969/j.issn.1005-8982.2017.26.017.
31. Fu Guanghua N, Zhaojian Z, Yanbing, et al. Influence of visceral fat area on laparoscopic radical gastrectomy for gastric cancer [J]. Chin J Gastrointest Surg. 2015;8804–7. https://doi.org/10.3760/cma.j.issn.1671-0274.2015.08.023.
32. Qiu GL, Li XW, Wang HJ, Wang PX, Liu JH, Zhu MK, Liao XH, Fan L, Che XM. [Influence of visceral lipids obesity on the early postoperative complications after radical gastrectomy]. Zhonghua Wei Chang Wai Ke Za Zhi. 2022;25(7):596–603. https://doi.org/10.3760/cma.j.cn441530-20210907-00365. Chinese.
33. Masamoto Y, Arai S, Sato T, Yoshimi A, Kubota N, Takamoto I, Iwakura Y, Yoshimura A, Kadowaki T, Kurokawa M. Adiponectin enhances antibacterial activity of hematopoietic cells by suppressing bone marrow inflammation. Immunity. 2016;44(6):1422–33. https://doi.org/10.1016/j.immuni.2016.05.010. Epub 2016 Jun 14.
34. Song Z, Xie W, Strong JA, Berta T, Ulrich-Lai YM, Guo Q, Zhang JM. High-fat diet exacerbates postoperative pain and inflammation in a sex-dependent manner. Pain. 2018;159(9):1731–41. https://doi.org/10.1097/j.pain.0000000000001259.
35. Asaka M, Kobayashi M, Kudo T, Akino K, Asaka Y, Fujimori K, Kikuchi S, Kawai S, Kato M. Gastric cancer deaths by age group in Japan: Outlook on preventive measures for elderly adults. Cancer Sci. 2020;111(10):3845–53. https://doi.org/10.1111/cas.14586. Epub 2020 Aug 18.

36. Xiao Q, Li X, Duan B, Li X, Liu S, Xu B, Shi S, Zhang J, Qin H, Duan X, Pu Y. Clinical significance of controlling nutritional status score (CONUT) in evaluating outcome of postoperative patients with gastric cancer. Sci Rep. 2022;12(1):93. https://doi.org/10.1038/s41598-021-04128-4.
37. Roshanaei G, Ghannad MS, Jafarabadi MA, Faradmal J, Sadighi S. Prognostic impact of risk factors in patients with gastric cancer in Iran. Asian Pac J Cancer Prev. 2011;12(11):3005–8.
38. Zheng Qiang Z, Man W, Cuina W, Zan Y, Changjun, Lu, Xianfu. ASA-PS classification and long-term risk of all-cause death in patients with gastric cancer [J]. Int J Anesthesiology Resusc. 2022;43(4):354–8. https://doi.org/10.3760/cma.j.cn321761-20211122-00518.
39. Wittekind C. The development of the TNM classification of gastric cancer. Pathol Int. 2015;65(8):399–403. https://doi.org/10.1111/pin.12306. Epub 2015 Jun 3.

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