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# CT-based body composition analysis to study the effect of visceral obesity on postoperative complications in ovarian cancer: implications for young patients

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## Abstract

**Purpose** Ovarian cancer is characterized by high morbidity and mortality, with surgery remaining the primary treatment modality. The occurrence of postoperative complications significantly impacts patient prognosis and quality of life. As cancer increasingly affects younger individuals, it is crucial to consider age-related differences. Meanwhile, epidemiology suggests a high prevalence of obesity among females. This study aims to evaluate the effect of visceral obesity (VO), diagnosed using computed tomography (CT)-based body composition analysis, on postoperative complications.

**Methods** A total of 309 patients operated between 2017 and 2022 were included in this study. Patients were stratified into two age groups: ≤65 years (younger group) and > 65 years (older group). The receiver operating characteristic (ROC) curve was employed to determine the threshold value for VO. Univariate and multivariate analyses were conducted to identify risk factors associated with postoperative complications.

**Results** According to the cut-off value, the incidence of postoperative complications was significantly higher in younger patients with VO compared to the non-VO group (56% vs. 36%, $p < 0.01$), whereas no difference was observed in older age groups. VO (OR = 1.980, $p = 0.031$), total protein < 65 g/L (OR = 3.704, $p = 0.045$), primary debulking surgery (PDS) (OR = 0.369, $p = 0.026$), duration of surgery (OR = 1.004, $p = 0.006$) and intraoperative bleeding volume (OR = 1.003, $p < 0.01$) were identified as independent predictors of postoperative complications in the younger age group. International Federation of Gynecology and Obstetrics (FIGO) stage for III or IV (OR = 4.00, $p = 0.029$) remained as the only independent predictor for the older age group.

**Conclusions** In young ovarian cancer patients, VO may serve as a predictor for postoperative complications, and appropriate preventive measures may be beneficial in reducing the incidence of postoperative complications.

**Highlights**

- Computed tomography scan images could be used for body composition analysis after processing.

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- The fat area greater than 330.08 $cm^2$ at the 12th level of the chest was considered visceral obesity.
- Ovarian cancer patients aged ≤ 65 years with visceral obesity were more likely to develop postoperative complications.

**Keywords** Ovarian cancer, Visceral obesity, Computed tomography, Visceral fat area, Postoperative complications

## Introduction

### Ovarian cancer and postoperative complications

Ovarian cancer (OC) is the fifth leading cause of cancer-related death among women in the United States and other developed countries, accounting for approximately 5% of all cancer-related mortality [1]. In China, 57,090 new cases and 39,306 deaths were reported in 2022 [2]. The insidious nature of ovarian cancer symptoms frequently compels patients to undergo complex surgical treatment at advanced stage rather than early ones [3]. However, the dilemma is that while surgery is necessary, complex procedures can lead to serious complications. These complications can prolong the recovery period and delay the initiation of adjuvant therapy, potentially worsening the overall prognosis [4]. Therefore, it is particularly important to evaluate and manage the risk of postoperative complications before surgery to maximize patient survival.

### Visceral obesity

Obesity is a well-established risk factor for hypertension, diabetes, ischemic heart disease, and cancer [5]. In recent years, research has increasingly focused on the metabolic syndrome associated with obesity, which may promote tumor development through chronic inflammation and insulin resistance, both of which can directly or indirectly stimulate cell proliferation. In addition, obesity may influence the risk of developing various tumors and alter their response to systemic therapy [6]. Evidence suggests that obese patients have a significantly higher rate of postoperative complications following major abdominal surgery compared to non-obese counterparts [7]. However, traditional measures of obesity, such as body mass index (BMI), often fail to accurately reflect the nutritional status of cancer patients due to tumor-related weight changes or the presence of ascites. It has been demonstrated that obesity, as defined by BMI, is not statistically associated with postoperative complications following abdominal surgery [8]. Notably, some patients may possess a large amount of body fat despite a normal BMI. In such case, fat constitutes the major component of their body weight rather than bone, muscle or visceral tissue [9]. Data indicate that this subset accounts for approximately 44% of the population [10]. Therefore, the accumulation of excessive visceral adipose tissue, referred to as VO, is regarded as a more reliable indicator of obesity than BMI, particularly in Asians [11]. This reliability is further supported by evidence demonstrating that VO significantly influences postoperative complications in conditions such as colorectal cancer [12] and advanced ovarian cancer [13]. In Japan, the diagnostic criteria for intra-abdominal obesity currently define a visceral fat area exceeding 100 $cm^2$ at the level of the umbilicus [14, 15]. However, standardized diagnostic criteria are still lacking in China, resulting in variability in clinical practice. Furthermore, specific criteria for diagnosing VO in females, based on visceral adipose tissue (VAT) measurements obtained from chest CT images at the T12 level, have not yet been established. This study aims to address these gaps by identifying an optimal cut-off value for visceral fat area using chest CT to define VO. Furthermore, it investigates the effect of VO on postoperative complications in ovarian cancer patients across different age groups and explores the contribution of other factors to postoperative complications. These findings seek to provide a foundation for standardized diagnostic approaches and improve the management of ovarian cancer patients.

## Patients and methods

### Patients

The subjects of this study were patients diagnosed with ovarian cancer who underwent radical ovarian cancer surgery at the First Hospital of Wenzhou Medical University between August 2017 and August 2022. Among the 656 ovarian cancer patients attending the hospital, 172 patients either declined surgery, opted for chemotherapy alone, or discontinued treatment. A total of 138 patients were excluded from the study due to the absence of preoperative plain CT scans of the chest or abdomen, or the use of enhanced CT or plain CT scans from other hospitals that were incompatible with the image processing software. Additionally, 30 patients with postoperative paraffin pathology indicating benign ovarian tumors or secondary malignancies were also excluded from this study. Seven Patients left the hospital after surgery without adhering to medical advice, resulting in missing data on short-term postoperative complications. Ultimately, 309 ovarian cancer patients who met the inclusion criteria were included in the study (Fig. 1). Because 3 patients were admitted on a flatbed or in a wheelchair, several individual BMI values were unavailable. In addition, preoperative liver function checklist records were unavailable for 9 patients. To minimize possible deviations, all surgeries were performed by attending or chief physician, each with over 200 cases of surgical experience. The surgical resection scopes strictly adhered to

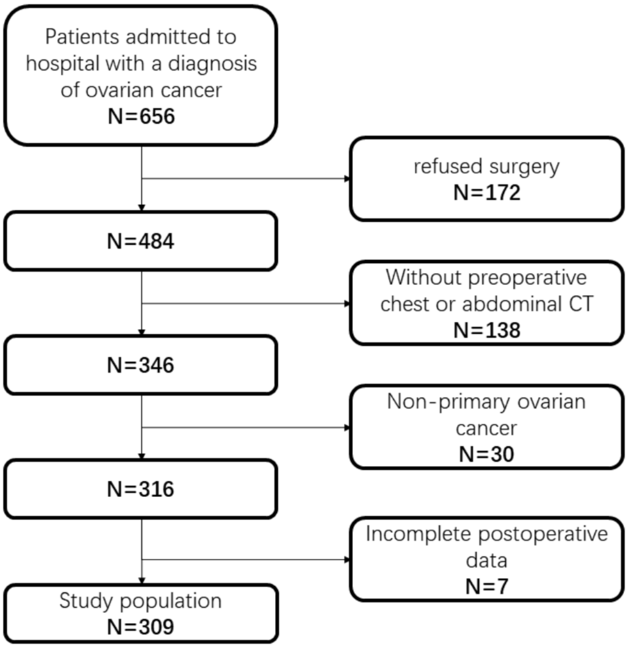


**Fig. 1** Flowchart of research subject selection

standardized guidelines. The study was also conducted with the approval from the Research Ethics Committee of the First Affiliated Hospital of Wenzhou Medical University and was exempted from requiring informed consent forms (KY2023-R288).

## Data collection

Three categories of information were collected for each patient: (1) Preoperative data, including clinicopathological characteristics such as age (years), BMI (kg/m²) based on height and weight, hemoglobin concentration (g/L), total serum protein (g/L), serum albumin (g/L), American Society of Anesthesiologists (ASA) class, Nutrition Risk Screening 2002 (NRS 2002) score, preoperative comorbidities, previous abdominal surgery and visceral fat area (VFA). (2) Surgical data, including the treatment plan, surgical approach, surgical outcome, lymph node dissection, intraoperative blood loss (mL), and whether an intraoperative blood transfusion was performed. (3) Postoperative data, including postoperative complications classified as grade I-IV according to the Clavien-Dindo classification system, with the observation period extending from the completion of surgery to the day of discharge.

## Body composition analysis

Visceral fat was defined as all adipose tissue located within the abdominal wall boundary. Single-slice measurements were considered closely correlated with the total volume. All patients underwent preoperative CT examinations within one week before their surgeries. This short interval was selected to ensure that the imaging accurately reflects the body composition at the time of the operation. Using image processing software with a predefined threshold of -150 to -50 Hounsfield Units (HU), the adipose tissue contours were displayed, and tissue edges were manually delineated. The VFA was then measured *(*Fig. 2*)*. ROC curves were utilized to determine the cut-off values for diagnosing VO.

## Statistical analysis

Statistical analysis was performed using Microsoft® Excel® 2016 MSO (version 2302 Build 16.0.16130.20298) and

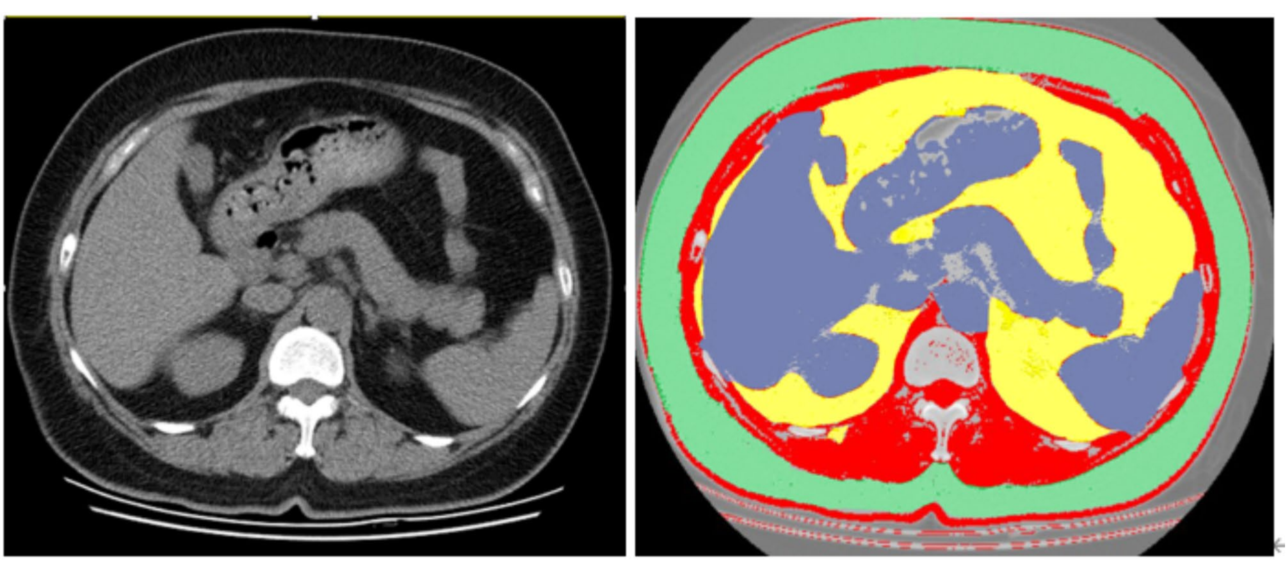

**Fig. 2** An example of segmentation of skeletal muscle area (red), visceral adipose tissue (yellow), and subcutaneous adipose tissue (green) from an axial image at the level of T12 of a CT scan. The visceral fat area (VFA)is the area of the yellow part

SPSS software (version R26.0.0.0, IBM Corp). To address missing values in the dataset, we employed multiple linear regression models using SPSS software. Predictor variables with complete data, including age, BMI, and preoperative hemoglobin levels, were utilized to estimate missing values for preoperative liver function indicators (e.g., total protein and albumin). This method ensures that the relationships between variables are maintained, minimizing potential bias while preserving the overall dataset integrity. The imputation process was performed separately for each missing variable to ensure the accuracy of the estimates. After imputing missing values using regression analysis, one-sample Kolmogorov-Smirnov tests were conducted to assess the normality of continuous numerical variables. Independent sample t-tests (or Mann-Whitney U tests) were employed to assess differences in continuous variables. Pearson's $\chi 2$ tests (or Fisher's exact tests) were used to compare differences between categorical variables. Univariate and multivariate logistic regression analyses were performed to screen for underlying risk factors associated with complications. A p-value of $< 0.05$ (two-tailed) was considered statistically significant.

## Results

### Selection of the threshold value for the diagnosis of VO

Between August 2017 and August 2022, a total of 309 ovarian cancer patients were included in this study. Among them, 171 patients experienced postoperative complications of grade 2 or higher, while 138 patients did not. Visceral fat data were obtained for all patients through image processing of T12 CT images and quantification of the VFA. Patients with postoperative complications had a significantly larger VFA compared to those without complications ($369.14 \pm 62.09$ cm² vs. $347.19 \pm 61.97$ cm², $p = 0.002$). An ROC curve was generated based on VFA and postoperative complication data, and the area under the curve (AUC) was calculated to assess the discrimination power of VFA in predicting postoperative complications. The optimal cut-off point was determined by the maximum value of the Youden index *(*Fig. 3*.)*. According to this cut-off value, patients with a VFA greater than 330.08 cm² were classified as having VO, while those with a VFA below this threshold were classified as non-VO. Additionally, patients with VO were found to be more likely to experience postoperative complications (62.7% vs. 41.7%, $p<0.01$).

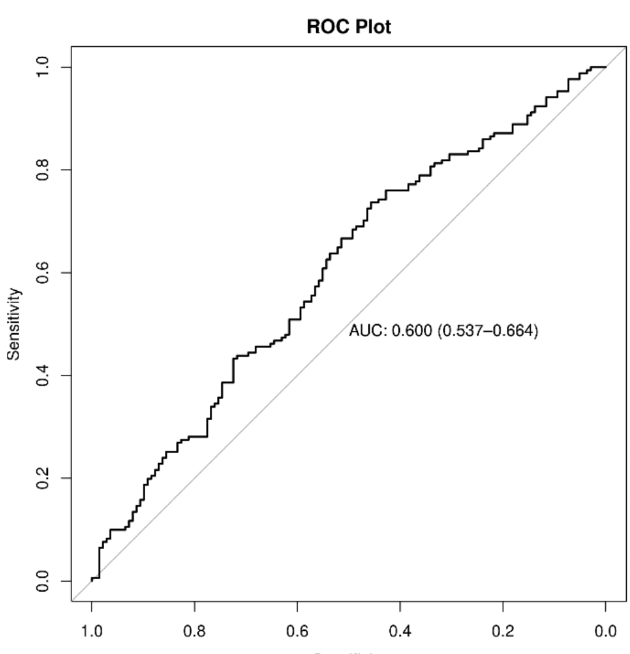


**Fig. 3** ROC curve based on postoperative complications versus visceral fat area

### Clinicopathological features of patients in different age groups

During the preliminary statistical analysis, VO was not identified as an independent risk factor for postoperative complications across all age groups of ovarian cancer patients ($p = 0.074$). Consequently, the patients were stratified into two groups: 234 patients aged less than or equal to 65 years were categorized as the low-age group, while 75 patients aged more than 65 years were categorized as the high-age group. In the low-age group, the mean age was 51 years (interquartile range: 14 years), and the average BMI was $22.76 \pm 3.20$ kg/m². In the high-age group, the mean age was 69 years (interquartile range: 7 years) and the mean BMI was $23.39 \pm 3.72$ kg/m².

In the low-age group, there were 140 patients with VO and 94 non-VO patients. Compared to non-VO patients, VO patients were older (52.50 years vs. 46.00 years, $p<0.01$), had higher BMI ($24.29 \pm 2.83$ kg/m² vs. $20.49 \pm 2.22$ kg/m², $p<0.01$), lower total protein levels (73.85 g/L vs. 76.45 g/L, $p = 0.006$), lower albumin levels (41.60 g/L vs. 43.40 g/L, $p = 0.002$), and longer operation times (216.00 min vs. 170.00 min, $p = 0.007$). Regarding the surgical approach, a higher proportion of open surgeries was performed on VO patients (87.10% vs. 72.3%, $p = 0.004$). In addition, the incidence of epithelial ovarian cancer was significantly higher in VO patients (90.7% vs. 79.8%, $p = 0.007$). In the high-age group, there were 61 patients with VO and 14 non-VO patients. No significant differences were observed between VO patients and non-VO patients, except for a higher BMI ($24.12 \pm 3.64$ kg/m² vs. $20.18 \pm 2.02$ kg/m², $p<0.01$). Other clinicopathological features are presented in Table 1.

### Effect of VO on short-term postoperative complications

The relationship between VO and postoperative complications across different age groups is presented in

**Table 1** The relationship between VO and clinical characteristics of patients with OC in younger age groups

| **Age≤65** | **Total(*n*=234)** | **VO (*n*=140)** | **Non-VO (*n*=94)** | ***p*** | | **Total(*n*=234)** | **VO (*n*=140)** | **Non-VO (*n*=94)** | ***p*** |
|---|---|---|---|---|---|---|---|---|---|
| **Age**, median (IQR), years | | | | | **Albumin**, median (IQR), g/L | | | | |
| | 51.0(14.0) | 52.50(12.0) | 46.0(15.0) | <0.01* | | 42.70(5.13) | 41.60(5.50) | 43.40(4.58) | 0.002* |
| **BMI**, mean (SD), $cm^2$ / $m^2$ | | | | | **Duration of surgery**, median (IQR), min | | | | |
| | 22.76(3.20) | 24.29(2.83) | 20.49(2.22) | <0.01* | | 200.0(142.0) | 216.0(139.50) | 170.0(150.0) | 0.007* |
| **Hemoglobin**, median (IQR), g/L | | | | | **Intraoperative bleeding** volume, median (IQR), ml | | | | |
| | 125.0(21.0) | 126.0(20.75) | 123.50(22.25) | 0.110* | | 100.0(250.0) | 100.0(250.0) | 100.0(250.0) | 0.098 |
| **Total protein**, median (IQR), g/L | | | | | **NRS 2002** scores, median (IQR) | | | | |
| | 74.55(7.75) | 73.85(7.30) | 76.45(7.60) | 0.006* | | 0.0(0.0) | 0.0(1.0) | 0.0(0.0) | 0.364 |
| **ASA** | | | | 0.703 | **Diabetes** | | | | 0.321 |
| I | 161(68.8%) | 95(67.9%) | 66(70.20%) | | No | 225(96.2%) | 133(95.0%) | 92(97.90%) | |
| II/III | 73(31.2%) | 45(32.1%) | 28(29.8%) | | Yes | 9(3.8%) | 7(5.0%) | 2(2.10%) | |
| **Cardiopulmonary comorbidity** | | | | 0.295 | **History of abdominal operation** | | | | 0.966 |
| No | 197(84.2%) | 115(82.1%) | 82(87.2%) | | No | 90(38.5%) | 54(38.6%) | 36(38.3%) | |
| Yes | 37(15.8%) | 25(17.9%) | 12(12.8%) | | Yes | 144(61.5%) | 86(61.4%) | 58(61.7%) | |
| **Therapy method** | | | | 0.672 | **Surgical satisfaction evaluation** | | | | 0.169 |
| Radical surgery | 102(43.6%) | 58(41.4%) | 44(46.8%) | | R0 | 205(87.6%) | 120(85.7%) | 85(90.4%) | |
| PDS+CT | 100(42.7%) | 63(45.0%) | 37(39.4%) | | R1 | 16(6.8%) | 9(6.4%) | 7(7.4%) | |
| NACT+IDS | 32(13.7%) | 19(13.6%) | 13(13.8%) | | R2 | 13(5.6%) | 11(7.9%) | 2(2.1%) | |
| **Operation method** | | | | 0.004* | **FIGO stage** | | | | 0.181 |
| Open | 190(81.2%) | 122(87.1%) | 68(72.3%) | | I/II | 132(56.4%) | 74(52.9%) | 58(61.7%) | |
| Laparoscopy | 44(18.8%) | 18(12.9%) | 26(27.7%) | | III/IV | 102(43.6%) | 66(47.1%) | 36(38.3%) | |
| **Lymph node dissection** | | | | 0.313 | **Postoperative pathology** | | | | 0.007* |
| Uncleaned/without metastatic | 199(85.0%) | 120(85.7%) | 79(84.0%) | | Epithelial tumor | 202(86.3%) | 127(90.7%) | 75(79.8%) | |
| Positive pelvic lymph nodes | 16(6.8%) | 7(5.0%) | 9(9.6%) | | Germinoma | 15(6.4%) | 3(2.1%) | 12(12.8%) | |
| Positive para-aortic lymph nodes | 19(8.1%) | 13(9.3%) | 6(6.4%) | | Sex cord-stromal tumor | 15(6.4%) | 9(6.4%) | 6(6.4%) | |
| **Intraoperative blood transfusion** | | | | 0.919 | Other types | 2(0.9%) | 1(0.7%) | 1(1.1%) | |
| No | 206(88.0%) | 123(87.9%) | 83(88.3%) | | | | | | |
| Yes | 28(12.0%) | 17(12.1%) | 11(11.7%) | | | | | | |

*Statistically significant ($P$ <0.05)

SD: standard deviation; IQR: interquartile range; BMI: body mass index; NRS: nutritional risk screening; ASA: American Society of Anesthesiologists; Comprehensive staged surgery: hysterectomy, bilateral salpingo-oophorectomy, omentectomy, pelvic lymph nodes dissection and para-aortic lymph node dissection; PDS: primary debulking surgery (hysterectomy, bilateral salpingo-oophorectomy, comprehensive staging and debulking as needed were performed after the patient's suitability for surgery and the best likelihood of cytoreduction were assessed); CT: chemotherapy (patients received 4 to 6 cycles of intravenous platinum-based therapy); NACT: neoadjuvant chemotherapy (after being confirmed poor surgical candidate or low likelihood of optimal cytoreduction, patients received 3 to 4 cycles of intravenous platinum-based therapy before interval debulking surgery); IDS: interval debulking surgery (completion hysterectomy, bilateral salpingo-oophorectomy and cytoreduction); R0: no visual residual tumor; R1: single residual tumor lesions with maximum longitudinal≤1 cm; R2: single residual tumor lesions with maximum longitudinal>1 cm

Table 2. Postoperative complications were classified using the Clavien-Dindo criteria. A patient experiencing more than one complication was classified according to the highest-grade complication. In both age groups, hypoalbuminemia was the most common postoperative complication. In the low-age group, a total of 113 patients experienced grade 2 or higher postoperative complications, including 79 from the VO group and 34 from the non-VO group. Notably, the only patient who developed a postoperative intestinal anastomotic fistula requiring secondary surgery was from the VO group. Three patients in the VO group were admitted to the intensive care unit (ICU) postoperatively, two developed shocks, and one suffered severe organ failure. Grade 3 or higher complications were not observed in the non-VO group. In summary, the VO group had a significantly higher rate of postoperative complications compared to the non-VO group in the low-age patients ($p$<0.01). Conversely, there was no statistical difference in postoperative complications between the VO and non-VO groups in elderly patients ($p$ = 1.00).

### Analysis of factors affecting postoperative complications

Univariate and multivariate analyses of factors influencing the postoperative course are presented in Table 3 and Table 4. In the low-age group, univariate logistic analysis

**Table 2** The relationship between VO and clinical characteristics of patients with OC in older age groups

**Age>65**

| | **Total (*n*=75)** | **VO (*n*=61)** | **Non-VO (*n*=14)** | ***p*** | | **Total (*n*=75)** | **VO (*n*=61)** | **Non-VO (*n*=14)** | ***p*** |
|---|---|---|---|---|---|---|---|---|---|
| **Age**, median (IQR), years | | | | | **Albumin**, median (IQR), g/L | | | | |
| | 69.0(7.0) | 69.0(5.50) | 68.50(12.50) | 0.742 | | 40.7(6.10) | 40.60(6.30) | 41.35(4.79) | 0.536 |
| **BMI**, mean (SD), $cm^2$ / $m^2$ | | | | | **Duration of surgery**, median (IQR), min | | | | |
| | 23.39(3.72) | 24.12(3.64) | 20.18(2.02) | <0.01* | | 227.0(146.0) | 234.0(171.0) | 176.0(83.40) | 0.185 |
| **Hemoglobin**, median (IQR), g/L | | | | | **Intraoperative bleeding** volume, median (IQR), ml | | | | |
| | 115.33(16.67) | 114.28(17.03) | 119.93(14.67) | 0.256 | | 300.0(400.0) | 300.0(400.0) | 150.0(525.0) | 0.502 |
| **Total protein**, median (IQR), g/L | | | | | **NRS 2002** scores, median (IQR) | | | | |
| | 73.80(8.40) | 73.80(7.85) | 74.15(11.85) | 0.935 | | 1.0(1.0) | 1.0(1.0) | 1.00(2.25) | 0.110 |
| **ASA** | | | | 0.636 | **Diabetes** | | | | 0.440 |
| I | 44(58.7%) | 35(57.4%) | 9(64.3%) | | No | 62(82.7%) | 49(80.3%) | 13(92.9%) | |
| II/III | 31(41.3%) | 26(42.6%) | 5(35.7%) | | Yes | 13(17.3%) | 12(19.7%) | 1(7.1%) | |
| **Cardiopulmonary comorbidity** | | | | 0.803 | **History of abdominal operation** | | | | 0.067 |
| No | 57(76.0%) | 46(75.4%) | 11(78.6%) | | No | 37(49.3%) | 27(44.3%) | 10(71.4%) | |
| Yes | 18(24.0%) | 15(24.6%) | 3(21.4%) | | Yes | 38(50.7%) | 34(55.7%) | 4(28.6%) | |
| **Therapy method** | | | | 0.335 | **Surgical satisfaction evaluation** | | | | 0.787 |
| Radical surgery | 15(20.0%) | 12(19.7%) | 3(21.4%) | | R0 | 57(76.0%) | 45(73.8%) | 12(85.7%) | |
| PDS+CT | 43(57.3%) | 33(54.1%) | 10((71.4%) | | R1 | 9(12.0%) | 8(13.1%) | 1(7.1%) | |
| NACT+IDS | 17(22.7%) | 16(26.2%) | 1(7.1%) | | R2 | 9(12.0%) | 8(13.1%) | 1(7.1%) | |
| **Operation method** | | | | 0.586 | **FIGO stage** | | | | 0.553 |
| Open | 69(92.0%) | 55(90.2%) | 14(100%) | | I/II | 27(36.0%) | 21(34.4%) | 6(42.9%) | |
| Laparoscopy | 6(8.0%) | 6(9.8%) | 0(0.00%) | | III/IV | 48(64.0%) | 40(65.6%) | 8(57.1%) | |
| **Lymph node dissection** | | | | 0.413 | **Postoperative pathology** | | | | 0.444 |
| Uncleaned/without metastatic | 63(84.0%) | 52(85.2%) | 11(78.6%) | | Epithelial tumor | 68(90.7%) | 56(91.8%) | 12(85.7%) | |
| Positive pelvic lymph nodes | 9(12.0%) | 6(9.8%) | 3(21.4%) | | Germinoma | 4(5.3%) | 3(4.9%) | 1(7.1%) | |
| Positive para-aortic lymph nodes | 3(4.0%) | 3(4.9%) | 0(0.0%) | | Sex cord-stromal tumor | 2(2.7%) | 1(1.6%) | 1(7.1%) | |
| **Intraoperative blood transfusion** | | | | 1.000 | Other types | 1(1.3%) | 1(1.6%) | 0(0.0%) | 1(1.6%) 0(0.0%) |
| No | 50(66.7%) | 41(67.2%) | 9(64.3%) | | | | | | |
| Yes | 25(33.3%) | 20(32.8%) | 5(35.7%) | | | | | | |

*Statistically significant (*P* <0.05)

SD: standard deviation; IQR: interquartile range; BMI: body mass index; NRS: nutritional risk screening; ASA: American Society of Anesthesiologists; Comprehensive staged surgery: hysterectomy, bilateral salpingo-oophorectomy, omentectomy, pelvic lymph nodes dissection and para-aortic lymph node dissection; PDS: primary debulking surgery (hysterectomy, bilateral salpingo-oophorectomy, comprehensive staging and debulking as needed were performed after the patient's suitability for surgery and the best likelihood of cytoreduction were assessed); CT: chemotherapy (patients received 4 to 6 cycles of intravenous platinum-based therapy); NACT: neoadjuvant chemotherapy (after being confirmed poor surgical candidate or low likelihood of optimal cytoreduction, patients received 3 to 4 cycles of intravenous platinum-based therapy before interval debulking surgery); IDS: interval debulking surgery (completion hysterectomy, bilateral salpingo-oophorectomy and cytoreduction); R0: no visual residual tumor; R1: single residual tumor lesions with maximum longitudinal≤1 cm; R2: single residual tumor lesions with maximum longitudinal>1 cm;

compared 113 patients with grade 2 or higher postoperative complications to 121 patients without complications. Factors associated with postoperative complications included VO ($p = 0.003$), age ($p = 0.004$), total protein <65 g/L ($p = 0.015$), albumin<40 g/L ($p = 0.004$), laparoscopic surgery ($p<0.01$), FIGO stage III or IV ($p<0.01$), intraoperative blood transfusion ($p<0.01$), duration of surgery ($p = 0.001$) and intraoperative bleeding volume ($p<0.01$). Notably, the risk of postoperative complications was higher with primary debulking surgery (PDS) (OR = 2.426, $p = 0.002$) and interval debulking surgery (IDS) after neoadjuvant chemotherapy (NACT) (OR = 2.259, $p = 0.048$) compared to comprehensive staged surgery. No significant differences were observed for other factors, such as BMI, preoperative hemoglobin, NRS2002 score, ASA classification, preoperative cardiopulmonary disease, comorbid diabetes, history of previous abdominal surgery, postoperative pathology, surgical satisfaction evaluation, and lymph node dissection. In the high-age group, a comparison of 58 patients with postoperative complications and 17 patients without postoperative complications, factors associated with complications included FIGO stage ($p = 0.007$), intraoperative blood transfusion ($p = 0.023$), duration of surgery ($p = 0.046$)

**Table 3** Univariate logistic analysis of factors associated with postoperative complications

| **Age≤65/ Age>65** | | | | | |
|---|---|---|---|---|---|
| | No complications(*n*=121/17) | Complications(*n*=113/58) | OR | 95%CI | *P* |
| **Age**, median (IQR), years | | | | | |
| | 49.00(15.50)/68.00(9.00) | 52.00(12.50)/69.00(5.50) | 1.037/0.976 | 1.012-1.063/0.881-1.080 | 0.004*/0.635 |
| **Total protein**, g/L | | | | | |
| ≥65 | 117/15 | 99/50 | 1/1 | | |
| <65 | 4/2 | 14/8 | 4.136/1.200 | 1.319-12.972/0.230-6.270 | 0.015*/0.829 |
| **Albumin**, g/L | | | | | |
| ≥40 | 97/12 | 71/34 | 1/1 | | |
| <40 | 245 | 42/24 | 2.391/1.694 | 1.329-4.303/0.527-5.441 | 0.004*/0.376 |
| **Therapy method** | | | | | |
| Radical surgery | 65/6 | 37/9 | 1/1 | | |
| PDS+CT | 42/7 | 58/36 | 2.426/3.429 | 1.377-4.274/0.923-12.738 | 0.002*/0.066 |
| NACT+IDS | 14/4 | 18/13 | 2.259/2.167 | 1.008-5.060/0.472-9.947 | 0.048*/0.320 |
| **Operation method** | | | | | |
| Open | 86/15 | 104/54 | 1/1 | | |
| Laparoscopy | 35/2 | 9/4 | 0.213/0.556 | 0.097-0.467/0.093-3.331 | <0.01*/0.520 |
| **FIGO stage** | | | | | |
| I/II | 82/11 | 50/16 | 1/1 | | |
| III/IV | 39/6 | 63/42 | 2.649/4.812 | 1.556-4.510/1.525-15.189 | <0.01*/0.007* |
| **Intraoperative blood transfusion** | | | | | |
| No | 118/16 | 88/34 | 1/1 | | |
| Yes | 3/1 | 25/24 | 11.174/11.294 | 3.270-38.190/1.401-91.017 | <0.01*/0.023* |
| **Duration of surgery**, median (IQR), min | | | | | |
| | 191.94 (102.89)/142.0(155.0) | 241.23 (104.15)/234.10(174.0) | 1.005/1.006 | 1.002-1.007/1.000-1.01 | 0.001*/0.046* |
| **Intraoperative bleeding volume**, median (IQR), ml | | | | | |
| | 100.0(70.0)/80.0(300.0) | 200.0(300.0)/300.0(550.0) | 1.004/1.004 | 1.002-1.006/1.001-1.007 | <0.01*/0.015* |
| **Visceral obesity** | | | | | |
| No | 60/3 | 61/11 | 1/1 | | |
| Yes | 61/14 | 79/47 | 2.285/0.916 | 1.336-3.911/0.224-3.747 | 0.003*/0.902 |

*Statistically significant (*P* <0.05)

OR, odds ratio; CI, confidence interval; BMI, body mass index; NRS, nutritional risk screening; ASA, American Society of Anesthesiologists; PDS: primary debulking surgery; CT: chemotherapy; NACT: neoadjuvant chemotherapy; IDS: interval debulking surgery; R0, no visual residual tumor; R1, single residual tumor lesions with maximum longitudinal≤1 cm; R2, single residual tumor lesions with maximum longitudinal>1 cm;

**Table 4** Multivariate logistic analysis of factors associated with postoperative complications

| Factor | β | OR | P |
|---|---|---|---|
| **Age≤65** | | | |
| Visceral obesity | 0.683 | 1.980 | 0.031 |
| Total protein <65 | 1.309 | 3.704 | 0.045 |
| PDS compared to comprehensive staged surgery | -0.998 | 0.369 | 0.026 |
| Duration of surgery | 0.004 | 1.004 | 0.006 |
| Intraoperative bleeding volume | 0.003 | 1.003 | 0.000 |
| **Age>65** | | | |
| FIGO stage for III or IV | 1.386 | 4.000 | 0.029 |

*Statistically significant (*P* <0.05)

β, regression coefficient; OR, odds ratio; PDS: primary debulking surgery

and intraoperative bleeding volume ($p = 0.015$). However, other factors, including VO, were not statistically associated with postoperative complications. After multivariate analysis, VO (OR = 1.980, $p = 0.031$), total protein <65 g/L (OR = 3.704, $p = 0.045$), laparoscopic surgery (OR = 0.369, $p = 0.026$), duration of surgery (OR = 1.004, $p = 0.006$) and intraoperative bleeding volume (OR = 1.003, $p < 0.01$) remained independent predictors of postoperative complications in the low-age group of ovarian cancer patients. While FIGO stage III or IV (OR = 4.00, $p = 0.029$) remained as the only independent predictor of the high-age group.

## Discussion

In this study, we defined the threshold for identifying VO at the T12 level of chest CT and investigated the effect of VO on postoperative complications in ovarian cancer patients. In addition, we age-stratified the patients to investigate the factors affecting postoperative complications in different age groups. Our results indicated that VO is an independent factor influencing the development of postoperative complications in younger patients. Other significant factors include total protein<65 g/L, PDS compared to comprehensive staged surgery, duration of surgery and intraoperative bleeding volume.

However, in the older age group, VO did not significantly impact postoperative complications.

From 1999 to 2000 through 2017–2018, the prevalence of both obesity and severe obesity increased among adults. According to 2017–2018 data from the National Center for Health Statistics (NCHS), the obesity rate for adult women in the United States is 41.4%, compared to 43.0% for men, and the difference between the two is not significant. However, the rate of severe obesity was higher in women, at 11.5%, compared with 6.9% in men. In addition, approximately 53% of African American women and 51% of Mexican American women were obese, compared with 39% Caucasian women [16]. These data suggest that the higher prevalence of obesity and severe obesity in women, especially in certain ethnic groups, has important epidemiological implications. In the general population, obesity is easily diagnosed, but it is more challenging to define in cancer patients [17]. BMI is commonly used to define obesity, with a BMI of ≥ 30 kg/m² indicating obesity. However, BMI fails to accurately reflect whole-body fat distribution [18]. In this study, we applied the concept of VO to differentiate obese cancer patients hidden within the normal range of BMI. In our study, a total of 198 patients had a BMI within the normal range and 96 of them had excess fat area, i.e. VO, accounting for 48%. However, a previous study reported that the percentage of VO in patients with a normal BMI ranged from 18 to 34% [19]. This discrepancy may be due to different fat distribution patterns between men and women, as our study included only female patients. A similar percentage (up to 44%) of visceral obese patients with normal BMI was also observed in a study on colorectal cancer, further supports our findings [10].

Whether visceral obesity can be used to predict postoperative complications remains controversial. Some researchers have found that abdominal obesity increases the risk of postoperative complications [13], while others believe that visceral obesity is not associated with postoperative complications [20, 21]. This discrepancy may be related to inconsistencies in patient characteristics, surgical timelines, selected CT scan images and measurement methods, as well as tumor types across these studies. A recent study found that visceral obesity is a significant risk factor for short-term postoperative complications in patients undergoing cytoreductive surgery for advanced ovarian cancer [22]. This finding aligns with the results of our study. However, the difference lies in the study population, as our research focused on younger ovarian cancer patients, while the aforementioned study examined patients with advanced ovarian cancer.

CT scanning is currently the most widely used method for determining body composition in preoperative patients. Previous studies have primarily utilized CT images at the L3-L4 vertebral level for body composition analysis [20], but due to the unavailability of preoperative conventional abdominal CT, CT images at the T12 level of the thoracic spine were utilized. Various HU ranges have been employed to define fat, bone, and muscle composition. For instance, some studies define the HU values for fat as -190 to -30 [23, 24], while others use − 150 to -40 [25] or -150 to -50 [26]. Consequently, there is no universally accepted standard. In this study, we adopted an HU range of -150 to -50 to distinguish fat and determined the cutoff value (330.08 cm²) for diagnosing VO using the maximum Youden's index. The differences in CT level selection and HU values have hindered direct comparison between our results and previous research. We recommend that future studies standardize preoperative abdominal CT examinations and adopt consistent HU value ranges to enhance the comparability of research findings. Another limitation of this study is the lack of consensus in the current literature regarding the optimal timing of preoperative CT scans to assess body composition. While we ensured that all patients underwent surgery within one week of their CT examinations to minimize discrepancies, it remains unclear whether shorter or longer intervals may influence the accuracy of body composition assessments. This highlights the need for further research to establish standardized guidelines for the timing of preoperative imaging in relation to surgery. Such studies would provide valuable insights into optimizing preoperative assessments and improving surgical outcomes.

In addition, an additional analysis was performed treating visceral obesity (VO) as a continuous variable. The results indicate that in low-age group, VFA is significantly associated with postoperative complications ($p = 0.003$). However, in high-age group, no statistically significant association was observed between VFA and postoperative complications ($p = 0.589$). These findings are consistent with our primary analysis. Categorizing VO allows us to identify this threshold, which can have direct clinical implications for identifying high-risk patients. Moreover, the use of a categorical variable aligns with the goal of this study to establish a clinically actionable definition of VO, facilitating its integration into routine preoperative assessments. However, we recognize that analyzing VO as a continuous variable could provide additional insights into its relationship with outcomes and encourage further studies with larger sample sizes to explore this relationship in more detail.

Patients with higher abdominal wall fat thickness are at an increased risk of pulmonary embolism. Therefore, VO is considered a risk factor for the development of postoperative pulmonary embolism [27]. However, in the present study, no case of postoperative pulmonary embolism was observed among patients, regardless of their

VO status. Furthermore, no statistically significant difference was found in the incidence of postoperative lower extremity deep vein thrombosis between viscerally obese patients and non-viscerally obese patients in this study (7.9% vs. 6.4%, $p = 0.670$).

The short interval between diagnosis and surgery in patients with ovarian cancer results in a very low likelihood of achieving a reduction in VO during this period. In addition, clinicians should pay more attention to the possibility of postoperative complications in obese patients and implement preventative measures to reduce the incidence of postoperative complications, shorten hospital stay and reduce healthcare costs. Furthermore, public health organizations should intensify efforts to decrease the prevalence of obesity in the population, particularly among individuals younger than 65 years of age, who may benefit from surgical treatment of different cancers such as gastrointestinal tumors, endometrial cancer, and the ovarian cancer studied here.

The retrospective design of this study has several limitations. We had to rely on medical records to identify the occurrence of complications. Patients may have tolerated minor complications without informing their physicians, potentially leading to an underestimation of the actual number of complications. Additionally, the establishment of inclusion and exclusion criteria resulted in the exclusion of a substantial number of patients due to the lack of CT images or data on postoperative complications, which may have introduced selection bias into the study results.

However, our findings also have several advantages. First, this study pioneered the use of the T12 dimension of chest CT to measure VO and delineate diagnostic thresholds, providing a foundation for subsequent studies. Second, employing a dichotomous approach to classify patients as either visceral obese or non-obese, rather than using a continuous value like VFA, facilitates clinical application.

In conclusion, this study demonstrates that the diagnosis of VO through CT analysis of body composition can aid in predicting the development of postoperative complications in young ovarian cancer patients. Additionally, it identifies several other independent risk factors associated with postoperative complications in ovarian cancer.

**Abbreviations**

| | |
|---|---|
| OC | Ovarian cancer |
| VO | Visceral obesity |
| non-VO | Non-visceral obesity |
| CT | Computed tomography |
| FIGO | International Federation of Gynecology and Obstetrics |
| BMI | Body mass index |
| ASA | American Society of Anesthesiologists |
| NRS 2002 | Nutrition Risk Screening 2002 |
| VFA | Visceral fat area |
| VAT | Visceral adipose tissue. |
| ROC | Receiver operating characteristic |
| AUROC | Area under the ROC |
| ICU | Intensive care unit |
| PDS | Primary debulking surgery |
| IDS | Interval debulking surgery |
| NACT | Neoadjuvant chemotherapy |

**Author contributions**

SS and YZ were involved in the study design; SS TW JB CF HJ MS and RS collected and collated clinical data; SS wrote the manuscript. All authors contributed to the article and approved the submitted version.

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**Data availability**

No datasets were generated or analysed during the current study.

## Declarations

**Approval of the research protocol by an institutional reviewer board**

Ethical approval for this study was obtained from the Research Ethics Committee of the First Affiliated Hospital of Wenzhou Medical University.

**Informed consent**

Not applicable.

**Registry and the registration**

Not applicable.

**Animal studies**

Not applicable.

**Consent to participate**

All authors approved the final manuscript and the submission to this journal.

**Competing interests**

The authors declare no competing interests.

**Conflict of interest**

The authors declare that there is no conflict of interests.

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## Publisher's note