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Association between body composition and incisional surgical site infection after laparoscopic appendectomy for complicated appendicitis

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Abstract

Purpose Surgical site infection (SSI) is common after laparoscopic appendectomy, resulting in prolonged hospital stay and increased costs. This study examined the relationship between body composition parameters and risk of incisional SSI in patients with complicated appendicitis.

Methods We included 411 patients who underwent laparoscopic surgery for complicated appendicitis at a single institution between March 2015 and October 2023. Body composition parameters were derived from preoperative computed tomography (CT). A nomogram was constructed based on the independent predictors of incisional SSI.

Results Overall, 45 (10.9%) patients developed incisional SSI. Visceral fat area (VFA) was independently associated with risk of incisional SSI (hazard ratio 1.015, 95% confidence interval 1.010–1.020, $P<0.001$). A nomogram integrating VFA and two other independent predictors (diabetes and conversion) demonstrated high discriminative (area under the curve = 0.793) and calibration abilities.

Conclusions CT-derived VFA could be a valuable predictor of incisional SSI in patients with complicated appendicitis undergoing laparoscopic surgery. A VFA-based nomogram may help in identifying patients at high risk of SSI.

Keywords Appendicitis, Surgical site infection, Laparoscopy, Body composition, Predictive model

Introduction

Appendicitis is one of the most common surgical emergencies in China, with complicated appendicitis accounting for approximately 20% of the cases [1]. Appendectomy is the cornerstone treatment for complicated appendicitis. Laparoscopic appendectomy has gained popularity owing to its favorable short-term efficacy [2, 3]. However, the incidence of incisional surgical site infection (SSI) after laparoscopic resection of complicated appendicitis remains high [4], occurring in up to 19% in some series [5]. SSI is associated with increased pain, prolonged hospital stay, increased costs for patients, and substantial economic burden on the healthcare system [6]. Thus,

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identification of the risk factors for SSI has become an important topic worldwide.

Obesity, which is typically assessed using the body mass index (BMI), is associated with a high risk of incisional SSI [7, 8]. However, BMI is not a perfect measure of abnormal fat accumulation as it fails to differentiate between fat mass and lean body mass [9]. For example, individuals with the same BMI may have significantly different levels of fat and muscle mass. Therefore, the impact of body composition parameters on SSI has attracted increasing interest. In a real-world study involving 906 patients undergoing laparoscopic general surgery, sarcopenic obesity was significantly associated with adverse postoperative outcomes, including a high incidence of SSI [10]. Whether body composition parameters (including muscle and fat distribution) could affect the risk of incisional SSI after laparoscopic appendectomy has not been extensively studied. We hypothesized that the body composition is a significant risk factor for incisional SSI. Thus, this study aimed to examine the association between body composition parameters and risk of incisional SSI after laparoscopic appendectomy for complicated appendicitis and to develop a predictive model for incisional SSI.

Materials and methods

Patients and treatments

In this retrospective study, adult patients diagnosed with complicated appendicitis who underwent laparoscopic surgery at our center between March 2015 and October 2023 were identified. Complicated appendicitis was diagnosed based on the intraoperative findings and defined as acute appendicitis presenting with perforation or intra-abdominal abscess(es) [5]. Patients were excluded if they had concomitant malignant tumors, autoimmune diseases, or had undergone extended resection or interval appendectomy. We also excluded patients without evaluable computed tomography (CT) images within two weeks before surgery. Finally, 411 patients were included in this study (Fig. 1). This study was approved by the ethics committee of our institution and performed in accordance with the Declaration of Helsinki. Written informed consent was obtained from all patients.

All patients underwent laparoscopic appendectomy with or without conversion to laparotomy according to the standard procedure [5]. A four-trocar approach was adopted, including one 12-mm trocar around the umbilicus and three 5-mm trocars in the suprapubic position, left lower abdomen, and right lower abdomen. The decision to convert to an open procedure was made by the operating surgeon in the presence of severe adhesions, generalized purulent peritonitis, or uncontrolled intraoperative complications. The resected appendix was extracted in a specimen retrieval bag via the umbilical incision. Thorough peritoneal lavage was performed using warm saline until the drained fluid appeared clear. Drains were placed according to the surgeons' preference. The incisions were closed using non-absorbable monofilament sutures immediately after the surgery. All surgeries, including wound closures, were performed by experienced surgeons who had performed at least 100

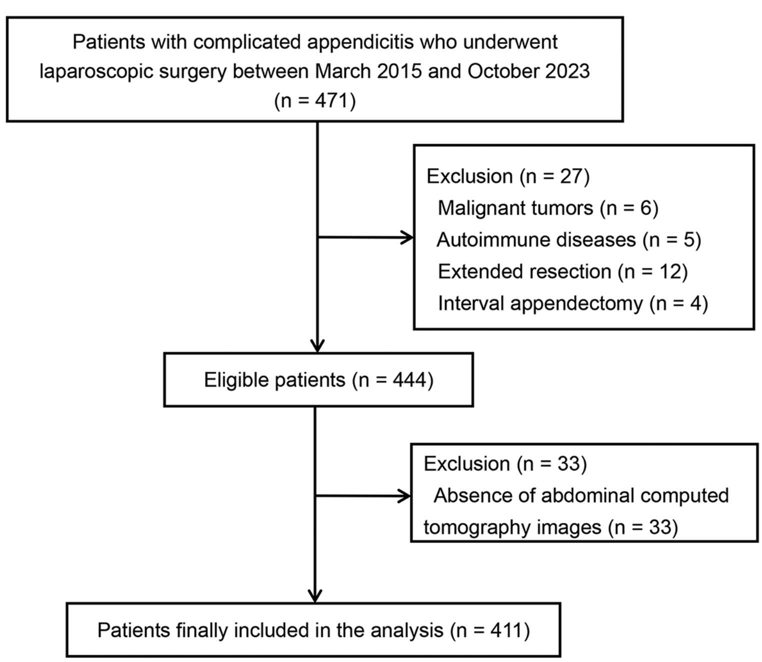

Fig. 1 Diagram of study population

laparoscopic appendectomies. Preoperative and postoperative intravenous antibiotics, which covered enteric gram-negative and facultative/anaerobic bacilli, were administered until the body temperature returned to normal for at least 24 h, and then switched to oral antibiotics for at least one week.

Study outcomes

The primary outcome was incisional SSI, defined as an infection involving the skin, subcutaneous tissue (superficial), or deep soft tissue (deep) at the incision site that occurs within 30 days of surgery, and has any of the following features: purulent drainage, positive culture for microorganisms from the fluid or tissue, or any of the following symptoms/signs: pain or tenderness, localized swelling, redness/heat, or opening of the wound by a physician without a positive culture [11]. An incisional SSI was diagnosed by the responsible physician before discharge and at the 1-month outpatient visit.

For each patient, the total fat area (TFA), visceral fat area (VFA), subcutaneous fat area (SFA), and skeletal muscle area (SMA) were measured at the level of the third lumbar vertebra using the latest preoperative CT scans [12]. Specific tissues were differentiated using the standard Hounsfield unit (HU) range. The VFA and SFA were defined as fat tissues within ranges of -150 and −50 HU, and −190 and −30 HU, respectively. A range between −29 and 150 HU was used to define the SMA. The TFA was defined as the sum of the SFA and VFA. The skeletal muscle density (SMD) was calculated as the mean radiation attenuation value of the entire SMA (Figure S1).

Statistical analysis

Categorical data were expressed as frequencies (percentages) and compared with the χ^2 test, with or without Yate's correction. Continuous data were expressed as means (standard deviation [SD]) and compared with the t-test. The optimal cutoff value for a continuous variable was determined using the Youden index. Univariate and multivariate logistic regression models were used to identify the independent risk factors for incisional SSI. To reduce multicollinearity and overfitting, stepwise multiple regression with Wald's backward selection was applied [1, 2]. A nomogram was constructed by integrating all independent predictors of incisional SSI. The predictive accuracy of the nomogram was evaluated using receiver operating characteristic (ROC) curves and the area under the curve (AUC). The nomogram was calibrated by comparing the predicted and observed incidence of incisional SSI after bias correction. A two-tailed P value of <0.05 was considered statistically significant. All statistical analyses were performed using the R software, version 4.2.3 (R Foundation for Statistical Computing, Vienna, Austria).

Results

During the study period, a total of 411 patients with complicated appendicitis were included in the analysis (Table 1). Of the included patients, 239 (58.2%) were men and 172 (41.8%) were women. The mean (SD) BMI was 22.8 (3.2) kg/m^2.

Risk factors for SSI

A total of 45 patients developed incisional SSI, with an incidence rate of 10.9%. Patients with incisional SSI were more likely to have diabetes (20.8% vs. 6.0%, $P=0.001$), undergo conversion to open surgery (31.1% vs. 10.1%, $P<0.001$), have higher BMI (mean: 24.6 vs. 22.6 kg/m^2, $P<0.001$), higher TFA (mean: 285 vs. 191 cm^2, $P<0.001$), higher VFA (mean: 157 vs. 85 cm^2, $P<0.001$), higher SFA (mean: 127 vs. 106 cm^2, $P=0.019$), higher SMA (mean: 140 vs. 130 cm^2, $P=0.021$), and lower SMD (mean: 44.9 vs. 48.5 HU, $P=0.012$, Table 1). Multivariate analysis revealed that the presence of diabetes (hazard ratio [HR] 3.012, 95% confidence interval [CI] 1.188–7.639, $P=0.020$), conversion to open surgery (HR 3.968, 95% CI 1.791–8.790, $P=0.001$), and higher VFA (HR 1.015, 95% CI 1.010–1.020, $P<0.001$) were independently associated with a higher risk of incisional SSI (Table 2).

We also examined the associations between body composition parameters and incisional SSI in two logistic regression models. After adjusting for BMI, diabetes, and conversion, only TFA and VFA were independently associated with incisional SSI (both $P<0.001$). However, TFA lost its predictive value after adding the VFA into the model ($P=0.186$; Table S1).

The optimum cutoff value of VFA for predicting the risk of SSI was 85 cm^2, with a sensitivity and specificity of 91.1% and 56.8%, respectively. In multivariate analysis, a a 2.7-fold, 3.4-fold, and 8.1-fold increased SSI risk was observed in patients with diabetes (95% CI 1.095–6.715, $P=0.031$), conversions (95% CI 1.564–7.262, $P=0.002$), and higher VFA (≥85 cm^2; 95% CI 3.306–19.847, $P<0.001$), respectively.

Association between VFA and general characteristics

A higher VFA was significantly associated with older age (mean 46.1 vs. 43.8 years, $P=0.004$), male sex (65.5% vs. 51.2%, $P=0.003$), diabetes mellitus (11.5% vs. 3.8%, $P=0.003$), more frequent conversions (16.0% vs. 9.0%, $P=0.032$), higher BMI (mean 24.3 vs. 21.4 kg/m^2, $P<0.001$), higher TFA (mean: 284 vs. 124 cm^2, $P<0.001$), higher SFA (mean: 135 vs. 83 cm^2, $P<0.001$), higher SMA (mean: 142 vs. 122 cm^2, $P<0.001$), and lower SMD (mean: 46.7 vs. 49.4 HU, $P=0.003$, Table 1).

Table 1 Baseline characteristics according to incisional surgical site infection and visceral fat area

Variable	Total (n=411)	SSI group (n=45)	Non-SSI group (n=366)	P value	Low-VFA (n=211)	High-VFA (n=200)	P value
Clinical characteristics							
Age, years	44.9 ± 8.2	46.2 ± 8.6	44.7 ± 8.1	0.260	43.8 ± 8.6	46.1 ± 7.6	0.004
Gender				0.122			0.003
Male	239 (58.2)	31 (68.9)	208 (56.8)		108 (51.2)	131 (65.5)	
Female	172 (41.8)	14 (31.1)	158 (43.2)		103 (48.8)	69 (34.5)	
BMI, kg/m^2	22.8 ± 3.2	24.6 ± 3.2	22.6 ± 3.1	< 0.001	21.4 ± 2.5	24.3 ± 3.2	< 0.001
ASA classification				0.522			0.179
I-II	351 (85.4)	37 (82.2)	314 (85.8)		185 (87.7)	166 (83.0)	
III	60 (14.6)	8 (17.8)	52 (14.2)		26 (12.3)	34 (17.0)	
Smoking	105 (25.5)	12 (26.7)	93 (25.4)	0.855	55 (26.1)	50 (25.0)	0.804
Diabetes	31 (7.5)	9 (20.0)	22 (6.0)	0.001	8 (3.8)	23 (11.5)	0.003
Hypertension	57 (13.9)	7 (15.6)	50 (13.7)	0.729	21 (10.0)	36 (18.0)	0.018
Body composition							
TFA, cm^2	202 ± 112	285 ± 119	191 ± 107	< 0.001	124 ± 73	284 ± 83	< 0.001
VFA, cm^2	93 ± 67	157 ± 74	85 ± 62	< 0.001	41 ± 26	149 ± 50	< 0.001
SFA, cm^2	108 ± 58	127 ± 67	106 ± 57	0.019	83 ± 54	135 ± 51	< 0.001
SMA, cm^2	132 ± 27	140 ± 26	130 ± 27	0.021	122 ± 23	142 ± 27	< 0.001
SMD, HU	48.1 ± 9.2	44.9 ± 9.9	48.5 ± 9.1	0.012	49.4 ± 8.8	46.7 ± 9.6	0.003
Intraoperative outcomes							
Operation time, min	87 ± 21	84 ± 18	88 ± 22	0.342	86 ± 23	89 ± 20	0.252
Conversions	51 (12.4)	14 (31.1)	37 (10.1)	< 0.001	19 (9.0)	32 (16.0)	0.032

Data are No. (%) or mean ± standard deviation. *Abbreviations*: BMI, body mass index; TFA, total fat area; VFA, visceral fat area; SFA, subcutaneous fat area; SMA, skeletal muscle area; SMD, skeletal muscle density

Table 2 Univariate and multivariate analysis for incisional surgical site infection

Characteristic	Univariate analysis		Multivariate analysis	
	HR (95% CI)	P value	HR (95% CI)	P value
Age (per 1year)	1.023 (0.983–1.066)	0.260		
Gender (Male vs. Female)	1.682 (0.866–3.268)	0.125		
BMI (per 1 kg/m^2)	1.207 (1.095–1.330)	< 0.001		
ASA classification (III vs. I-II)	1.306 (0.576–2.960)	0.523		
Smoking (Yes vs. No)	1.067 (0.529–2.153)	0.855		
Diabetes (Yes vs. No)	3.909 (1.674–9.129)	0.002	3.012 (1.188–7.639)	0.020
Hypertension (Yes vs. No)	1.164 (0.493–2.750)	0.729		
TFA (per 1 cm^2)	1.007 (1.004–1.010)	< 0.001		
VFA (per 1 cm^2)	1.015 (1.010–1.020)	< 0.001	1.015 (1.010–1.020)	< 0.001
SFA (per 1 cm^2)	1.006 (1.001–1.011)	0.021		
SMA (per 1 cm^2)	1.013 (1.002–1.025)	0.022		
SMD (per 1 HU)	0.959 (0.928–0.991)	0.013		
Conversions (Yes vs. No)	4.016 (1.961–8.224)	< 0.001	3.968 (1.791–8.790)	0.001

Abbreviations: HR, hazard ratio; CI, confidence interval; BMI, body mass index; TFA, total fat area; VFA, visceral fat area; SFA, subcutaneous fat area; SMA, skeletal muscle area; SMD, skeletal muscle density

Development and validation of the nomogram

A nomogram was established to predict the risk of incisional SSI by combining diabetes, conversion, and VFA (Fig. 2A). Diabetes, conversion, and a VFA of ≥85 cm^2 were scored as 4, 5, and 10 points, respectively, with the total points ranging from 0 to 19. The incidence of incisional SSI was the lowest (1.1%) in patients with a total score of 0 and the highest (80%) in those with a total score of 19. The nomogram showed high discriminative ability, with the AUC value of 0.793 (95% CI 0.732–0.854) (Fig. 2B). Moreover, the calibration curves showed good concordance between the prediction of the nomogram and the actual observation (Fig. 2C).

Sensitivity analysis

A sensitivity analysis was conducted by excluding the patients with conversion to open surgery. Multivariate analysis revealed that presence of diabetes (HR 3.096, 95% CI 1.051–9.115, P=0.040) and higher VFA (HR 1.016, 95% CI 1.011–1.022, P<0.001) remained

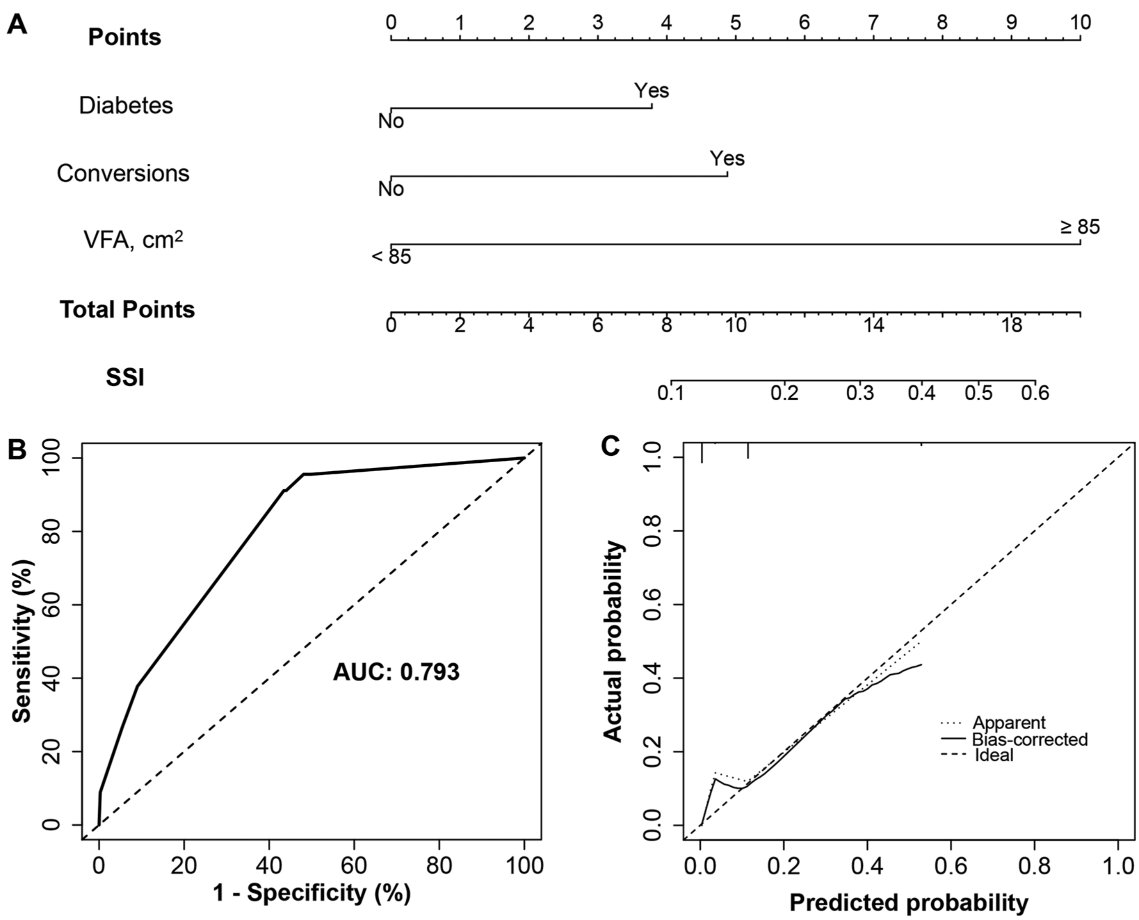

Fig. 2 A nomogram to predict the probability of incisional surgical site infection (**A**). Model performance was assessed by receiver operator characteristics curve (**B**) and calibration curve (**C**)

independent risk factors for incisional SSI. A nomogram incorporating diabetes and VFA also showed high discriminative ability (AUC=0.770) and good fit (Figure S2).

Discussion

To our knowledge, this is the first study to explore the relationship between body composition and risk of incisional SSI following laparoscopic appendectomy for complicated appendicitis. In the entire cohort, the incidence rate of incisional SSI was 10.9% (45/411), which is similar to the rates reported in several randomized clinical trials (5–19%) [5, 13, 14]. Among the body composition parameters, a higher TFA, VFA, SFA, and SMA and lower SMD were significantly associated with a higher incidence of incisional SSI. However, after adjusting for other clinical factors, only the VFA was found to be an independent risk factor for incisional SSI. A VFA-based nomogram was then established which demonstrated good performance.

Obesity, especially visceral obesity, is widely acknowledged to negatively affect the postoperative outcomes [15, 16]. In obesity, adipocytes accumulate not only in the intra-abdominal depot but also in organs such as the liver, pancreas, and muscle tissues. This surge in adipocytes results in chronic inflammation due to the production of proinflammatory cytokines [17]. Because of the inability of BMI to accurately indicate the body distribution of fat, the association between BMI and post-appendectomy SSI was not stable [18]. In a recent prospective study of 90 patients who underwent open appendectomy, the subcutaneous fat thickness measured by preoperative ultrasound, rather than BMI, was shown to be significantly associated with the risk of incisional SSI [19]. In the present study, we found that among all body composition parameters and BMI, only the VFA was an independent predictor of incisional SSI. This finding could be explained as follows: visceral obesity is associated with systemic inflammation and insulin resistance, which might impair the appropriate response to operative stress and promote the occurrence of SSI [12].

To provide a clinically relevant quantifiable method for predicting the risk of incisional SII, we constructed a nomogram that combined VFA, diabetes, and conversion. The two clinical factors (i.e., diabetes [20] and conversion to laparotomy [21, 22]) included in the nomogram have been previously associated with SSI in other studies. Notably, this study is the first to report the negative impact of conversion on incisional SII development after laparoscopic appendectomy. According to a recent meta-analysis, the laparoscopic approach to appendectomy resulted in significantly fewer SIIs than the open approach (odds ratio: 0.30). Moreover, the laparoscopic conversion rate to open appendectomy is even higher, varying from 0 to 18% [2]. Our study reported a conversion rate of 12.4%, consistent with the previous results. The mechanisms underlying conversion and SSI after laparoscopic appendectomy remain unclear. A feasible explanation is that conversion to open appendectomy had a similar SSI risk as primary open appendectomy and therefore had a higher SSI risk than laparoscopic appendectomy [23]. Additionally, surgeon fatigue and consequent technical compromise after conversion might be a significant factor for increased SSI incidence [24].

However, this study has some limitations that need to be addressed. First, this was a retrospective, single-center study, and a selection bias may have been introduced. Additionally, we only analyzed the easily available clinical data; therefore, some confounding factors could not be avoided. Second, all body composition parameters were derived from the preoperative CT images. Due to the low prevalence of preoperative CT in low-income countries, it is necessary to identify other noninvasive and economical ways to measure the body composition. Third, all patients in this study were from China and underwent laparoscopic appendectomy. Whether our findings also apply to patients undergoing open surgery and other populations requires further investigation.

In conclusion, our study is the first to demonstrate an association between visceral obesity and incisional SSI after laparoscopic appendectomy in complicated appendicitis. A nomogram was developed based on the VFA, diabetes, and conversion. For patients at high risk of SSI development, we recommend specific surgical techniques, such as delayed wound closure and use of subcutaneous drains. Moreover, external validation is required to confirm the generalizability of our findings.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12893-024-02541-w.

Supplementary Material 1

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None.

Author contributions
Teng S and Liu Z conceived of the study and designed the study; Yin P, Li H, and Wang J helped collect data; Teng S analyzed the data; Teng S wrote the manuscript; Liu Z helped revise the manuscript critically for important intellectual content. All authors read and approved the final manuscript.

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None.

Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study was approved by the Institutional Review Board of the Jiaozhou Central Hospital of Qingdao (approval number: 2024Y0013), and conducted in accordance with the Declaration of Helsinki (revised in 2013). Written informed consent to participate was obtained from all patients for being included in the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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