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ORIGINAL CLINICAL RESEARCH REPORT

Association Between Two Muscle-Related Parameters and Postoperative Complications in Patients Undergoing Colorectal Tumor Resection Surgery

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BACKGROUND: This study aimed to investigate the associations of 2 preoperative muscle-related parameters, the third lumbar vertebra skeletal muscle index (L3 SMI) for muscle mass and the Hounsfield unit average calculation (HUAC) for muscle density, with the occurrence of postoperative complications among patients undergoing colorectal tumor resection surgery under general anesthesia. We hypothesized that muscle-related parameters are associated with the occurrence of postoperative complications.

METHODS: This was a single-center, retrospective observational study. Adult patients who underwent colorectal tumor resection surgery under general anesthesia between 2018.09.01 and 2021.09.01 were enrolled. The last abdominal computed tomography (CT) scan images obtained within 3 months before surgery were used to calculate the L3 SMI and HUAC. The primary outcome was defined as the occurrence of any postoperative complications corresponding to Clavien-Dindo classification before discharge. The secondary outcome was defined as the occurrence of any severe postoperative complications (Clavien-Dindo grade ≥3) before discharge. Multivariable logistic regression analyses were used to estimate the association between muscle-related parameters and incidence of postoperative complications. Patients' baseline demographics, past medical history and intraoperative parameters were adjusted in the multivariable logistic regression analysis.

RESULTS: A total of 317 patients with a median age of 66 (58–72) years were included. Sarcopenia (muscle mass reduction) patients in our cohort and myosteatosis (muscle density decline) were present in 254 (80.1 %) and 79 (24.9%) patients, respectively. A total of 135 patients (42.6 %) developed postoperative complications. According to the multivariable logistic regression, myosteatosis (odds ratio [OR], 1.8, 95% confidence interval [CI], 1.0–3.3, $P = .039$) was significantly associated with postoperative complications.

CONCLUSIONS: A significant association was observed between myosteatosis and postoperative complications (corresponding to Clavien-Dindo classification before discharge), especially severe postoperative complications (Clavien-Dindo grade ≥3) in patients undergoing colorectal tumor resection. Screening for myosteatosis with HUAC using the CT before surgery may help clinicians identify high-risk perioperative patients early. (Anesth Analg 2025;141:343–51)

KEY POINTS

- **Question:** What are the associations between 2 muscle-related parameters and postoperative complications in patients undergoing colorectal tumor resection surgery?
- **Findings:** Myosteatosis (low skeletal muscle radiodensity) is associated with a significantly increased odds of postoperative complications, especially severe postoperative complications (Clavien-Dindo grade ≥3).
- **Meaning:** The increased odds of postoperative complications in patients with myosteatosis supporting preoperative Hounsfield unit average calculation (HUAC) as a valuable indicator of prediction for postoperative complications in patients under colorectal tumor resection surgery.

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Colorectal cancer currently ranks third in morbidity and second in mortality among malignant tumors.[1–3] Due to the reduction in food intake and metabolic abnormalities in patients with malignant tumors, there is obvious skeletal muscle consumption,[4] so the measurement of muscle-related parameters is more consistent with the characteristics of malnutrition in cancer patients.

Sarcopenia was originally used to describe the age-related loss of skeletal muscle mass and function.[5] In recent years, it has been recognized as a progressive, systemic skeletal muscle disease associated with poor outcomes, such as falls, fractures, disability, and increased mortality.[6] In this study, sarcopenia was narrowly defined as decreased skeletal muscle quantity. Regarding the assessment of muscle quality, myosteatosis can represent decreased skeletal muscle radiodensity and has been reported to be associated with impaired skeletal muscle contraction, poor physical fitness, extended hospital stay, and reduced overall survival, which are more significantly than sarcopenia.[7–10]

A meta-analysis showed that the incidence of sarcopenia among older hospitalized patients in China ranges from 23% to 29.7%, while the incidence increases to 44% among patients with nonmetastatic colorectal cancer.[11,12] The incidence of myosteotosis in patients with colorectal cancer can vary from 19.3% to 77.6%.[13] Chen et al[10] found that patients with sarcopenia are susceptible to pulmonary complications, and those with myosteatosis are more likely to suffer from surgical incision site infections and have shorter overall survival than patients without myosteotosis. Hanna DN et al[14] suggested that malnutrition and frailty should be screened for and treated early to improve postoperative outcomes. However, preoperative screening for sarcopenia or myosteatosis has not received sufficient attention.

Currently, the commonly used measurement of muscle quantity includes dual-energy X-ray absorptiometry (DXA), bioelectrical impedance analysis (BIA), computed tomography (CT), and magnetic resonance imaging (MRI).[4] Considering the abdominal CT scan was the routine preoperative examination of colorectal tumor resection, and skeletal muscle mass of a single layer is linearly positively correlated with that of the whole body,[15] the third lumbar vertebra level skeletal muscle index (L3 SMI) and Hounsfield unit average calculation (HUAC) were used for muscle assessment in this study.

We hypothesized that muscle-related parameters are associated with the occurrence of postoperative complications in patients undergoing colorectal tumor resection surgery. This study primarily aimed to investigate the association of L3 SMI and HUAC with the occurrence of postoperative complications, and secondarily explored the association with the occurrence of severe postoperative complications.

METHODS

This was a single-center, retrospective, observational study. The Ethics Committee of Scientific Research, Beijing Shijitan Hospital, Capital Medical University approved the study protocol (sjtkyll-lx-2022(18), 2022.01.24). The data collected in the present study were masked from the information center, and the investigators could not find the subject. The requirement for informed consent of participants was waived. This study adheres to the STROBE guidelines (Supplemental Digital Content 1, Supplemental Table 1, http://links.lww.com/AA/F97).

Participants

Adult patients (aged ≥18 years) who underwent colorectal tumor resection surgery (laparoscopic sigmoid colectomy, laparoscopic left colectomy, extended radical resection for rectal cancer, etc) with general anesthesia between September 1, 2018 and September 1 2021 were eligible for analyses. Patients with an abdominal CT scan not exceeding 3 months before surgery and those who were pathologically diagnosed with a malignant tumor were included. The exclusion criteria were as follows: (1) emergency operation, (2) combined with spinal anesthesia, (3) insufficient laboratory data, and (4) CT images that could not be analyzed.

Perioperative Parameters and Confounding Variables

Baseline data, including demographic characteristics, comorbidities, age-adjusted Charlson comorbidity index (aCCI; see Supplemental Digital Content 1, Supplemental Table 2, http://links.lww.com/AA/F97),[16] laboratory test results, and American Society of Anesthesiologists (ASA) classification, were collected from the Information Center of Beijing Shijitan Hospital. Intraoperative data such as the degree of reduction in mean arterial pressures (MAPs) between the anesthesia induction and the skin cut, referred to hereafter as the change of postinduction blood pressure, surgery time, fluid management, blood management, open surgery or laparoscopic surgery, receiving nerve block, and the dosage of opioid analgesics, vasoconstrictors, vasodilators, esmolol, atropine, and neostigmine were extracted from the anesthesia records. Other traditional nutritional evaluation indicators, such as body mass index (BMI), serum albumin (Alb), and prognostic nutritional index (PNI)[17] which have been shown to be significantly associated with the clinical outcomes of patients with cancer, were also collected. Dosages of opioid analgesics: dosages of sufentanil+ dosages of remifentanil/10.[18]

The change of postinduction blood pressure = (the $MAP_{baseline}$ - the lowest $MAP_{postinduction}$)/ the $MAP_{baseline}$. The parameters mentioned above, including age, gender, ASA classification, aCCI, surgery time, urine output, blood loss, crystalloid, colloidal, and blood transfusion were confounding variables considered for adjustment when assessing the associations between muscle-related parameters and postoperative complications. Age, gender, aCCI and Hb were adjusted for the relationship between muscle-related parameters and other nutritional assessment parameters.

Imaging Measures

The last abdominal CT scan images before surgery were extracted and analyzed using SliceOmatic (5.0 Rev-16c) software. We first found the twelfth thoracic vertebra by the twelfth rib, and the third vertebral body appearing below was the third lumbar vertebra (L3). We then took the plane where both transverse processes of L3 appear as the L3 level. The muscle tissue was defined as the area with Hounsfield unit (HU) thresholds of –29 to 150.[19]

The skeletal muscle area (SMA) was manually determined as the total area of the erector spinae, quadratus lumborum, psoas major muscle, external oblique, internal oblique, transversus abdominis, and rectus abdominis. The skeletal muscle index at the L3 level (L3 SMI), an indicator of skeletal muscle mass, was obtained through the normalized SMA based on the square of the patient's height.

The skeletal muscle quality was estimated by psoas density, which was measured as Hounsfield unit average calculation (HUAC) and calculated by summing the product of the right psoas Hounsfield unit (RPHU) and right psoas area (RPA) with that of the left psoas Hounsfield unit (LPHU) and left psoas area (LPA), then dividing by the sum of RPA and LPA: [(RPHU × RPA) + (LPHU × LPA)]/(RPA + LPA).[20]

According to the international consensus,[4] a sex-specific categorical variable, L3 SMI <55 $cm^2.m^{-2}$ for males and L3 SMI <39 $cm^2.m^{-2}$ for females, is the cut-off value for defining sarcopenia. For HUAC, the sex-specific lowest 25th percentile values met the criteria for myosteatosis.[21]

Outcome Measures

Postoperative complications were extracted from medical records and classified by the Clavien-Dindo classification (see Supplemental Digital Content 1, Supplemental Tables 3 and 4, http://links.lww.com/AA/F97).[22] The severe complications were defined as complications classified as Clavien-Dindo grade ≥3 for those resulted in an intervention, ICU admission or death. The primary outcome was defined as the occurrence of any postoperative complications corresponding to Clavien-Dindo classification before discharge. In addition, the secondary outcome was defined as the occurrence of any severe postoperative complications (Clavien-Dindo grade ≥3) before discharge.

Statistical Analysis

SPSS, version 26.0 and PASS, version 15 were used for the analysis. The demographic characteristics and perioperative parameters of the subjects were compared between the complication and noncomplication, sarcopenia and nonsarcopenia, and myosteatosis and nonmyosteatosis groups. The normality of continuous data was tested using the Kolmogorov–Smirnov test, histograms, and Q-Q plots. Continuous data conforming to a normal distribution were expressed as mean (SD), and an independent-sample *t* test was used for comparison between groups. Nonnormally distributed continuous data are expressed as median (IQR), and the Mann-Whitney *U* test was used for comparison between groups. Enumeration data were expressed as number (proportion), and χ^2 test and Fisher exact test were used for comparison between groups. The Pearson correlation coefficient and multiple linear regression analysis were used for the correlation analysis of 2 muscle-related parameters, which was equal to "L3 SMI and HUAC" or "sarcopenia and myosteatosis" hereafter, and other nutritional assessment parameters.

The relationship between L3 SMI/HUAC and postoperative complications was first analyzed using univariate analysis, followed by multivariable logistic regression analysis. The association of interest was first adjusted by age and ASA classification. On this basis, potential confounding factors including age, gender, ASA classification, aCCI, surgery time, urine output, blood loss, crystalloid, colloidal, blood transfusion were further adjusted. The results of the univariate and multivariable logistic regression analyses were expressed as odds ratios (OR), 95% confidence intervals (CI), and *P* values. The variance inflation factor (VIF) was used to test for potential multicollinearity among independent variables. Statistical significance was set at $P < .05$.

All the adult patients (aged ≥18 years) who underwent colorectal tumor resection surgery with general anesthesia between 2018.09.01 and 2021.09.01 were included in this study consecutively. According to previous studies,[23,24] the power analysis was conducted based on the odds ratio of sarcopenia and myosteatosis in postoperative complications, which were 4.758 and 2.86, and the estimated incidence of postoperative complications in nonsarcopenia group and nonmyosteatosis group, which were 24% and 26.5%. The power of sarcopenia versus nonsarcopenia and myosteatosis versus nonmyosteatosis were 0.99

and 0.97, respectively. There were no missing data in this study.

RESULTS

According to "Adult patients who underwent colorectal tumor resection surgery with general anesthesia between September 1, 2018 and September 1, 2021," a total of 421 cases were selected. Twelve patients were excluded due to repeated operations, 13 due to emergency operations, 50 due to lack of laboratory examination or abdominal CT scan results, 18 due to the type of anesthesia, and 11 due to unanalyzable CT images with large abdominal and/or pelvic masses or postoperative artifacts of the lumbar spine (Figure).

Demographic Characteristics of the Patients

This study included 317 patients with a median age of 66 (58–72) years. Among the eligible subjects, 205 (64.7%) were male. Postoperative complications occurred in 135 (42.6%) patients (Table 1). Participants were characterized as "sarcopenia (low skeletal muscle mass)" or "nonsarcopenia" based on an international consensus of cancer cachexia. Of the 317 patients, 254 (80.1%) had sarcopenia in our study population. The median age was 66 (61–74) years in the sarcopenia group and 56 (51–67) years in the nonsarcopenia group. Males comprised 70.1% of the sarcopenia group and 42.9% of the nonsarcopenia group. Patients with sarcopenia had higher levels of aCCI and venous thromboembolism (VTE) risk score, lower levels of consumption of opioid analgesics and Alb, were more likely to accept open surgery, more likely to use vasodilators compared to patients without sarcopenia (Table 2).

Additionally, gender specific lowest 25th percentile of values, which is 34.76HU for males and 31.82HU for females, were used to identified "myosteatosis (low skeletal muscle radio density)" (n = 79; median [IQR] age, 71 [66–79]) or "non- myosteatosis" (n = 238; median [IQR] age, 64 [56–69]). Patients with myosteatosis had higher aCCI and VTE risk scores, lower levels of hemoglobin (Hb) and serum albumin (Alb), longer postoperative hospital stay, and were more likely to accept blood transfusion and vasoconstrictors than patients without myosteatosis (Table 2).

Primary Outcome

The primary outcome of postoperative complications occurred in 116 of 254 patients (45.7%) in the sarcopenia group and 19 of 63 patients (30.2%) in the nonsarcopenia group, which was also observed in 46 of 79 participants (58.2%) in the myosteatosis group and in 89 of 238 participants (37.4%) in the nonmyosteatosis group (Table 2). In the univariate analysis, sarcopenia (odds ratio [OR] 1.9, 95% confidence interval [CI] 1.1–3.5, $P = .027$) and myosteatosis (OR 2.3; 95%CI 1.4–3.9; $P = .001$) were significantly associate with postoperative complications. In the multivariable analysis, a

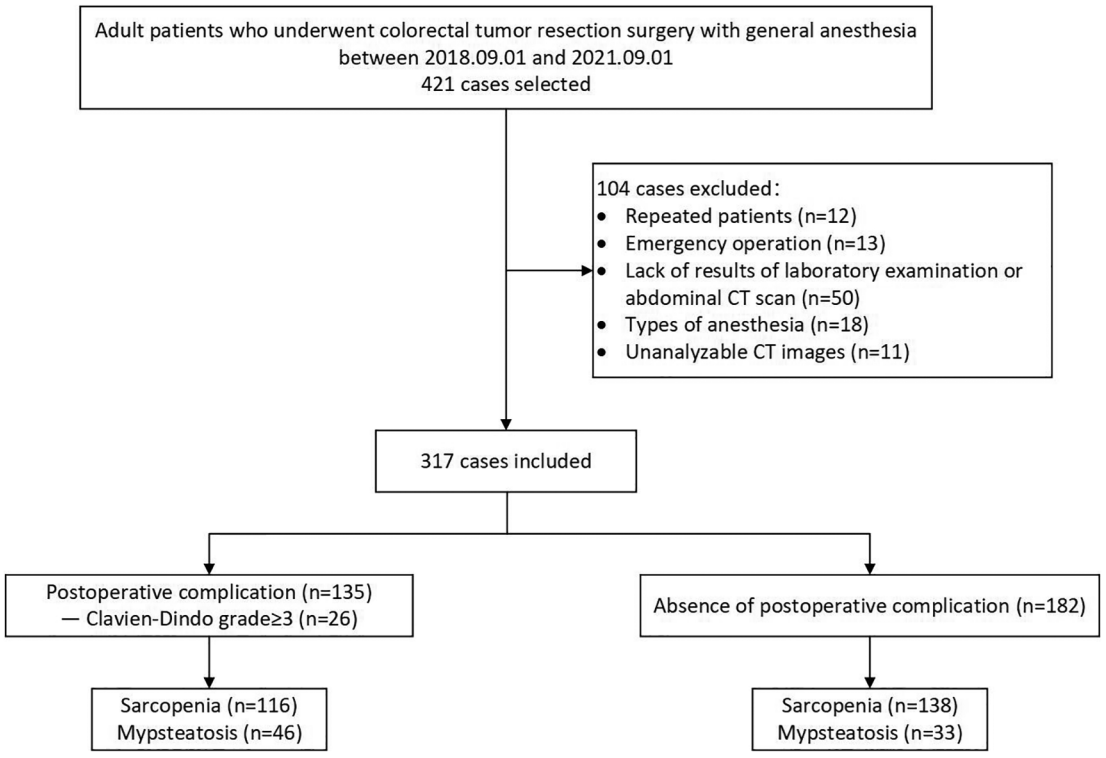

Figure. Study flow diagram.

Table 1. Baseline Characteristics of Patients Undergoing Colorectal Tumor Rection Surgery (Mean [SD], Median [IQR], and Number [Proportion])

Variable	All patients (n = 317)	Noncomplication group (n = 182)	Complication group (n = 135)	*P* value
Age, y	66 (58–72)	65 (56–70)	67 (60–74)	.005
BMI, $kg.m^{-2}$	23.4 (21.2–25.4)	23.4 (21.5–25.4)	23.4 (20.8–25.4)	.510
aCCI	5 (4–7)	5 (4–6)	6 (4–7)	.001
VTE risk score	4 (3–4)	4 (3–4)	4 (3–5)	.010
WBC, $*10^9.L^{-1}$	5.60 (4.61–7.01)	5.55 (4.70–6.83)	5.80 (4.36–7.41)	.908
Hb, $g.L^{-1}$	124 (108–138)	128 (112–139)	120 (102–133)	.004
Alb, $g.L^{-1}$	38.41 (5.01)	39.23 (4.72)	37.31 (5.19)	.001
PNI	46.10 (6.13)	47.10 (5.65)	44.74 (6.50)	.001
L3 SMI, $cm^2.m^{-2}$	42.25 (8.71)	43.35 (9.09)	40.77 (7.97)	.009
HUAC, HU	37.67 (6.65)	38.25 (6.20)	36.88 (7.17)	.076
Postinduction blood pressure fluctuation[a]	0.24 (0.16–0.32)	0.24 (0.16–0.32)	0.24 (0.14–0.32)	.956
Surgery time, hour	3.85 (3.06–5.09)	3.65 (3.00–4.98)	4.17 (3.27–5.47)	.012
Opioid analgesics, μg	240 (180–311)	235 (180–319)	248 (180–305)	.508
Blood loss, mL	100 (50–200)	100 (50–200)	200 (50–300)	.002
Urine output, mL	800 (500–1300)	800 (500–1300)	800 (450–1300)	.627
Crystalloid, mL	2600 (2100–3100)	2600 (2100–3100)	2600 (2100–3200)	.117
Colloidal, mL	500 (500–1000)	500 (500–1000)	500 (500–1000)	.275
Postoperative hospital stay, d	12 (10–16)	11 (9–13)	15 (12–21)	<.001
Gender				.176
Female	112 (35.3%)	70 (38.5%)	42 (31.1%)	
Male	205 (64.7%)	112 (61.5%)	93 (68.9%)	
ASA				.059
I	2 (0.6%)	1 (0.5%)	1 (0.7%)	
II	222 (70%)	136 (74.7%)	86 (63.7%)	
III	92 (29%)	45 (24.7%)	47 (34.8%)	
IV	1 (0.3%)	0 (0)	1 (0.7%)	
TNM				.376
I	46 (14.5%)	27 (14.8%)	19 (14.1%)	
II	108 (34.1%)	68 (37.4%)	40 (29.6%)	
III	108 (34.1%)	60 (33.0%)	48 (35.6%)	
IV	55 (17.4%)	27 (14.8%)	28 (20.7%)	
Open surgery	48 (15.1%)	24 (13.2%)	24 (17.8%)	.260
Nerve block	14 (4.4%)	10 (5.5%)	4 (3.0%)	.278
Blood transfusion	158 (49.8%)	75 (41.2%)	83 (61.5%)	<.001
Sarcopenia	254 (80.1%)	138 (75.8%)	116 (85.9%)	.026
Myosteatosis	79 (24.9%)	33 (18.1%)	46 (34.1%)	.001
Vasoconstrictors	129 (40.7%)	62 (34.1%)	67 (49.6%)	.005
Vasodilators	52 (16.4%)	32 (17.6%)	20 (14.8%)	.511
Esmolol	36 (11.4%)	17 (9.3%)	19 (14.1%)	.189
Atropine	165 (52.1%)	101 (55.5%)	64 (47.4%)	.154
Neostigmine	116 (36.6%)	76 (41.8%)	40 (29.6%)	.027

Abbreviations: aCCI, age-adjusted Charlson Comorbidity Index; Alb, albumin; ASA, American Society of Anesthesiologists; BMI, body mass index; IQR, interquartile range; Hb, hemoglobin; HUAC, Hounsfield unit average calculation; L3, third lumbar vertebra; PNI, prognostic nutrition index; SD, standard deviation; SMI, skeletal muscle index; TNM, Tumor Node Metastasis; VTE, Venous thromboembolism; WBC, white blood cell.

[a]The degree of reduction in mean arterial pressures (MAPs) between the anesthesia induction and the skin cut.

significant association was observed between myosteatosis (OR 1.8, 95% CI 1.0–3.3, $P = .039$) and postoperative complications after adjusted for age, gender, ASA classification, aCCI, surgery time, urine output, blood loss, crystalloid, colloidal, and blood transfusion (Table 3).

Secondary Outcomes

Clavien-Dindo Grade 3 and Above Postoperative Complications. As for severe postoperative complication (Chavien-Dindo grade ≥3), it happened in 25 of 254 subjects (9.8%) in the sarcopenia group, 1 of 63 subjects (1.6%) in the nonsarcopenia group, 14 of 79 participants (17.7%) in the myosteatosis group and 12 of 238 participants (5.0%) in the nonmyosteatosis group (Table 2). Univariate and multivariable logistic regression analyses showed that myosteatosis was associated with a significantly increased odds of severe postoperative complications in patients undergoing colorectal tumor resection (OR 4.1, 95%CI 1.8–9.2, $P = .001$; OR 3.8, 95%CI 1.5–9.6, $P = .005$; Table 3).

Correlations Between 2 Muscle-Related Parameters and Other Nutritional Parameters. In our study, age and aCCI were found to be negatively associated with L3 SMI ($r = –0.365$, $P < .001$; $r = –0.269$, $P < .001$) and HUAC ($r = –0.443$, $P < .001$; $r = –0.291$, $P < .001$). Hb, Alb and PNI were positively associated with L3 SMI ($r = 0.296$, $P < .001$; $r = 0.276$, $P < .001$; $r = 0.270$, $P < .001$) and HUAC ($r = 0.196$, $P < .001$; $r = 0.286$, $P < .001$; $r = 0.301$, $P < .001$). BMI was positively correlated with L3 SMI ($r = 0.512$, P

Table 2. Patient Characteristics Comparing Sarcopenia (L3 SMI <55 $cm^2.m^{-2}$ for Males, <39 $cm^2.m^{-2}$ for Females) and Nonsarcopenia or Myosteatosis (HUAC <34.76HU for Male, <31.82HU for Female) and Nonmyosteatosis (Mean [SD], Median [IQR], Number [Proportion])

Variable	Nonsarcopenia group (n = 63)	Sarcopenia group (n = 254)	*P* value	Nonmyosteatosis group (n = 238)	Myosteatosis group (n = 79)	*P* value
Age, y	56 (51–67)	66 (61–74)	<.001	64 (56–69)	71 (66–79)	<.001
BMI, $kg.m^{-2}$	25.7 (23.5–28.1)	22.9 (20.8–24.7)	<.001	23.4 (21.4–25.4)	23.4 (20.8–25.4)	.865
aCCI	4 (3–6)	5 (4–7)	<.001	5 (4–6)	6 (5–7)	<.001
VTE risk score	4 (3–4)	4 (3–5)	.023	4 (3–4)	4 (3–5)	.007
WBC, $*10^9.L^{-1}$	5.78 (4.83–6.96)	5.57 (4.58–7.07)	.578	5.69 (4.64–7.03)	5.46 (4.50–6.96)	.521
Hb, $g.L^{-1}$	127 (116–138)	123 (108–137)	.220	125 (111–140)	120 (98–134)	.009
Alb, $g.L^{-1}$	40.06 (4.74)	38.01 (5.00)	.004	39.17 (4.81)	36.15 (4.95)	<.001
PNI	48.07 (5.65)	45.61 (6.15)	.004	47.05 (5.86)	43.22 (6.05)	<.001
L3 SMI, $cm^2.m^{-2}$	/	/	/	43.45 (8.72)	38.62 (7.67)	<.001
HUAC, HU	39.89 (5.51)	37.12 (6.81)	.003	/	/	/
Postinduction blood pressure fluctuation[a]	0.22 (0.14–0.28)	0.24 (0.16–0.32)	.294	0.24 (0.16–0.32)	0.25 (0.16–0.31)	.834
Surgery time, hour	4.22 (3.28–5.77)	3.74 (3.05–5.01)	.056	3.80 (3.05–5.12)	3.97 (3.07–5.03)	.861
Opioid analgesics, μg	274 (215–380)	230 (175–299)	0.002	240 (176–323)	238 (193–290)	.996
Blood loss, mL	100 (50–300)	100 (50–200)	.953	100 (50–200)	200 (100–200)	.190
Urine output, mL	1000 (550–1400)	800 (500–1200)	.105	800 (500–1300)	900 (500–1300)	.349
Crystalloid, mL	2700 (2100–3600)	2600 (2100–3100)	.107	2600 (2100–3100)	2600 (2100–3100)	.693
Colloidal, mL	500 (500–1000)	500 (500–1000)	.132	500 (500–1000)	500 (500–1000)	.208
Postoperative hospital stay, day	12 (9–14)	13 (10–16)	.063	12 (10–15)	14 (11–17)	.014
Gender			<.001			.981
Female	36 (57.1%)	76 (29.9%)		84 (35.3%)	28 (35.4%)	
Male	27 (42.9%)	178 (70.1%)		154 (64.7%)	51 (64.6%)	
ASA			.107			<.001
I	1 (1.6%)	1 (0.4%)		1 (0.4%)	1 (1.3%)	
II	50 (79.4%)	172 (67.7%)		181 (76.1%)	41 (51.9%)	
III	12 (19.0%)	80 (31.5%)		55 (23.1%)	37 (46.8%)	
IV	0 (0)	1 (0.4%)		1 (0.4%)	0 (0)	
TNM			.641			.728
I	12 (19.0%)	34 (13.4%)		36 (15.1%)	10 (12.7%)	
II	20 (31.7%)	88 (34.6%)		78 (32.8%)	30 (38.0%)	
III	22 (34.9%)	86 (33.9%)		84 (35.3%)	24 (30.4%)	
IV	9 (14.3%)	46 (18.1%)		40 (16.8%)	15 (19.0%)	
Open surgery	4 (6.3%)	44 (17.3%)	.030	33 (13.9%)	15 (19.0%)	.271
Nerve block	1 (1.6%)	13 (5.1%)	.317	11 (4.6%)	3 (3.8%)	1.000
Blood transfusion	32 (50.8%)	126 (49.6%)	.866	111 (46.6%)	47 (59.5%)	.048
Sarcopenia	/	/	/	182 (76.5%)	72 (91.1%)	0.005
Myosteatosis	7 (11.1%)	72 (28.3%)	.005	/	/	/
Vasoconstrictors	16 (25.4%)	113 (44.5%)	.006	88 (37.0%)	41 (51.9%)	.019
Vasodilators	11 (17.5%)	41 (16.1%)	.800	37 (15.5%)	15 (19.0%)	.474
Esmolol	6 (9.5%)	30 (11.8%)	.609	23 (9.7%)	13 (16.5%)	.099
Atropine	43 (68.3%)	122 (48.0%)	.004	132 (55.5%)	33 (41.8%)	.035
Neostigmine	32 (50.8%)	84 (33.1%)	.009	95 (39.9%)	21 (26.6%)	.033
All complication	19 (30.2%)	116 (45.7%)	.026	89 (37.4%)	46 (58.2%)	.001
Clavien-Dindo Grade ≥3	1 (1.6%)	25 (9.8%)	.033	12 (5.0%)	14 (17.7%)	<.001

Abbreviations: aCCI, age-adjusted Charlson Comorbidity Index; Alb, albumin; ASA, American Society of Anesthesiologists; BMI, body mass index; Hb, hemoglobin; HUAC, Hounsfield unit average calculation; IQR, interquartile range; L3, third lumbar vertebra; NM, tumor node metastasis; PNI, prognostic nutrition index; SD, standard deviation; SMI, skeletal muscle index; VTE, Venous thromboembolism; WBC, Caucasian blood cell.

[a]The degree of reduction in mean arterial pressures (MAPs) between the anesthesia induction and the skin cut.

< .001) but has no correlation with HUAC (r = 0.005, *P* = .930; Table 4). The multiple linear regression analysis of L3 SMI and HUAC were statistically significant (for L3 SMI: adjusted R^2=0.659, F=88.356, *P* < .001; for HUAC: adjusted R^2=0.278, F=188.414, *P* < .001). BMI was positively associated with L3 SMI after adjusted for age, gender, aCCI, and Hb. (B=1.148, *P* < .001; Table 5).

DISCUSSION

We assessed the relationship between 2 muscle-related parameters obtained from routine preoperative abdominal CT scans, the L3 SMI and HUAC, and the occurrence of postoperative complications in patients after colorectal tumor resection surgery under general anesthesia. Myosteatosis was found to be significantly associated with postoperative complications in univariate and multivariable analyses, and was also a significant factor for severe postoperative complications (Clavien-Dindo grade ≥3). This support that the odds of postoperative complications in patients with myosteatosis is higher than that in patients with normal skeletal muscle density. In addition, HUAC might

Table 3. Univariate and Multivariable Analyses of Sarcopenia and Myosteatosis With All Postoperative Complications and Postoperative Complications of Clavien-Dindo Grade ≥3 in 317 Patients Undergoing Colorectal Tumor Resection Surgery

	All complications								
	Univariate analysis			Multivariable logistic regression analysis[a]			Multivariable logistic regression analysis[b]		
Variable	OR	95% CI	*P* value	OR	95% CI	*P* value	OR	95% CI	*P* value
Sarcopenia	1.9	1.1–3.5	.027	/	/	/	/	/	/
Myosteatosis	2.3	1.4–3.9	.001	1.9	1.1–3.3	.026	1.8	1.0–3.3	.039
	Postoperative complications of Clavien-Dindo grade ≥3								
	Univariate analysis			Multivariable logistic regression analysis[a]			Multivariable logistic regression analysis[b]		
Variable	OR	95% CI	*P* value	OR	95% CI	*P* value	OR	95% CI	*P* value
Sarcopenia	6.8	0.9–50.9	.063	/	/	/	/	/	/
Myosteatosis	4.1	1.8–9.2	.001	3.4	1.4–8.4	.006	3.8	1.5–9.6	.005

All continuous variable variance inflation factor (VIF) were <10.

Abbreviations: aCCI, age-adjusted Charlson Comorbidity Index; ASA, American Society of Anesthesiologists; CI, confidence interval; OR, odds ratio.

[a]Adjusted for age and ASA classification.

[b]Adjusted for age, gender, ASA classification, aCCI, surgery time, urine output, blood loss, crystalloid, colloidal, and blood transfusion.

be a valuable indicator of prediction for postoperative complications in patients under colorectal tumor resection surgery.

Frailty has become an important indicator of physiological abnormalities and is associated with morbidity, unplanned skilled nursing facility admission, extended hospital stay, readmission and mortality in elective and emergency surgical procedures.[25,26] Sarcopenia and myosteatosis were crucial components of the frailty syndrome, they share common pathophysiological mechanisms and similar definition, which provide objective evaluation indicators for frailty.[27,28] CT and MRI were gold standards for noninvasive muscle mass assessment.[6] CT scan images of patients undergoing selective operation can be acquired without additional radiation amount. Studies have shown that the skeletal muscle mass of a single layer is linearly positively correlated with that of the whole body, with the highest correlation at the L3 vertebral level, indicating the feasibility of L3 SMI and HUAC as objective, measurable, and surrogate markers of sarcopenia.[15,29]

This study revealed a high incidence of sarcopenia in patients undergoing colorectal tumor resection surgery. Since the incidence of sarcopenia in surgical populations was higher,[11] and the muscle mass of Caucasians was greater than that of Asians.[30] Given that the cutoff value of myosteatosis has no internationally accepted standard, we chose the sex-specific lowest 25th percentile of values to define myosteatosis.[21] The correlations between L3 SMI/HUAC and other nutritional parameters after adjusted for confounding factors were not as significant as before, which can be supported by results from major gynecologic surgery population in Lu Che's study.[31] Given the significant association between myosteatosis and postoperative complications, combining muscle-related parameters with traditional nutritional assessment method may help to comprehensively evaluate the nutritional statement of patients with colorectal tumor.

Results indicated that patients with lower level of skeletal muscle radiodensity were vulnerable to postoperative complications,[32,33] especially Clavien-Dindo grade ≥3. A study including 921 patients who underwent radical surgery for colorectal cancer showed that patients with myosteatosis suffered more from surgical site infection than other postoperative complications, which could be explained by the hypoxia in the surrounding area caused by fatty infiltration.[10] However, these conclusions remain controversial. Lu Che, et al[31] found that myosteatosis was an independent risk factor for postinduction hypotension, but not for postoperative complications (Clavien-Dindo grade 1/2). This difference may be attributed to complication grades, sex and different cutoff values for low skeletal muscle radiodensity. Therefore, prospective studies with larger sample sizes are needed to determine the usefulness of sarcopenia and myosteatosis in predicting postoperative complications.

Table 4. Correlations Between the Muscle-related Parameters and Other Nutritional Assessment Parameters

		Age	BMI	aCCI	Hb	Alb	PNI
L3 SMI	Pearson correlation	−0.365	0.512	−0.269	0.296	0.276	0.270
	P value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
HUAC	Pearson correlation	−0.443	0.005	−0.291	0.196	0.286	0.301
	P value	<0.001	0.93	<0.001	<0.001	<0.001	<0.001

Abbreviations: aCCI, age-adjusted Charlson Comorbidity Index; Alb, albumin; BMI, body mass index; Hb, hemoglobin; HUAC, Hounsfield unit average calculation; L3, third lumbar vertebra; PNI, prognostic nutrition index; SMI, skeletal muscle index.

Table 5. Multiple Linear Regression Analysis Between 2 Muscle-Related Parameters and Other Nutritional Assessment Parameters

	L3 SMI[a]				HUAC[a]			
Variable	**B**	**St. error**	β	***P* value**	**B**	**St. error**	β	***P* value**
BMI	1.148	0.087	0.442	.000	−0.178	0.097	−0.090	.067
Alb	0.077	0.120	0.044	.522	0.011	0.133	0.009	.932
PNI	0.103	0.101	0.072	.309	0.217	0.112	0.200	.054

All continuous variable variance inflation factor (VIF) were <10.

Abbreviations: aCCI, age-adjusted Charlson Comorbidity Index; Alb, albumin; B, unstandardized regression coefficient; BMI, body mass index; β, standardized regression coefficient; Hb, hemoglobin; HUAC, Hounsfield unit average calculation; L3, third lumbar vertebra; PNI, prognostic nutrition index; SMI, skeletal muscle index; St. error, coefficient standard error.

[a]Adjusted for age, gender, aCCI, and Hb.

Myosteatosis, characterized by low muscle radiodensity, has been shown to promote systemic inflammatory responses and insulin resistance (IR) in the noncancer population and cancer patients.[34–36] Inflammation-induced lipolysis and redistribution lead to the accumulation of lipids and their derivatives in intermyocellular/intramuscular adipose tissue (IMAT) or perimuscular adipose tissue, and its secondary metabolites, such as diacylglycerols, ceramides, and other lipids, are major mechanisms of IR. As local IR causes impaired lipid utilization, it can increase free fatty acids levels, aggravating myosteatosis. IMAT can promote immune cell polarization into a proinflammatory type, leading to increased inflammation in the skeletal muscle tissue. This vicious circle promotes local lipid accumulation during systemic inflammation. When it comes to the systematic level, IMAT also causes mitochondrial dysfunction and results in impaired muscle function.[37–39] A preclinical study separated the effect of IMAT itself from its drivers, and showed that without mature adipocytes, intramuscular glycerol injection cannot impair the contraction force of muscle, which demonstrated that the decline in skeletal muscle contraction ability could not be explained by the decrease in muscle mass but was related to muscle quality.[8] Malcolm et al[9] focused on 123 patients undergoing hepatobiliary surgery and found that the decrease in muscle quality rather than the decrease in muscle quantity was related to a decrease in patients' aerobic fitness. These highlight the importance of early screening and improvement of myosteatosis status.

The intraoperative dosages of opioid analgesics and vasoconstrictive drugs, was significant different between nonsarcopenia and sarcopenia groups, which indicated that patients with sarcopenia have poor tolerance to opioid analgesics and hemodynamic changes. Soysal et al[40] demonstrated that decreased muscle mass, rather than reduced muscle strength, is associated with orthostatic hypotension, which could be explained by autonomic dysfunction accompanied by sarcopenia. These results supported that sarcopenia impairs the compensatory effect on hemodynamic changes.

Our study had several limitations. First, as a retrospective observational study, other characteristics of sarcopenia and preoperative chemotherapy could not be collected; therefore, we could not diagnose sarcopenia comprehensively, and the effect of preoperative chemotherapy on patients' muscle status should be analyzed in a prospective study. Second, the lack of anesthesia management cause anesthetic agents to become confounding factors that were difficult to adjust, necessitating prospective studies. Third, the single-center study may affect the generalizability of the findings to other populations or settings of our results. Fourth, the morbidity of postoperative complication of Clavien-Dindo grade 3 and above were at a low level, which may lead the analyses about severe postoperative complications underpowered, larger sample size analysis may need in the further to release the potential relationship between sarcopenia and postoperative complications.

In summary, myosteatosis was associated with the occurrence of postoperative complications, especially complications of Clavien-Dindo grade 3 and above, in patients undergoing colorectal tumor rection surgery. Screening for myosteatosis with HUAC using the CT before surgery may help clinicians identify perioperative high-risk patients early. ■

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DISCLOSURES

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