World Journal of Surgical Oncology

RESEARCH

Open Access

Body composition analysis using CT at three aspects of the lumbar third vertebra and its impact on the diagnosis of sarcopenia

Hui Yang[1†], Zekan Gao[2†], Qingzheng Shen[2†], Huaiqing Zhi[2], Wentao Cai[3], Xiang Wang[4], Xiaodong Chen[2*], Xian Shen[2*] and Weiteng Zhang[2*]

Abstract

Purpose The European Working Group on Sarcopenia in Older People (EWGSOP) revised the consensus in 2018, including that using computed tomography (CT) imaging of the lumbar third vertebra (L3) for the evaluation of muscle mass. However, there is currently discrepancy and confusion in the application of specific cross-sectional and cut-off values for L3. This study aimed to standardize the diagnosis of low muscle mass using L3-CT.

Materials and methods This study included patients who underwent radical gastrectomy for gastric cancer between July 2014 and February 2019. Sarcopenia factors were measured preoperatively. Patients were followed up to obtain actual clinical outcomes. We used the cutoff values obtained based on the inferior aspect of L3-CT images to diagnose sarcopenia in three aspects, respectively. Univariate and multivariate analyses were used to compare long-term and short-term postoperative prognostic differences.

Results Sarcopenia was found to be an independent risk factor for postoperative complications and overall survival in patients with all three diagnoses of sarcopenia. According to the multivariate model for predicting postoperative complications, patients with inferior-L3 sarcopenia ($n=154$,13.8%) had a greater odds ratio (OR) than patients with superior-L3 sarcopenia ($n=220$,19.7%) or transverse-L3 sarcopenia ($n=194$,17.4%) did (OR, inferior sarcopenia vs. superior sarcopenia, transverse sarcopenia, 2.030 vs. 1.608, 1.679). Furthermore, patients with inferior-L3 sarcopenia had the highest hazard ratio (HR) (HR, inferior sarcopenia vs. superior sarcopenia, transverse sarcopenia, 1.491 vs. 1.408, 1.376) in the multivariate model for predicting overall survival.

Conclusion We recommend that when diagnosing low muscle mass using L3-CT, the intercepted cross section should be uniform and consistent with the aspect on which the cutoff value is based.

Keywords Sarcopenia, Gastric cancer, Muscle quantity, Lumbar third vertebra, Computed tomography

†Hui Yang, Zekan Gao and Qingzheng Shen contributed equally to this work.

*Correspondence:
Xiaodong Chen
15167797063@163.com
Xian Shen
Shenxian1120@126.com
Weiteng Zhang
jyzwt545@126.com
Full list of author information is available at the end of the article

Introduction

Sarcopenia is a syndrome characterized by a progressive decrease in skeletal muscle mass, strength, and physical performance with aging [1]. Both the European Working Group on Sarcopenia in Older People (EWGSOP) and the Asian Working Group for Sarcopenia (AWGS) have clarified the diagnosis of skeletal muscle strength, including convenient measurement methods and corresponding cutoff values [2, 3]. However, the diagnostic method for skeletal muscle mass has certain limitations, as its measurement methods, such as dual-energy X-ray absorptiometry (DXA) or bioelectrical impedance analysis (BIA), are not easily available in clinical practice. Additionally, the accuracy of DXA and BIA measurements depends largely on the accuracy of the equipment equations and evaluation conditions, such as temperature, humidity, and skin conditions. Therefore, there is a need for more convenient, accessible, and accurate methods for diagnosing muscle mass. Since the gold standard for skeletal muscle mass is derived from whole-body computed tomography (CT) [4], in clinical practice, the whole body of a patient is rarely scanned. Thus, we generally adopt the aspect of muscle area on CT to reflect whole-body muscle mass [5, 6]. The skeletal muscle area (SMA) of the thoracic 12th vertebra CT imaging and lumbar 3rd vertebra (L3) CT imaging have been widely applied to evaluate muscle mass in sarcopenia patients, and their correlation with whole-body muscle mass has been confirmed by several studies [7–11].

Gastric cancer is the fifth most common malignancy and the fourth leading cause of cancer-related death worldwide and is mainly treated by curative gastrectomy [12]. Several studies have found that sarcopenia is an independent risk factor for postoperative complications and overall survival in patients with gastric cancer [13–17]. Patients with gastric cancer routinely undergo preoperative CT of the abdomen to assess gastric cancer staging. Thus, the SMA can be measured via L3-CT imaging without additional examinations to facilitate the clinical assessment of sarcopenia.

Several research teams have used different L3-CT imaging cross-sections to diagnose skeletal muscle mass. Carey et al. used the superior aspect [18], Martin et al. intercepted the transverse aspect [19], and Zhuang et al. used the inferior aspect as the foundation for their diagnoses [14]. Moreover, certain teams lack precise representations of the chosen cross-sections [20], while others have intercepted aspects that utilize the cutoffs of other teams that are inconsistent with the aspect from which the cutoff originates [15, 21, 22]. This study compared data, including muscle area, on three aspects of L3-CT imaging and compared prognostic differences in the diagnosis of sarcopenia for the first time using different L3-CT imaging aspects.

Materials and methods

Patients

This study was approved by the Ethics Committee of the First Affiliated Hospital of Wenzhou Medical University. All patients who underwent radical gastrectomy for gastric cancer in the Department of Gastroenterology, The First Affiliated Hospital of Wenzhou Medical University, between July 2014 and February 2019 were included in this study. The inclusion criteria were as follows: (1) planned to undergo gastrectomy with curative intent for gastric cancer; (2) had preoperative abdominal CT available for review (no more than 1 month prior to surgery); and (3) agreed to participate in this study and signed an informed consent form. The exclusion criteria included (1) having physical deformities that prevented them from performing muscle strength or physical fitness tests and (2) those who underwent palliative surgery. All patients were routinely managed according to the 2010 Japanese Gastric Cancer Treatment Guidelines (ver. 3) [23]. All procedures were performed by experienced surgeons who independently performed > 200 standard gastric cancer surgeries.

Follow-up

All patients were followed up within 1 month of surgery. Thereafter, patients were followed-up every 3 months for 2 years, every 6 months thereafter for up to 5 years, and every 1 year thereafter. Patients were contacted by telephone and scheduled to return to the hospital at the aforementioned time points to complete the follow-up program. The follow-up schedule included laboratory tests, ultrasound, computed tomography (CT), or endoscopy. The final follow-up date was November 2021.

Assessment of the skeletal muscle index

All patients underwent routine preoperative abdominal computed tomography. As shown in Fig. 1, L3-CT images of the superior, transverse, and inferior aspects was intercepted from the Picture Archiving and Communication System. According to the EWGSOP, we used skeletal muscle area to represent skeletal muscle mass [2]. ImageJ (National Institutes of Health, Bethesda, MD, USA, 1.52v) was used to assess the skeletal muscle area using particular Hounsfield Unit (HU) criteria of -29 to 150. As needed, tissue boundaries were manually drawn for each of the three aspects. Muscle area was normalized by height squared and reported as the skeletal muscle index (SMI, cm^2/m^2).

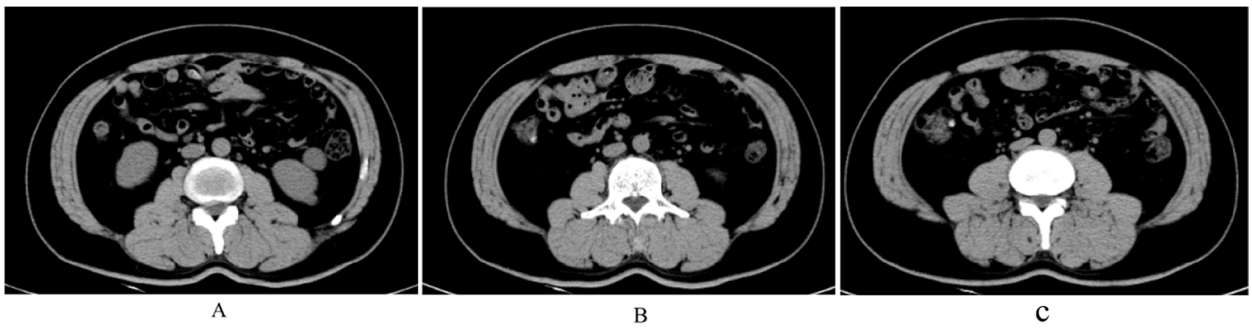

Fig. 1 Diagram of CT image intercept levels of the superior (**A**), transverse (**B**) and inferior (**C**) aspects of L3

Muscle strength and physical performance

Preoperative grip strength and a usual gait speed of 6 m were measured according to the EWGSOP and AWGS definitions of sarcopenia to separately determine the muscle strength and physical performance of each patient. Patients were tested for preoperative grip strength using an electronic hand dynamometer (EH101; Camry Electronics Co., Ltd., Zhongshan, Guangdong, China) with a dominant hand squeeze. The time between the first and last steps over 6 m was used to measure the usual gait speed. Both parameters were measured within 7 days preoperatively, and the maximum value of three repeated tests was recorded.

The diagnosis of sarcopenia

Patients with low skeletal muscle mass, low muscle strength, and/or low physical performance were considered to have sarcopenia, as defined by the EWGSOP and the AWGS. In this study, sarcopenia was diagnosed as follows: (1) low muscle mass (L3 skeletal muscle index (SMI) $\leq$ 40.8 cm^2/m^2 in males and $\leq$ 34.9 cm^2/m^2 in females) [2, 14]; (2) low muscle strength (grip strength < 28 kg in males and < 18 kg in females) [3]; and (3) low muscle performance (6 m usual gait speed < 1 m/s) [3]. The cutoff value was based on the inferior aspect of the L3-CT image. Sarcopenia diagnosed in the muscle area from the superior aspect of L3-CT images was referred to as superior sarcopenia, the transverse aspect of L3-CT imaging as transverse sarcopenia, and the inferior aspect of L3-CT images was considered inferior sarcopenia.

Data collection

For each patient enrolled in this study, the following data were collected at the time of patient admission: preoperative patient characteristics, including age, sex, body mass index (BMI), Charlson comorbidity index, skeletal muscle mass(SMA at the three aspects of L3-CT), muscle strength(grip strength) and physical performance (6 m usual gait speed); surgical details, including laparoscopic-assisted surgery, combined organ resection, type of resection, and operative time, were collected at the end of the patient's surgery; postoperative outcomes were collected during the postoperative hospitalization and at postoperative outpatient follow-up, including tumor pathological features and postoperative complications (within 30 days postsurgery).

Analysis

The agreement of SMA and SMI among the three aspects of L3-CT was calculated using the Wilcoxon rank sum test, and the agreement among the three diagnoses of sarcopenia was analyzed using kappa tests. Student's t test was used to compare continuous normally distributed data, and the Mann–Whitney U test was applied to continuous nonnormally distributed data. Spearman correlations were used for evaluation of the association between non-normally distributed data. Categorical data were compared using the chi-square test or Fisher's exact test. Univariate analysis was used to assess the relationships between categorical variables. Univariate Cox proportional hazards models with all potential baseline predictors were constructed to calculate risk ratios (HR) and 95% CI. Variables with a trend ($P < 0.05$) in the univariate analysis were selected, and multivariate logistic regression or Cox proportional risk models were constructed using forward stepwise variable selection. The Kaplan–Meier method was used to estimate survival curves, and the log-rank test was used to compare the data. The data analysis was performed using the statistical package IBM SPSS Statistics software (SPSS) version 25.0.

Results

Comparison of body composition data at three L3 aspects

As shown in the Supplementary Fig. 1, we excluded unsuitable patients and finally 1116 patients were included in the study. As illustrated in Supplementary Fig. 2, a comparative analysis of the three aspects

reveals that grip strength and step speed exhibit the highest correlation with SMA and SMI of the Inferior aspect. We divided all patients into two groups according to sex, and the SMA and SMI of males and females according to the three aspects are summarized in Table 1. As shown, there were significant differences in the SMA and SMI between these three dimensions for both men and women, all with increases from top to bottom. All three aspects remained highly correlated between the two aspects for both sexes (superior aspect vs. transverse aspect: SMA-$R^2=0.956$; SMI-$R^2=0.935$; transverse aspect vs. inferior aspect: SMA-$R^2=0.952$; SMI-$R^2=0.930$; inferior aspect vs. superior aspect: SMA-$R^2=0.924$; and SMI-$R^2=0.887$).

Diagnostic consistency of three aspects of L3

We considered inferior sarcopenia the gold standard. As shown in Table 2 and Fig. 2, the sensitivity of the superior aspect was 0.955, the specificity was 0.924, and the AUC value was 0.939. The sensitivity of the transverse aspect was 0.941, the specificity was 0.949, and the AUC value was 0.945, which suggests that the diagnosis of the transverse aspect and the superior aspect had a high degree of agreement with that of the inferior aspect. The kappa value for the transverse aspect was 0.803, and the kappa value for the superior aspect was 0.745; both factors also showed a high degree of consistency compared to that of the inferior aspect.

Table 2 The concordance and discrepancy of diagnosis of the three aspects

Inferior aspect	Transverse aspect		superior aspect	
	Normal	sarcopenia	Normal	sarcopenia
Normal	913	49	899	73
Sarcopenia	9	145	7	147

The data are expressed as the number of patients

Sensitivity at the transverse aspect = 0.941; specificity = 0.949

The sensitivity at the superior aspect = 0.955, specificity = 0.924

Population heterogeneity in three types of sarcopenia

As shown in Table 3, the prevalence of superior sarcopenia, transverse sarcopenia, and inferior sarcopenia were 19.7%, 17.4%, and 13.8%, respectively, which revealed that the superior and transverse aspects were used to screen more patients with sarcopenia than was the inferior aspect. However, there were no significant differences in hospitalization costs (superior sarcopenia vs. inferior sarcopenia, $p=0.622$; transverse sarcopenia vs. inferior sarcopenia, $p=0.511$), postoperative hospitalization time (superior sarcopenia vs. inferior sarcopenia, $p=0.335$; transverse sarcopenia vs. inferior sarcopenia, $p=0.255$), or other indicators between superior sarcopenia and transverse sarcopenia with inferior sarcopenia. Thus, we divided the patients into superior sarcopenia and transverse sarcopenia groups and found that patients with superior sarcopenia and without inferior sarcopenia, both men and women, had slightly higher SMI compared

Table 1 SMA (cm^2) and SMI (cm^2/m^2) measurements of three aspects of L3-CT and the coefficient of determination between adjacent aspects

		Overall		Male		Female	
		Median (range)	R^2	Median (range)	R^2	Median (range)	R^2
SMA	Superior aspect	114.5 (60.9–189.7)	0.956[b]	122.6 (76.4–189.7)[a,b]	0.924[b]	89.0 (60.9–142.6)[a,b]	0.909[b]
	Transverse aspect	117.2 (59.7–199.4)	0.952[c]	126.5 (78.9–199.4)[a,c]	0.914[c]	91.8 (59.7–142.4)[a,c]	0.917[c]
	Inferior aspect	120.1 (64.0–197.3)	0.924[d]	129.7 (78.2–197.3)[a,d]	0.869[d]	92.8 (64.0–153.5)[a,d]	0.840[d]
SMI	Superior aspect	42.7 (24.7–66.7)	0.935[b]	44.3 (26.9–66.7)[a,b]	0.915[b]	36.1 (24.7–53.0)[a,b]	0.895[b]
	Transverse aspect	43.7 (24.3–70.6)	0.930[c]	45.8 (27.5–70.6)[a,c]	0.903[c]	37.0 (24.3–52.9)[a,c]	0.902[c]
	Inferior aspect	44.8 (25.0–70.1)	0.887[d]	46.6 (27.5–70.1)[a,d]	0.854[d]	38.4 (25.0–57.0)[a,d]	0.813[d]

SMA skeletal muscle area, *SMI* skeletal muscle index

[a] Statistically significant

[b] Comparison between superior aspect and transverse aspect

[c] Comparison between the transverse aspect and the inferior aspect

[d] Comparison between superior aspect and inferior aspect

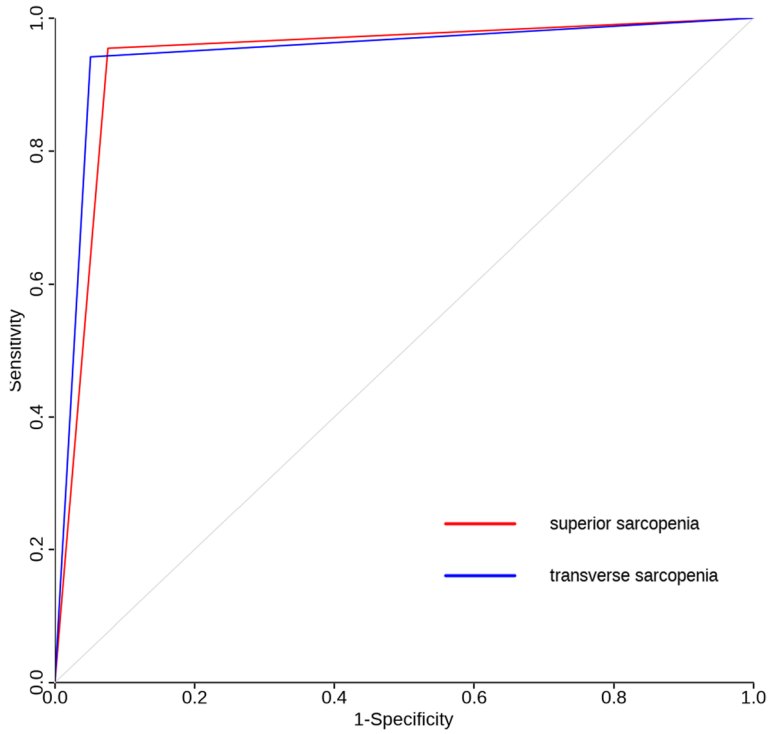

Fig. 2 The ROC curve of superior sarcopenia and transverse sarcopenia. (superior sarcopenia, AUC = 0.939; transverse sarcopenia, AUC = 0.945)

with those with inferior sarcopenia; moreover, their hospitalization cost was reduced by approximately 10%, and their overall hospitalization time was shortened by one day. Furthermore, patients with transverse sarcopenia without inferior sarcopenia had a slightly greater SMI in both men and women, compared with those with inferior sarcopenia, and while women with transverse sarcopenia without inferior sarcopenia had a slightly greater BMI than did those with inferior sarcopenia.

Short-term postoperative complications

We evaluated postoperative complications that occurred within 30 days after gastrectomy and graded the complications according to the Clavien system [24], including those of Grade II or higher. The results of the univariate and multivariate analyses of the predictors of postoperative complications are presented in Table 4. The univariate analysis showed that advanced age, superior sarcopenia, transverse sarcopenia, inferior sarcopenia, Charlson Comorbidity Index, TNM staging, combined organ removal, and open surgery were risk factors for postoperative complications. The multivariate analysis showed a higher dominance ratio for inferior sarcopenia (OR = 2.030, $p < 0.001$) than for superior sarcopenia (OR = 1.608, $p = 0.005$) and transverse sarcopenia (OR = 1.679, $p = 0.004$).

Long-term postoperative survival outcome

The median postoperative follow-up period was 59 months. The 5-year survival rates were 66.2%, 65.9%, and 65.5% for patients with superior, transverse, and inferior sarcopenia, respectively. As shown in Fig. 3, Kaplan–Meier analysis revealed that overall survival (OS) (log-rank, superior sarcopenia, $p = 0.0015$; transverse sarcopenia, p = 0.0024; inferior sarcopenia, $p = 0.003$) was significantly shorter in patients with sarcopenia than in those without sarcopenia, regardless of the aspect-based diagnosis of sarcopenia. As shown in Table 5, multivariate Cox models showed that inferior sarcopenia (HR = 1.491, $p = 0.004$), histologic type, TNM staging, and resection type were independently associated with poorer overall survival. When using superior sarcopenia (HR = 1.408, $p = 0.005$) or transverse sarcopenia (HR = 1.376, $p = 0.012$) instead of inferior sarcopenia, the inclusion of sarcopenia remained in the multifactorial model. Compared to those of inferior sarcopenia, the risks of superior sarcopenia and transverse sarcopenia appeared to be lower.

Discussion

This study compared skeletal muscle area among three aspects of L3-CT imaging and investigated, for the first time, the differences in predicting patient prognosis

Table 3 Comparisons among patients with superior sarcopenia, transverse sarcopenia and inferior sarcopenia

Factors		Superior aspect		Transverse aspect		Inferior aspect	
		Superior sarcopenia[b]	Superiorsarcopenia alone[b]	Transverse sarcopenia[b]	Transverse sarcopenia alone[b]	Inferior sarcopenia[c]	Normal[b]
Number		220[a]	73	194[a,b]	49	154	962
Age, mean (SD), (years)		71(11)	70(12)	72(11)	72(11)	72(12)	64(14)
gender(males)		142(64.5%)	51(69.9%)	123(63.4%)	33(67.3%)	95(61.7%)	722(75.1%)
BMI, mean (SD), (kg/m^2)	Total	20.7(2.4)	21.1(2.4)[a]	20.7(2.4)	21.3(2.3)[a]	20.5(5.8)	22.9(3.0)
	male	20.7(2.3)	20.9(1.9)	20.5(2.4)	22.1(2.7)	20.4(2.5)	22.9(2.9)
	female	20.8(2.5)	21.5(3.3)	21.0(2.2)	21.0(2.1)[a]	20.6(2.2)	23.2(3.2)
SMI, median (IQR), (cm^2/m^2)	total	34.8(6.2)	38.3(5.5)[a]	34.8(5.6)	38.6(6.0)[a]	34.9(6.1)	45.9(8.3)
	male	37.7(4.5)	39.7(2.1)[a]	37.6(4.4)	39.8(1.9)[a]	38.2(3.7)	48.0(7.5)
	female	31.4(4.1)	33.8(1.7)[a]	32.2(3.3)	34.2(1.2)[a]	32.5(3.0)	39.7(5.7)
Tumor size, median (IQR), (cm)		4(3.5)	4(3.5)	4(3.3)	3.5(3.6)	4(3.5)	3(3)
TNM stage							
I		66	25	57	17	45	360
II		52	11	47	6	42	194
III		102	37	90	26	67	408
Hospitalization time, median (IQR), (days)		14(9)	13(6)[a]	14(10)	13(7)	14(10)	13(6)
Hospitalization expenses, median (IQR), (¥)		63,835 (25,752)	59,275 (21,122)[a]	64,333 (25,198)	60,158 (16,415)[a]	65,869 (30,724)	57,928 (21,176)

The data are expressed as the number of patients unless indicated otherwise

Superior sarcopenia alone, exclusion of patients with inferior sarcopenia from those with superior sarcopenia; Transverse sarcopenia alone, exclusion of patients with inferior sarcopenia from those with transverse sarcopenia

BMI body mass index, *SMI* skeletal muscle index, *SD* standard deviation, *IQR* interquartile range

[a] Statistically significant, $P < 0.05$

[b] Compared with inferior sarcopenia patients

[c] Compared with normal

caused by the diagnosis of sarcopenia using muscle data obtained from different aspects of L3-CT imaging. This study showed that the SMA and the SMI increased sequentially from the top to the bottom of the L3-CT image, SMA and SMI at the inferior aspect exhibit the most robust correlation with grip strength and walking speed. However, there was a high correlation among these three aspects, and the results were consistent with those of previous studies [25]. For this reason, more patients were diagnosed with sarcopenia in a descending sequence, from top to bottom, with more patients diagnosed with sarcopenia in the superior and transverse aspects than in the inferior aspect. Overall, there was high agreement in the diagnosis of the three aspects (superior sarcopenia vs. inferior sarcopenia, kappa value = 0.745, $p < 0.001$; transverse sarcopenia vs. inferior sarcopenia, kappa value = 0.803, $p < 0.001$). There were also significant differences in the SMA and SMI among the three aspects, with a certain consistency in diagnosis. Therefore, further analysis is needed to clarify whether this difference impacts the prediction of clinical outcomes.

Several studies have shown that patients with sarcopenia have higher hospitalization costs [26], longer hospital stays [26], and shorter postoperative survival [14] than patients without sarcopenia, in agreement with the findings of our study. We found no significant differences in postoperative length of stay and hospitalization costs among the three sarcopenia populations. After further splitting the patients into superior sarcopenia and transverse sarcopenia cohorts, patients with superior sarcopenia alone (negative for inferior sarcopenia) had a greater SMI in both sexes than did those with inferior sarcopenia. Patients in these groups also spent less on hospitalization than patients with inferior sarcopenia and had a slightly shorter length of postoperative hospitalization, while patients with transverse sarcopenia alone (negative for inferior sarcopenia) had the same SMI and postoperative hospitalization cost as patients with superior sarcopenia alone. Previous studies have revealed that a low SMI can

Table 4 Univariate and multivariate logistic regression analyses for postoperative complications (In the multivariate analysis, three subgroups were included in the analysis only for that group of sarcopenia)

Factors	Univariate analysis		Multivariate analysis					
			Superior sarcopenia		Transverse sarcopenia		Inferior sarcopenia	
	OR (95%CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Age		< 0.001[a]		0.011[a]		0.014[a]		0.019[a]
≥ 75/ < 75	2.040(1.478–2.815)		1.561(1.107–2.201)		1.543(1.093–2.179)		1.514(1.072–2.138)	
Gender		0.777						
Male/female	1.045(0.770–1.419)							
BMI		0.996						
> 25/ < 25	0.999(0.711–1.405)							
Superior sarcopenia		< 0.001[a]		0.006[a]				
Yes/No	1.852(1.348–2.543)		1.608(1.145–2.257)					
Transverse sarcopenia		< 0.001[a]				0.004[a]		
Yes/No	1.989(1.431–2.764)				1.679(1.180–2.389)			
Inferior sarcopenia		< 0.001[a]						< 0.001[a]
Yes/No	2.335(1.638–3.329)						2.030(1.389–2.968)	
Charlson Comorbidity Index								
1/0	1.521(1.104–2.097)	0.010[a]	1.439(1.033–2.004)	0.031[a]	1.424(1.023–1.984)	0.036[a]	1.446(1.037–2.017)	0.030[a]
≥ 2/0	2.587(1.810–3.696)	< 0.001[a]	2.410(1.664–3.491)	< 0.001[a]	2.407(1.662–3.488)	< 0.001[a]	2.446(1.687–3.547)	< 0.001[a]
Histologic type		0.339						
Undifferentiated/differentiated	0.875(0.667–1.150)							
TNM stage								
II/I	1.878(1.296–2.719)	0.001[a]						
III/I	1.613(1.174–2.218)	0.003[a]						
Type of resection		0.021[a]						
Total/Subtotal	1.380(1.049–1.816)							
Combined resection		0.002[a]		0.032[a]		0.030[a]		0.036[a]
Yes/No	2.067(1.302–3.281)		1.702(1.045–2.770)		1.718(1.055–2.798)		1.691(1.035–2.761)	
Laparoscopic surgery		< 0.001[a]		< 0.001[a]		< 0.001[a]		< 0.001[a]
Yes/No	0.441(0.323–0.602)		0.487(0.351–0.676)		0.49(0.353–0.681)		0.488(0.351–0.678)	
Operative durations > 4 h		0.528						
Yes/No	0.908(0.671–1.227)							

[a] Statistically significant

be used as an independent risk factor for predicting postoperative length of stay [27], cost [28], complications [29] and long-term prognosis [30], whereas patients with a high SMI have been found to have a better postoperative prognosis. This may partially explain the relatively better length of stay and cost performance of patients with superior sarcopenia and transverse sarcopenia.

Further analysis of postoperative complications revealed that inferior sarcopenia had the best predictive ability (superior sarcopenia, OR = 1.608; transverse sarcopenia, OR = 1.769; inferior sarcopenia, OR = 2.030). According to our analysis of long-term survival, inferior sarcopenia appeared to retain high predictive power for survival (superior sarcopenia, HR = 1.408; transverse sarcopenia, HR = 1.376; inferior sarcopenia, HR = 1.491). Taken together, these findings showed that patients with superior and transverse sarcopenia had relatively high SMI, as described previously. This was perhaps because the superior and transverse sarcopenia cohort included more patients with suspected sarcopenia, for whom the short- and long-term prognostic performance was slightly better than that of patients with inferior sarcopenia. This has led to superior and transverse sarcopenia to present a relatively low risk predictive ability in

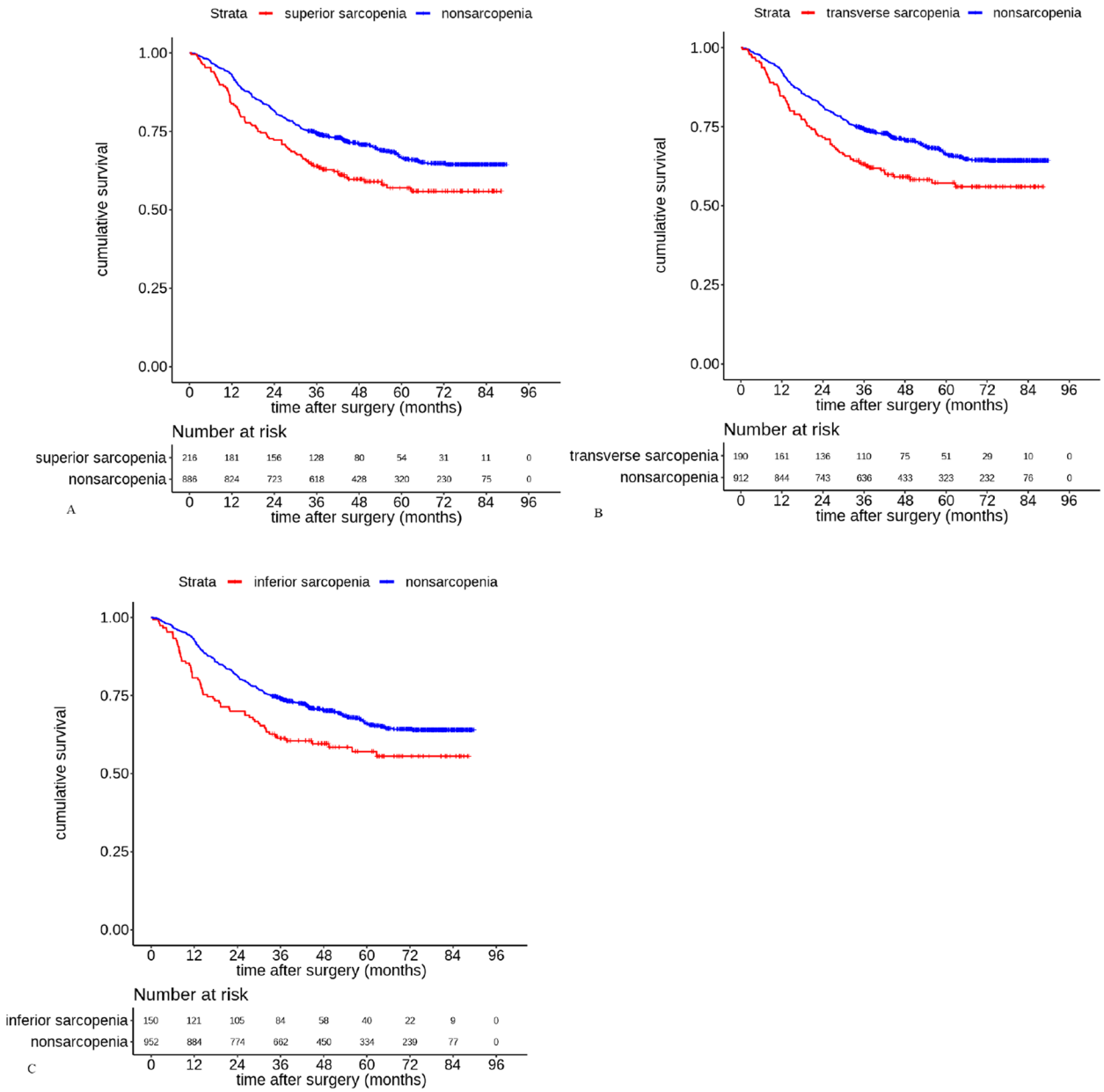

Fig. 3 KaplaneMeier curves for overall survival in patients with and in those without sarcopenia (**A** superior sarcopenia; **B** transverse sarcopenia; **C** Inferior sarcopenia). **A** $P=0.0015$; **B** $P=0.0024$; **C** $P=0.003$(log rank test)

prognostic predictions. At the root of this, despite the high correlation of SMA between the three aspects, differences remain in SMA values. We uniformly used a cutoff that was obtained according to the L3 inferior aspect as the basis for the diagnosis of low SMI in this study, and applying this cutoff to the superior aspect and transverse aspect may be the underlying cause of this difference.

This study has several limitations. First, this was a single-center study, and a larger multicenter study is needed to validate our findings. In addition, although we clarified that the cutoff value should be consistent with the intercept, whether a specific aspect of L3 selection would yield a better prognostic value remains unclear.

Conclusion

In this study, we explored in detail the diagnosis of low muscle mass in patients with sarcopenia and found that when using a uniform cutoff at the inferior aspect, it may be possible that a lower SMI at the superior and transverse aspects, compared to the inferior aspect screened

Table 5 Univariate and multivariate analyses for predictors of overall survival (In the multivariate analysis, three subgroups were included in the analysis only for that group of sarcopenia)

Factors	Univariate analysis		Multivariate analysis					
			Superior sarcopenia		Transverse sarcopenia		Inferior sarcopenia	
	HR (95% CI)	*P*	HR (95% CI)	*P*	HR (95% CI)	*P*	HR (95% CI)	*P*
Age		< 0.001[a]						
≥ 75/ < 75	1.910(1.520–2.401)							
Gender		0.054						
Male/female	1.322(1.035–1.688)							
BMI		0.243						
> 25/ < 25	0.854(0.654–1.114)							
Superior sarcopenia		0.002[a]		0.005[a]				
Yes/No	1.463(1.153–1.857)		1.408(1.109–1.788)					
Transverse sarcopenia		0.003[a]				0.012[a]		
Yes/No	1.460(1.139–1.872)				1.376(1.073–1.766)			
Inferior sarcopenia		0.004[a]						0.004[a]
Yes/No	1.494(1.139–1.959)						1.491(1.135–1.959)	
Charlson Comorbidity Index								
1/0	1.236(0.977–1.562)	0.077						
≥ 2/0	1.211(0.911–1.619)	0.187						
Histologic type		< 0.001[a]		0.002[a]		0.002[a]		0.003[a]
Undifferentiated/differentiated	1.824(1.477–2.251)		1.396(1.127–1.729)		1.395(1.126–1.728)		1.387(1.119–1.718)	
TNM stage								
II/I	2.517(1.712–3.700)	< 0.001[a]	2.172(1.471–3.206)	< 0.001[a]	2.169(1.469–3.203)	< 0.001[a]	2.139(1.448–3.161)	< 0.001[a]
III/I	7.071(5.152–9.705)	< 0.001[a]	5.623(4.052–7.804)	< 0.001[a]	5.640(4.064–7.926)	< 0.001[a]	5.657(4.078–7.848)	< 0.001[a]
Type of resection		< 0.001[a]		< 0.001[a]		< 0.001[a]		< 0.001[a]
Total/Subtotal	2.088(1.703–2.560)							
Combined resection		0.001[a]						
Yes/No	1.732(1.243–2.414)							
Laparoscopic surgery		< 0.001[a]						
Yes/No	0.582(0.461–0.737)							
Operative durations > 4 h		0.327						
Yes/No	1.118(0.895–1.396)							

[a] Statistically significant

out more critical patients with suspected sarcopenia, which is clearly detrimental to the predictive power of the model. We recommend that when diagnosing low SMI, the aspect of interception should be uniform and consistent with the aspect of the truncation values. Since it has the potential to be incorporated into risk-scoring systems for postoperative prognosis and to improve clinical decision-making in patients, this study of patients with gastric cancer emphasizes the need for a standardized assessment of sarcopenia.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12957-024-03634-9.

Supplementary Material 1: Supplementary Figure 1. Flowchart for exclusion of patients not suitable for enrollment.

Supplementary Material 2: Supplementary Figure 2. Comparison of the correlation between grip strength, gait speed, and muscle data(SMA and SMI) at three aspects.

Acknowledgements
We would like to thank our patients, without whom this study would not be possible.

Authors' contributions
W.Z, X.C and X.S. made substantial contributions to the conception and design of the study. H.Y., H.Q., Q.S. and Z.G. were involved in the collection and analysis of the data, H.Y. wrote the manuscript, and W.C. and X.W. provided final approval and revised the manuscript. All the authors read and approved the final manuscript.

Funding
No funds were involved in this study.

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

Declarations

Ethics approval and consent to participate
The studies involving human participants were reviewed and approved by the Ethics Committee of The First Affiliated Hospital of Wenzhou Medical University. The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Anesthesia, The First Affiliated Hospital of Wenzhou Medical University, Wenzhou, Zhejiang, China. [2]Department of Gastrointestinal Surgery, The First Affiliated Hospital of Wenzhou Medical University, Wenzhou, Zhejiang, China. [3]Department of Trauma & Emergency Surgery, The First Affiliated Hospital of Wenzhou Medical University, Wenzhou, Zhejiang Province, China. [4]Department of Thoracic Surgery, The First Affiliated Hospital of Wenzhou Medical University, Wenzhou, Zhejiang, China.

Received: 8 March 2024 Accepted: 23 December 2024
Published online: 26 February 2025

References

1. Cruz-Jentoft A, Sayer A. Sarcopenia. Lancet (London, England). 2019;393(10191):2636–46.
2. Cruz-Jentoft A, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T, et al. Sarcopenia: revised European consensus on definition and diagnosis. Age Ageing. 2019;48(1):16–31.
3. Chen LK, Woo J, Assantachai P, Auyeung TW, Chou MY, Iijima K, et al. Asian Working Group for Sarcopenia: 2019 Consensus Update on Sarcopenia Diagnosis and Treatment. J Am Med Dir Assoc. 2020;21(3):300-307.e2.
4. Beaudart C, McCloskey E, Bruyère O, Cesari M, Rolland Y, Rizzoli R, et al. Sarcopenia in daily practice: assessment and management. BMC Geriatr. 2016;16(1):170.
5. Mourtzakis M, Prado CMM, Lieffers JR, Reiman T, McCargar LJ, Baracos VE. A practical and precise approach to quantification of body composition in cancer patients using computed tomography images acquired during routine care. Appl Physiol Nutr Metab. 2008;33(5):997–1006.
6. Fearon K, Strasser F, Anker SD, Bosaeus I, Bruera E, Fainsinger RL, et al. Definition and classification of cancer cachexia: an international consensus. Lancet Oncol. 2011;12(5):489–95.
7. Kang SH, Jeong WK, Baik SK, Cha SH, Kim MY. Impact of sarcopenia on prognostic value of cirrhosis: going beyond the hepatic venous pressure gradient and MELD score. J Cachexia Sarcopenia Muscle. 2018;9(5):860–70.
8. van Vugt JLA, Alferink LJM, Buettner S, Gaspersz MP, Bot D, Darwish Murad S, et al. A model including sarcopenia surpasses the MELD score in predicting waiting list mortality in cirrhotic liver transplant candidates: a competing risk analysis in a national cohort. J Hepatol. 2018;68(4):707–14.
9. Hanai T, Shiraki M, Nishimura K, Ohnishi S, Imai K, Suetsugu A, et al. Sarcopenia impairs prognosis of patients with liver cirrhosis. Nutrition. 2015;31(1):193–9.
10. Yang M, Tan L, Xie L, Hu S, Liu D, Wang J, et al. Factors that improve chest computed tomography-defined sarcopenia prognosis in advanced non-small cell lung cancer. Front Oncol. 2021;11:754975.
11. Nemec U, Heidinger B, Sokas C, Chu L, Eisenberg RL. Diagnosing sarcopenia on thoracic computed tomography: quantitative assessment of skeletal muscle mass in patients undergoing transcatheter aortic valve replacement. Acad Radiol. 2017;24(9):1154–61.
12. Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, et al. Global Cancer Statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin. 2021;71(3):209–49.
13. Sato T, Aoyama T, Hayashi T, Segami K, Kawabe T, Fujikawa H, et al. Impact of preoperative hand grip strength on morbidity following gastric cancer surgery. Gastric Cancer. 2016;19(3):1008–15.
14. Zhuang C-L, Huang D-D, Pang W-Y, Zhou C-J, Wang S-L, Lou N, et al. Sarcopenia is an independent predictor of severe postoperative complications and long-term survival after radical gastrectomy for gastric cancer: analysis from a large-scale cohort. Medicine (Baltimore). 2016;95(13):e3164.
15. Tegels JJW, van Vugt JLA, Reisinger KW, Hulsewé KWE, Hoofwijk AGM, Derikx JPM, et al. Sarcopenia is highly prevalent in patients undergoing surgery for gastric cancer but not associated with worse outcomes. J Surg Oncol. 2015;112(4):403–7.
16. Fukuda Y, Yamamoto K, Hirao M, Nishikawa K, Nagatsuma Y, Nakayama T, et al. Sarcopenia is associated with severe postoperative complications in elderly gastric cancer patients undergoing gastrectomy. Gastric Cancer. 2016;19(3):986–93.
17. Huang DD, Zhou CJ, Wang SL, Mao ST, Zhou XY, Lou N, et al. Impact of different sarcopenia stages on the postoperative outcomes after radical gastrectomy for gastric cancer. Surgery. 2017;161(3):680–93.
18. Carey EJ, Lai JC, Wang CW, Dasarathy S, Lobach I, Montano-Loza AJ, et al. A multicenter study to define sarcopenia in patients with end-stage liver disease. Liver Transpl. 2017;23(5):625–33.
19. Martin L, Birdsell L, Macdonald N, Reiman T, Clandinin MT, McCargar LJ, et al. Cancer cachexia in the age of obesity: skeletal muscle depletion is a powerful prognostic factor, independent of body mass index. J Clin Oncol. 2013;31(12):1539–47.
20. Takagi K, Yagi T, Yoshida R, Shinoura S, Umeda Y, Nobuoka D, et al. Sarcopenia and American Society of Anesthesiologists Physical Status in the Assessment of Outcomes of Hepatocellular Carcinoma Patients Undergoing Hepatectomy. Acta Med Okayama. 2016;70(5):363–70.
21. Ebadi M, Wang CW, Lai JC, Dasarathy S, Kappus MR, Dunn MA, et al. Poor performance of psoas muscle index for identification of patients with higher waitlist mortality risk in cirrhosis. J Cachexia Sarcopenia Muscle. 2018;9(6):1053–62.
22. Bhanji RA, Narayanan P, Moynagh MR, Takahashi N, Angirekula M, Kennedy CC, et al. Differing impact of sarcopenia and frailty in nonalcoholic steatohepatitis and alcoholic liver disease. Liver Transpl. 2019;25(1):14–24.
23. Japanese Gastric Cancer Association. Japanese gastric cancer treatment guidelines 2010 (ver. 3). Gastric Cancer. 2011;14(2):113–23.
24. Dindo D, Demartines N, Clavien P-A. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg. 2004;240(2):205–13.
25. Schweitzer L, Geisler C, Pourhassan M, Braun W, Glüer C-C, Bosy-Westphal A, et al. What is the best reference site for a single MRI slice to assess whole-body skeletal muscle and adipose tissue volumes in healthy adults? Am J Clin Nutr. 2015;102(1):58–65.
26 Lo YTC, Wahlqvist ML, Huang YC, Chuang SY, Wang CF, Lee MS. Medical costs of a low skeletal muscle mass are modulated by dietary diversity and physical activity in community-dwelling older Taiwanese: a longitudinal study. Int J Behav Nutr Phys Act. 2017;14(1):31.

27. Giani M, Rezoagli E, Grassi A, Porta M, Riva L, Famularo S, et al. Low skeletal muscle index and myosteatosis as predictors of mortality in critically ill surgical patients. Nutrition. 2022;101:111687.
28. Koter S, Cohnert TU, Hindermayr KB, Lindenmann J, Brückner M, Oswald WK, et al. Increased hospital costs are associated with low skeletal muscle mass in patients undergoing elective open aortic surgery. J Vasc Surg. 2019;69(4):1227–32.
29. Ansari E, Chargi N, van Gemert JTM, van Es RJJ, Dieleman FJ, Rosenberg AJWP, et al. Low skeletal muscle mass is a strong predictive factor for surgical complications and a prognostic factor in oral cancer patients undergoing mandibular reconstruction with a free fibula flap. Oral Oncol. 2020;101:104530.
30. Zheng ZF, Lu J, Xie JW, Wang JB, Lin JX, Chen QY, et al. Preoperative skeletal muscle index vs the controlling nutritional status score: Which is a better objective predictor of long-term survival for gastric cancer patients after radical gastrectomy? Cancer Med. 2018;7(8):3537–47.

Publisher's Note