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EFFICACY ANALYSIS OF ULTRASONIC DIAGNOSIS FOR SARCOPENIA IN PATIENTS IN THE INTENSIVE CARE UNIT

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Abstract: Objective: To Explore the Efficacy of Ultrasound in Diagnosing Sarcopenia in the Intensive Care Unit (ICU)Introduction: Critically ill patients with sarcopenia experience prolonged mechanical ventilation duration, extended hospital stay, and increased mortality. Ultrasound is characterized by convenience, radiation-free nature, and low cost in the ICU setting; however, few studies have investigated its efficacy in diagnosing sarcopenia among ICU patients. Methods: The skeletal muscle area at the third lumbar vertebra (L3 SMA) was calculated by analyzing abdominal computed tomography (CT) images acquired at the time of patient admission. Ultrasound was used to scan the cross-sectional area (RFCSA) and thickness (RFMT) of the rectus femoris muscle in the patients' right lower limbs. With CT as the gold standard, a diagnostic study was conducted to evaluate the efficacy of ultrasound in diagnosing sarcopenia in ICU patients. Results: Among the 366 enrolled patients, regardless of gender, those with sarcopenia had lower values of age, body mass index (BMI), L3 SMA, RFCSA, and RFMT compared with patients without sarcopenia. For the diagnosis of sarcopenia in ICU patients using ultrasound-measured RFCSA, the area under the curve (AUC) was 0.794 in males and 0.766 in females. When using ultrasound-measured RFMT for diagnosis, the AUC was 0.791 in males and 0.736 in females. The combined use of these two ultrasound parameters further improved the diagnostic efficacy. Conclusion: Ultrasound can serve as a reliable method for sarcopenia screening in ICU patients.
Keywords: ICU; Ultrasound; Sarcopenia; Diagnostic efficacy

1 INTRODUCTION

In 2010, the European Working Group on Sarcopenia in Older People (EWGSOP) defined sarcopenia as a syndrome characterized by the concurrent presence of reduced skeletal muscle mass and impaired skeletal muscle function (including muscle strength and physical function) [1]. Studies [2–4] have found that under stressful conditions such as acute illness or surgery, patients are more prone to developing acute skeletal muscle loss.Patients in the ICU (Intensive Care Unit) are in critical condition, long-term bedridden, and in a hypercatabolic state, making them more prone to developing acute sarcopenia. A study by Wu et al [5]. found that within 28 days of ICU admission, the thickness of the rectus femoris decreases by 0.84% per day, and the thickness of the vastus medialis decreases by 0.98% per day. In addition, results from a meta-analysis [6] showed that critically ill patients experience significant muscle loss during the first week after ICU admission: the thickness of the rectus femoris decreases by an average of 1.75% per day, the cross-sectional area of the rectus femoris decreases by an average of 2.1% per day, the cross-sectional area of the biceps brachii decreases by 2.23% per day, and the thickness of the biceps brachii decreases by 1.64% per day.ICU sarcopenia can lead to a variety of adverse consequences for patients, their families, and social healthcare services [7]. Results from a meta-analysis by Jiang et al. [8] showed that mechanical ventilation combined with sarcopenia increases the mortality rate of ICU patients (OR = 2.13; 95% CI: 1.70–2.67), prolongs the duration of mechanical ventilation (MD = 1.22; 95% CI: 0.39–2.05), and extends the length of ICU stay (MD = 1.31; 95% CI: 0.43–2.19).In addition, findings from a 5-year follow-up study of 109 ICU survivors by Herridge et al. [9] indicated that the decreases in muscle strength and physical function caused by sarcopenia can persist for 5 years after discharge. This leads to reduced quality of life in survivors and increased healthcare costs. Thus, it is evident that ICU sarcopenia can cause numerous harms to patients both during hospitalization and after discharge. Therefore, the early identification of high-risk groups and the reduction of acute sarcopenia incidence in ICU patients are of great significance for improving outcomes in ICU patients.

EWGSOP 2 points out that the main methods for measuring sarcopenic muscle mass include bioelectrical impedance analysis (BIA), dual-energy X-ray absorptiometry (DXA), computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound (US). Both CT and MRI involve a certain amount of radiation and have high diagnostic costs; furthermore, there is a certain transfer risk for ICU patients who need to be moved outside for CT or MRI scans. In contrast, the reliability of DXA and BIA decreases in cases of body dehydration or excessive edema [10]. Therefore, the aforementioned assessment tools all have certain limitations in the diagnosis of sarcopenia in ICU patients.CT is regarded as the gold standard for skeletal muscle mass assessment. The skeletal muscle index (SMI) determined by CT scanning at the level of the third lumbar vertebra (L3) is significantly correlated with total body muscle mass and has been widely used to evaluate skeletal muscle quantity in ICU patients [11]. The measurement method is as follows: based on the skeletal muscle threshold (−29 to +150 Hounsfield units), assistive tools are used to measure the total area of the psoas major muscle, erector spinae muscle, quadratus lumborum muscle, transversus abdominis muscle, external oblique muscle, internal oblique muscle, and rectus abdominis muscle at the L3 level. The SMI is then obtained by adjusting this total area by the square of the patient's height [12]. A study [13] showed that the muscle quantity in the

L3 region analyzed by CT images was significantly correlated with the total body muscle quantity measured by DXA ($r= 0.94$, $P < 0.001$). According to the latest recommendations of EWGSOP 2, SMI is the optimal parameter for CT-based assessment of skeletal muscle mass [4].Ultrasound generates two-dimensional images by converting the reflection, refraction, and diffraction signals of sound waves into electrical frequency signals. The common parameters of musculoskeletal ultrasound mainly include muscle thickness(MT), muscle cross-sectional area(CSA),, echo intensity (EI), and pennation angle [14]. Ultrasound is used to evaluate muscle quantity by measuring a patient's muscle thickness or muscle cross-sectional area, and can also be used to qualitatively assess changes in muscle quality by analyzing echo intensity [15]. A meta-analysis by Fazzini et al. [6] which included 3,251 ICU patients, showed that 85% of the studies used ultrasound to evaluate changes in muscle quantity/quality in ICU patients. A study by Lambell et al. [16] indicated that ultrasound had a high degree of consistency with the gold standard (CT) in assessing acute muscle mass reduction in ICU patients ($r = 0.82$, $P < 0.001$). Results from a diagnostic meta-analysis by Fu et al. [17], which included 2,143 subjects, showed the following: the pooled sensitivity of ultrasound for diagnosing sarcopenia by measuring the rectus femoris cross-sectional area was 84%, with a pooled specificity of 69%; the pooled sensitivity for diagnosing sarcopenia by measuring the rectus femoris muscle thickness was 63%, with a pooled specificity of 77%; moreover, the diagnostic efficacy of ultrasound for sarcopenia by combining rectus femoris cross-sectional area measurement with echo intensity was superior to that of measuring muscle cross-sectional area or muscle thickness alone.To summarize, ultrasound has good reliability and validity for measuring muscle quality/quantity in sarcopenic populations. For ICU patients in particular, ultrasound is convenient to use, low-cost, and radiation-free, enabling dynamic and quantitative measurement of muscle quantity/quality

However, there are currently no unified standards or cut-off values for the ultrasonic diagnosis of acute sarcopenia in ICU patients. A meta-analysis by Fu et al. [17] on the accuracy of ultrasound in diagnosing sarcopenia showed that domestic and international studies on the diagnostic efficacy and cut-off values of ultrasound for sarcopenia have mainly focused on community-dwelling healthy individuals and hospitalized elderly patients, while relatively few studies on sarcopenia assessment via ultrasound have been conducted in the ICU setting.A literature review [6] found that the commonly used muscle sites for assessing muscle quantity/quality in the ICU environment are the rectus femoris, quadriceps femoris, and gastrocnemius, among which the rectus femoris is the most frequently used measurement site. The commonly applied ultrasonic parameters include muscle thickness, muscle cross-sectional area, and echo intensity. The cut-off values for ultrasonic diagnosis of sarcopenia in ICU patients may vary depending on differences in reference standards, ultrasonic measurement sites, and measurement parameters.To summarize, there are relatively few studies on the optimal cut-off values for ultrasonic diagnosis of sarcopenia in the ICU setting. Furthermore, the cut-off values for ultrasonic diagnosis of sarcopenia may vary depending on differences in measurement sites and measurement parameters. Therefore, additional relevant studies are still needed to determine the optimal cut-off values for diagnosing sarcopenia in ICU patients [18]. Consequently, with the "gold standard" (CT) as the reference, exploring the optimal cut-off values for domestic ultrasonic diagnosis of acute sarcopenia in ICU patients is of great significance for the early identification of acute sarcopenia in these patients.

2 MATERIAL AND METHODS

This study adopted a cross-sectional design and used the convenience sampling method to select ICU patients from the First Affiliated Hospital of Soochow University for investigation, with the study period ranging from November 2024 to June 2025.This study was approved by the Ethics Committee of The First Affiliated Hospital of Soochow University. All study participants who signed the informed consent form were enrolled in this study and underwent sample collection.Inclusion Criteria: 1. Admitted to the ICU and aged ≥ 18 years;2.Having undergone an abdominal CT scan before admission or within 48 hours after admission;3.Informed consent obtained from the patient or their family members.Exclusion Criteria:1.Patients with amputation on the limb to be studied or those who have undergone lower limb orthopedic surgery; 2. Patients with trauma (e.g., fractures, burns) in the region to be studied, which prevents measurement;3.Patients unable to meet the body position requirements for ultrasound measurement due to their disease.The patient enrollment process is shown in Figure 1. Literature search revealed that the area under the curve (AUC) of ultrasound-measured parameters related to the cross-sectional area of the rectus femoris muscle for diagnosing sarcopenia was 0.8 in males and 0.7 in females [18]. The sample size was calculated using PASS 15.0.5 software (Power Analysis of Sample Size, PASS) with the sample size estimation method for diagnostic tests. With α set at 0.05 and $1-\beta$ at 0.90, the software calculation showed that a total of 34 male patients and 82 female patients were needed, resulting in a final required sample size of 116 cases.In the context of acute illness, patients' muscle strength and physical function are prone to being affected by weakness and changes in consciousness [1]. Therefore, the diagnosis of acute sarcopenia in ICU patients mostly relies on the criteria of low muscle quantity or quality. In this study, a low skeletal muscle index (measured by CT) was used as the diagnostic criterion for acute sarcopenia in ICU patients, with the cutoff values of < 44.77 cm²/m² in males and < 32.5 cm²/m² in females [19]. Abdominal CT images of patients obtained within 48 hours before and after admission were retrieved via the hospital's imaging system, and the sequence containing the third lumbar vertebra (L3) was identified using DICOM Viewer software. At the level near the endplate of the L3 vertebra, images were analyzed with SliceOmatic 5.0 Rev-9 software (Tomovision, Montreal, QB, Canada). The threshold for skeletal muscle was set at −29 Hounsfield units (HU) to +150 HU. Skeletal muscles were manually colored to calculate the skeletal muscle area (SMA) at the L3 level, including the psoas major muscle, quadratus lumborum muscle, erector spinae muscles, transversus abdominis muscle, rectus abdominis muscle, internal oblique muscles, and external oblique muscles. The skeletal muscle index (SMI) was then calculated as follows: SMI = SMA (cm^2) / height squared (m^2). Acute sarcopenia in ICU patients was diagnosed based on this SMI (Figure 2).Within 48 hours of ICU admission, the cross-sectional area and thickness of the rectus femoris muscle were measured. The measurement site was the rectus femoris muscle of the right lower limb, specifically at the distal one-third of the line connecting the anterior superior iliac spine (ASIS) and the superior border of the patella [20]. The site was marked with a marker pen after measurement using a tape measure. All operators were medical staff with formal ultrasound training and proficient skills.For the measurement, ICU patients were placed in a supine position with the head of the bed elevated at 30°. Their forearms were externally rotated and placed alongside the body, knees were extended and relaxed, and toes were pointing upward. A Portable Color Doppler Ultrasound Diagnostic System Rev.1 (GE Healthcare) was used, equipped with a linear probe (frequency: 4–12 MHz). The musculoskeletal (MSK) ultrasound mode was selected, and the measurement depth was set to 5 cm; adjustments to the depth were allowed if the muscle thickness could not be fully displayed on the ultrasound interface. The gain was set to 0. At the marked site (distal one-third between the ASIS and the superior border of the patella on the right lower limb), the ultrasound probe was placed perpendicular to the leg skin surface, with a sufficient amount of ultrasound gel applied to maintain minimal pressure between the probe and the skin, thereby obtaining images of the rectus femoris (RF)muscle.Two investigators independently measured the data on the original ultrasound screen, and the average value was taken. If the error between the two measurements exceeded 10%, a third experienced ultrasound physician performed the measurement again, and the average of the three measurements was calculated (Figure 3).

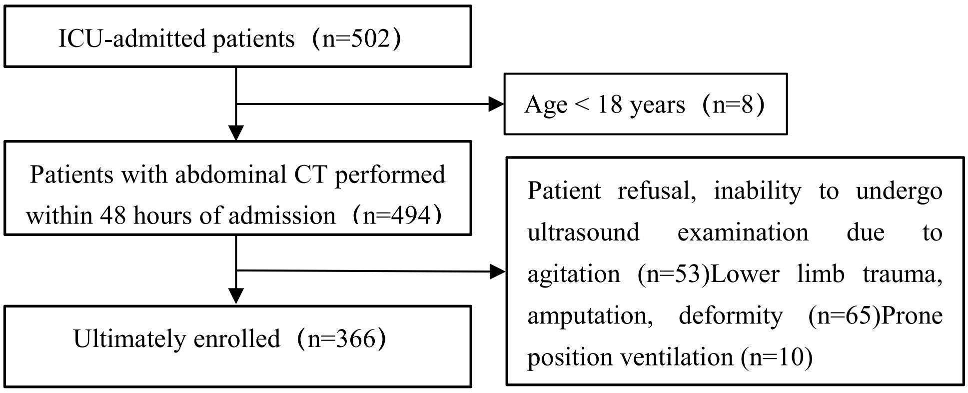

Figure1 Flow Chart

Figure 2 L3 CT Skeletal Muscle Area Image

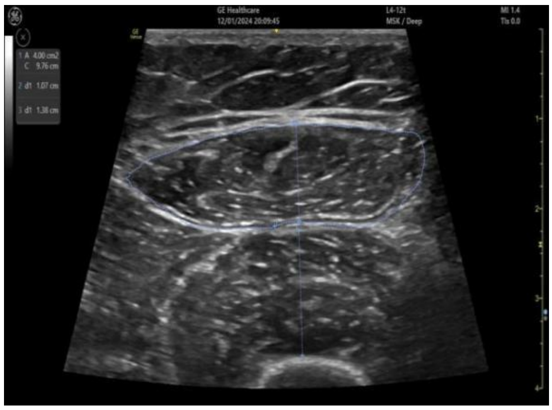

Figure 3 Rectus Femoris Muscle image

2.1 Statistical Analysis

All data in this study were subjected to statistical analysis using SPSS 26.0 software.Descriptive Analysis of DataFor quantitative data: The Shapiro-Wilk test was used to determine whether the data conformed to a normal distribution.If the data conformed to a normal distribution, they were expressed as mean ± standard deviation ($\bar{x} \pm s$);If the data did not conform to a normal distribution, they were expressed as median M (P25, P75) .For categorical data: They were expressed as frequency (percentage).Inferential Statistical Analysis For comparisons of normally distributed quantitative data, the t-test was used.For comparisons of non-normally distributed quantitative data and ordinal data, the rank-sum test (Mann-Whitney Test) was used.The diagnostic efficacy of ultrasound for sarcopenia was analyzed using three indicators: sensitivity, specificity, and the receiver operating characteristic (ROC) curve.

Table1 CT-based Population Characteristics of ICU Sarcopenia Patients

	Population(n=366)		Z	*P*	Man(n=185)		Z	*P*	Female(n=181)		Z	*P*
	Sacopemia (n=122)	No sarcopenia (n=244)			Sacopemia (n=77)	No sarcopenia (n=108)			Sacopemia (n=45)	No sarcopenia (n=136)		
Age（year）	66.00(57.00,81.00)	58.00(45.00,71.00)	-4.557	＜0.001	68.00(55.00,77.00)	57.00(43.00,93.50)	-3.927	＜0.001	65.00(59.00,82.00)	60.00(46.00,74.00)	-2.932	0.003
BMI(kg/m^2）	21.15(18.37,23.10)	24.20 (21.45,26.65)	-7.084	＜0.001	20.94(18.40,22.90)	25.10(22.50,27.60)	-6.901	＜0.001	21.50 (18.25,25.39)	23.40 (20.80,25.40)	-3.267	0.001
SMA(cm^2)	100.69(77.42,120.80)	126.85(99.02,152.20)	-7.790	＜0.001	116.50 (102.1,126.70)	153.40 (140.60,169.55)	-10.978	＜0.001	75.34(70.56,80.11)	101.00 (91.68,114.35)	-9.868	＜0.001
SMI（cm^2/m^2）	35.71(31,53,41.73)	46.49(39.38,52.48)	-5.071	＜0.001	39.86(36.48,43.25)	48.95(48.72,56.67)	-11.581	＜0.001	31.53(27.37,32.22)	40.24(37.13,45.04)	-10.045	＜0.001
RFCSA (cm^2）	2.70(1.93, 3.58)	3.13(2.49,4.15)	-10.862	＜0.001	3.11(2.65, 371)	4.25(3.57, 5.19)	-6.817	＜0.001	1.90(1.70, 2.33)	2.66(2.21, 3.23)	-4.734	＜0.001
RFMT（cm）	0.93(0.83, 1.21)	1.21(0.98,1.42)	-5.993	＜0.001	1.00(0.93, 1.26)	1.35(1.23, 1.62)	-6.749	＜0.001	0.83(0.71, 0.91)	1.05(0.90, 1.26)	-5.351	＜0.001

3 RESULTS

Analysis of the characteristics of sarcopenia in ICU patients based on CT diagnosis is shown in Table 1.atients with sarcopenia are more likely to be older and have a lower BMI, and this trend is consistent in both males and females.Whether referring to indicators reflecting "whole-body muscle mass" (SMA, SMI) or those reflecting "local muscle mass of the lower limbs" (RFCSA, RFMT), the sarcopenia group showed significantly lower values than the non-sarcopenia group (all $P<0.001$ or $P=0.001$)—a finding that fully aligns with the core definition of sarcopenia as "reduced muscle mass".The absolute values of SMA, SMI, RFCSA, and RFMT in males were all higher than those in females (a physiological difference). However, the trend of differences between "sarcopenia vs. non-sarcopenia" was completely consistent in both male and female subgroups, indicating that the muscle mass characteristics of sarcopenia have no gender specificity.Analysis of the diagnostic efficacy of ultrasound for sarcopenia in ICU patients is shown in Table 2.Both RFCSA and RFMT exhibit moderate to moderately good diagnostic efficacy for sarcopenia in ICU patients (AUC: 0.736–0.794), with no "ineffective diagnostic" indicators observed.Females performed better in terms of sensitivity (84.4%, resulting in fewer missed diagnoses), while males showed superior specificity in RFCSA (72.2%, leading to fewer misdiagnoses).The combined use of RFCSA and RFMT can slightly improve diagnostic efficacy, with a more pronounced improvement observed in male patients (with the AUC exceeding 0.8).The ROC curve for ultrasound diagnosis of sarcopenia in ICU patients is shown in Figure 4 and Figure 5.

Table2 Efficacy Analysis of Ultrasonic Diagnosis for Sarcopenia in ICU

	RFCSA		RFMT		Joint Prediction	
	Man	Female	Man	Female	Man	Female
AUC	0.794	0.766	0.791	0.736	0.807	0.768
Cut off	3.730	2.340	1.250	0.920	/	/
Sensitivity	0.753	0.844	0.753	0.844	/	/
Specificity	0.722	0.706	0.657	0.721	/	/

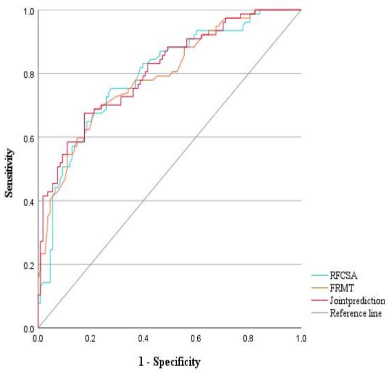

Figure 4 ROC Curve for Ultrasonic Diagnosis in Males

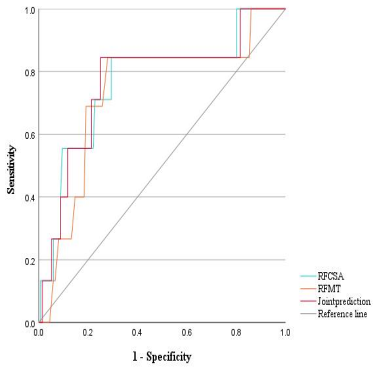

Figure 5 ROC Curve for Ultrasonic Diagnosis in Females

4 DISCUSSION

Ultrasound can achieve moderate diagnostic efficacy using either RFCSA or RFMT alone, meeting the need for "rapid screening of sarcopenia" in the ICU—given the high portability of bedside ultrasound, which is suitable for critically ill patients.While the combined prediction of RFCSA + RFMT can improve diagnostic accuracy, it is particularly suitable for scenarios where "precise identification of sarcopenia is required to guide nutritional support/rehabilitation interventions".It is essential to set cut-off values based on gender; otherwise, diagnostic accuracy will be severely compromised.If prioritizing the avoidance of missed diagnoses (e.g., screening for high-risk patients in the ICU), RFCSA/RFMT may be preferred (with 84.4% sensitivity in females). If prioritizing the avoidance of misdiagnoses (e.g., preventing unnecessary interventions), RFCSA is preferred for males (72.2% specificity) and RFMT is preferred for females (72.1% specificity).

Ultrasound has emerged as the preferred tool for diagnosing sarcopenia in ICU patients, primarily due to its bedside immediacy and radiation-free nature—attributes that align perfectly with the special needs of critically ill individuals who require frequent, non-harmful assessments. Notably, its efficacy conclusions are consistent with findings from multiple field studies, further validating its clinical value.In a multicenter study published by [18] et al., ultrasound was used to diagnose sarcopenia in ICU patients. The results showed that the Area Under the Curve (AUC) of the Rectus Femoris Cross-Sectional Area (RFCSA) was 0.80 for male patients and 0.70 for female patients. These figures are highly consistent with the data from the present study, where the AUC of RFCSA was 0.794 for males and 0.766 for females[17]. Both studies collectively confirm that a single ultrasound parameter (e.g., RFCSA) can meet the demand for rapid sarcopenia screening in ICU settings, streamlining the diagnostic process without compromising accuracy.Regarding diagnostic efficacy, the present study also verified that the diagnostic performance of rectus femoris cross-sectional area (RFCSA) for sarcopenia is superior to that of rectus femoris thickness—a conclusion that aligns with the consensus of most current researchers. This finding provides clear guidance for clinical practice: when selecting muscle sites for ultrasound assessment, researchers and clinicians should prioritize lower limb muscles. This preference is largely attributed to the relatively large volume and stable anatomical structure of lower limb muscles, which are less affected by patient positioning— a critical advantage when examining critically ill individuals in the ICU who often have limited mobility and require stable life support. When choosing measurement parameters, cross-sectional area should be the priority, as it more comprehensively reflects overall muscle mass compared to linear thickness, which may be influenced by local tissue edema or compression. Additionally, it is essential to establish different cutoff values based on gender, considering the inherent physiological differences in muscle distribution and baseline muscle mass between males and females—this personalized adjustment helps further improve the accuracy of ultrasound diagnosis for sarcopenia in ICU patients.

This study verified that the combined diagnostic value of skeletal muscle cross-sectional area (CSA) + muscle thickness (MT) based on ultrasound imaging for sarcopenia in ICU patients is higher than that of CSA or MT alone, providing evidence for the following conclusions:Ultrasound may offer higher diagnostic accuracy for sarcopenia in critically ill patients;When diagnosing sarcopenia using different ultrasound parameters, priority can be given to muscle cross-sectional area (CSA).However, this study also has certain limitations. It only used conventional two-dimensional ultrasound (transverse section) to construct a single-modal ultrasound radiomics model. In the future, researchers can further integrate conventional two-dimensional ultrasound (transverse and longitudinal sections), contrast-enhanced ultrasound, and elastography to construct multi-modal ultrasound radiomics models. This integration will enable multi-dimensional and more detailed feature extraction, which helps reduce subjective variability among clinicians, thereby further improving diagnostic accuracy.

5 CONCLUSION

In conclusion, this study reveals that ultrasound, as an assessment tool for diagnosing sarcopenia in ICU patients, exhibits favorable diagnostic efficacy. Specifically, the combination of the Rectus Femoris Cross-Sectional Area

(RFCSA) and Rectus Femoris Thickness (RFMT) yields higher diagnostic cutoff values. In the future, ultrasound—this non-invasive tool—can be used to perform early screening for sarcopenia in ICU patients.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] Liu Dandan, Tan Lingling, Yang Ming, et al. Research Progress of Acute Sarcopenia. Chinese Journal of Multiple Organ Diseases in the Elderly, 2023, 22(1): 71-75.

[2] Huang D-D, Ji Y-B, Zhou D-L, et al. Effect of surgery-induced acute muscle wasting on postoperative outcomes and quality of life. Journal of Surgical Research, 2017, 218: 58–66.

[3] Mayer K P, Thompson Bastin M L, Montgomery-Yates A A, et al. Acute skeletal muscle wasting and dysfunction predict physical disability at hospital discharge in patients with critical illness. Critical Care, 2020, 24(1): 637.

[4] Cruz-Jentoft A J, Bahat G, Bauer J, et al. Sarcopenia: revised european consensus on definition and diagnosis. Age and Ageing, 2019, 48(1): 16–31.

[5] Wu R-Y, Sung W-H, Cheng H-C, et al. Investigating the rate of skeletal muscle atrophy in men and women in the intensive care unit: a prospective observational study. Scientific Reports, 2022, 12(1): 16629.

[6] Fazzini B, Märkl T, Costas C, et al. The rate and assessment of muscle wasting during critical illness: a systematic review and meta-analysis. Critical Care, 2023, 27(1): 2.

[7] Akan B, Gokcinar D, Damgaci L, et al. Sarcopenia detected in aged patients in intensive care units is associated with poor prognosis. Authorea Preprints, 2021.

[8] Jiang T, Lin T, Shu X, et al. Prevalence and prognostic value of preexisting sarcopenia in patients with mechanical ventilation: a systematic review and meta-analysis. Critical Care, 2022, 26(1): 140.

[9] Herridge M S, Diaz-Granados N, Cooper A, et al. Functional disability 5 years after acute respiratory distress syndrome. The New England Journal of Medicine, 2011.

[10] Mundi M S, Patel J J, Martindale R. Body composition technology: implications for the icu. Nutrition in Clinical Practice, 2019, 34(1): 48–58.

[11] Lopez-Ruiz A, Kashani K. Assessment of muscle mass in critically ill patients: role of the sarcopenia index and images studies. Current Opinion in Clinical Nutrition & Metabolic Care, 2020, 23(5): 302–311.

[12] Steele S, Lin F, Le T-L, et al. Segmentation and linear measurement for body composition analysis using slice-o-matic and horos. Journal of Visualized Experiments, 2021(169): 61674.

[13] Mourtzakis M, Prado C M M, Lieffers J R, et al. A practical and precise approach to quantification of body composition in cancer patients using computed tomography images acquired during routine care. Applied Physiology, Nutrition, and Metabolism, 2008, 33(5): 997–1006.

[14] Tagliafico A S, Bignotti B, Torri L, et al. Sarcopenia: how to measure, when and why. La radiologia Medica, 2022, 127(3): 228–237.

[15] Giovannini S, Brau F, Forino R, et al. Sarcopenia: diagnosis and management, state of the art and contribution of ultrasound. Journal of Clinical Medicine, 2021, 10(23): 5552.

[16] Lambell K J, Tierney A C, Wang J C, et al. Comparison of ultrasound-derived muscle thickness with computed tomography muscle cross-sectional area on admission to the intensive care unit: a pilot cross-sectional study. Journal of Parenteral and Enteral Nutrition, 2021, 45(1): 136–145.

[17] Fu H, Wang L, Zhang W, et al. Diagnostic test accuracy of ultrasound for sarcopenia diagnosis: a systematic review and meta-analysis. Journal of Cachexia, Sarcopenia and Muscle, 2023, 14(1): 57–70.

[18] Nakanishi N, Miyajima I, Saijo T, et al. Cut-off values for an ultrasound-based muscle mass assessment at intensive care unit admission: a retrospective study. Clinical Nutrition Open Science, 2024, 55: 263–273.

[19] Zeng X, Shi Z, Yu J, et al. Sarcopenia as a prognostic predictor of liver cirrhosis: a multicentre study in china. Journal of Cachexia, Sarcopenia and Muscle, 2021, 12(6): 1948–1958.

[20] Van Ruijven I M, Stapel S N, Molinger J, et al. Monitoring muscle mass using ultrasound: a key role in critical care. Current Opinion in Critical Care, 2021, 27(4): 354–360.