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Essam Ibrahim Saber Ibrahim
Professor of Anesthesia, Intensive Care and pain management, Faculty of Medicine, Al-Azhar University, Cairo, Egypt

Ali Abdallah Alkumity
Lecturer of Anesthesia, Intensive Care and pain management, Faculty of Medicine, Al-Azhar University, Cairo, Egypt

Ahmed Mohamed El-Deeb
Lecturer of Diagnostic Radiology, Faculty of Medicine, Al-Azhar University, Cairo, Egypt

Ali Abd Elhamed Gharabawy
MBBcH of Anesthesia, Intensive Care and pain management, Faculty of Medicine, Al-Azhar University, Cairo, Egypt, dr.ali.801@gmail.com

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ORIGINAL ARTICLE

Evaluation of the Prognostic Value of Rectus Abdominis Muscle Thickness and Rectus Femoris Muscle Thickness Guided by Ultrasound in Intensive Care Patients: An Observational Study

Essam Ibrahim Saber Ibrahim [a], Ali Abdallah Alkumity [a], Ahmed Mohamed El-Deeb [b], Ali Abd Elhamed Gharabawy [a,*]

[a] Department of Anesthesia, Intensive Care and Pain Management, Egypt
[b] Department of Diagnostic Radiology, Faculty of Medicine, Al-Azhar University, Cairo, Egypt

Abstract

Background: **Early prediction of prognosis of patients is important in critical care Intensive care unit-acquired weakness. It has been documented that there is an association between the aforementioned condition and the need for prolonged mechanical breathing as well as a lengthy stay in the ICU. A potential technique to measure muscle thickness is ultrasound (US), which is noninvasive, and frequently used in ICU.**

Objective: **Evaluation of the prognostic value of rectus abdominis and rectus femoris muscle thickness guided by US in ICU patients and which of them undergoes more rapid changes and gives an earlier prognosis.**

Patients and methods: **Seventy (70) patients admitted ICU were enrolled. The thickness of rectus abdominis and rectus femoris muscles were measured using US at admission, 3rd and 7th days of admission. The clinical prognosis was measured using Acute Physiology and Chronic Health Evaluation II scoring system at the day of admission. The primary outcome of our study was the evaluation of the prognostic value of rectus abdominis and rectus femoris muscle thickness guided by the US in ICU patients. Secondary outcomes were assessing the association of degree of muscle wasting assessed by US, and ICU stay, need for mechanical ventilation, mortality incidence in ICU.**

Results: **The lower mean value of rectus abdominal and rectus femoral muscle thickness was associated and negatively correlated with a higher mean value of Acute Physiology and Chronic Health Evaluation score, prolonged hospital stay, and higher mortality rates.**

Conclusion: **An accurate and practical quantitative technique that can be used to assess the morbidity and mortality risks in the intensive care unit is the thickness of the rectus abdominis and rectus femoris muscles as assessed by ultrasonography.**

Keywords: Prognostic value, Rectus abdominis muscle, Rectus femoris muscle, Ultrasound

1. Introduction

Every year, millions of patients are monitored in the intensive care unit (ICU) during the perioperative period or due to various diseases, and some of these patients die, others stay in the ICU for an extended period of time, and some require mechanical ventilation.[1]

Early prognosis prediction may aid in not only controlling the mortality rate of ICU patients but also in reducing their length of stay to preserve patients' lives and decrease expenses.[2]

Many factors influence mortality in ICU patients, including age, sex, weight, chronic illness, vital signs, and test values such as serum creatinine level.[3]

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* Corresponding author at: Elmaasra, Helwan, Cairo Governorate, 11884, Egypt.
E-mail address: dr.ali.801@gmail.com (A.A.E. Gharabawy).

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Unfortunately, while these measures can help predict patient mortality, none of them can predict their prognosis, requirement for mechanical ventilation, or length of ICU stay. As a result, parameters that can predict this are being examined.[4]

Intensive care unit-acquired weakness refers to a condition characterized by a widespread decline in muscle strength that manifests during a patient's stay in the ICU. This weakness cannot be attributed to any source other than the acute illness or the medical interventions employed to treat it.[5]

Numerous studies examining the correlation between muscular weakness and clinical outcomes have consistently demonstrated that muscle weakness serves as a significant and autonomous prognostic indicator for mortality, extended duration of ventilator use, and prolonged length of stay in the ICU.[6]

Numerous studies have investigated alterations in anabolic and catabolic signaling pathways, employing ultrasonography as a modality for identifying muscle characteristics. The primary objective of these investigations is to enhance our understanding of pathophysiology and facilitate the timely detection of abnormalities.[7]

2. Patients and methods

This prospective observational study was conducted at the Anesthesia, Intensive Care and Pain Management Department, Faculty of Medicine, Al Azhar University Hospitals from August 2022 to June 2023. Patients who are admitted to the ICU must meet specific requirements:

Inclusion criteria: any patients in ICU above 21 years old admitted for 7 days or more.

Exclusion criteria: represented by, patients with pre-existing neuromuscular pathology, patients with myopathy, individuals who have undergone hip disarticulation surgery, and individuals who have been released from the ICU before the seventh day.

2.1. Sample size justification

A cohort including 70 individuals was included in the study, after consenting each of them. This number of cases was adopted by using MedCalc for Windows version 19.4 program, (MedCalc Software, Ostend, Belgium) by setting alpha error of 5%, 95% confidence level, and 80% power sample. The sample size for this study was calculated from the incidence of intensive care unit-acquired weakness syndromes which was 40%, according to previous study of (Appleton et al., 2015).[8] Equations are described in (Sakpal, 2010).[9]

2.2. Ethical considerations

2.2.1. Patient data and informed consent

Before their inclusion in the study, the patient provided consent to participate after receiving a comprehensive explanation, presented in a comprehensible way, regarding the nature, extent, and potential ramifications of the clinical investigation. All patients or their legal guardians, in the case of unconscious patients, were duly notified of the procedure.

The preservation of patient confidentiality: was ensured through the utilization of patient initials exclusively in the case report form. Furthermore, in instances where the patient's name was required on any other document, it was securely stored by the investigators. The investigators utilized a personal patient identification list, consisting of patient initials paired with their respective patient names, to facilitate the identification of records.

2.2.2. Protocol approval

Before commencing the study, adherence to local regulations was ensured by submitting the protocol and associated documents for ethical and research approval to the council of the Department of Anesthesia, Intensive Care, and Pain Management at Al Azhar University.

2.3. Study interventions and procedures

At the time of admission, US was utilized to evaluate the muscular thickness of the rectus abdominis and rectus femoris muscles, 3rd and 7th days of admission. The clinical prognosis was measured using Acute Physiology and Chronic Health Evaluation (APACHE II) scoring system on the day of admission. No evidence of harmful effects of the study intervention.

2.4. Evaluation of muscle thickness

The assessment of the patients was conducted on the day of admission utilizing comprehensive history gathering, clinical examination, and necessary laboratory investigations All patients' or legal guardians (if the patient was unconscious) were informed of the procedure. The researchers employed a portable ultrasound machine, specifically the Sonosite model, in their study. The machine was equipped with a linear transducer operating at a frequency range of 5–10 MHz, as well as a curvilinear transducer operating at a frequency range of 2–5 MHz. US measurements were conducted within a 24 h timeframe subsequent to the patient's admission to the intensive care unit (ICU). Subsequent pictures were acquired on the third and seventh day following admission to the ICU. Muscle thickness was measured and recorded in centimeters.

2.5. Measurement of rectus abdominis muscle

The measurement of rectus abdominis muscle thickness over the upper abdomen was conducted using B-mode US The patient assumed a supine position and maintained silent breathing during the procedure. The probe was positioned perpendicular to the upper abdominal wall and a generous amount of gel was applied. A scan of the upper abdomen was conducted, starting at the level of the umbilicus and extending 5 cm upwards, to identify the region with the greatest muscle thickness. Subsequently, the probe was adjusted to achieve a suitable inclination, resulting in the clear visualization of both muscle sheaths on the monitor. Subsequently, the image was immobilized and the inter-sheath distances were quantified on the ultrasound monitor, utilizing centimeters as the unit of measurement. The measurement was performed using a (Sonosite portable US machine) (Fig. 1).

(1) The utilization of US for the quantification of the rectus abdominis. Despite the patient being in a supine position and exhibiting quiet breathing without muscle contraction, the probe was positioned perpendicular to the upper abdominal wall, accompanied by a generous application of gel. A scan of the upper abdomen was conducted, starting at the level of the umbilicus and extending 5 cm upwards, to identify the region with the greatest muscle thickness. Subsequently, the probe was adjusted in a manner that resulted in the clear visualization of both sheaths of the muscle on the monitor.
(2) When the visual representation of both muscle sheaths was distinctly observed, the image was captured and the separation distance between the sheaths was subsequently quantified on the US machine's monitor.[10]

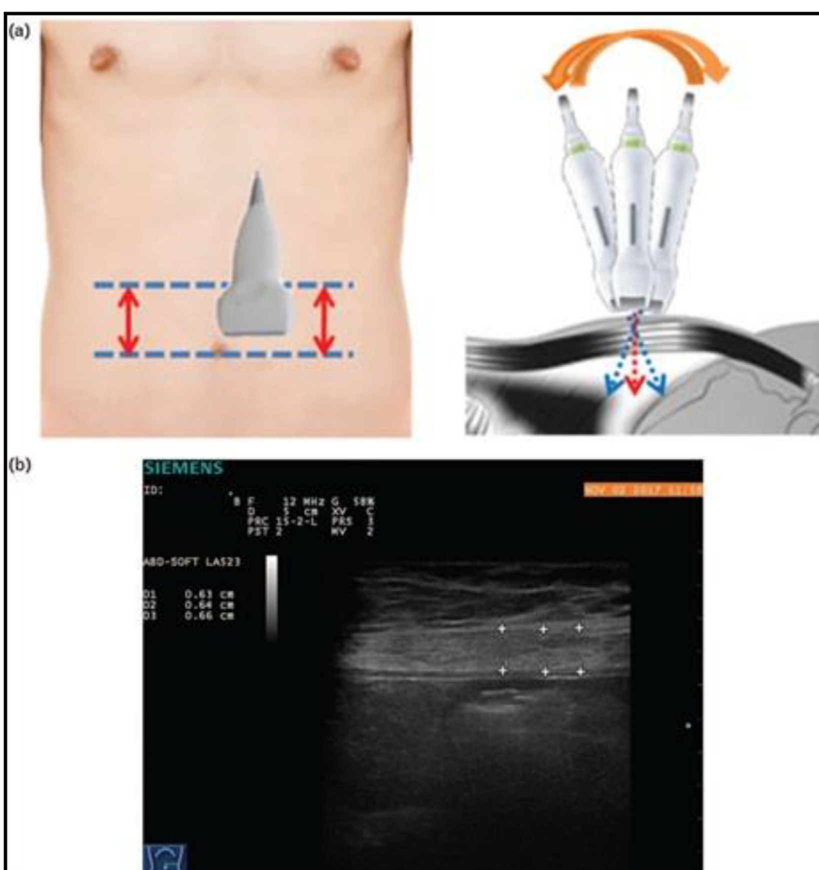

Fig. 1. Measurement of rectus abdominis thickness by ultrasound.

2.6. Measurement of rectum femoris muscle

A linear transducer was employed to perform B-mode imaging, while the participant maintained a supine position with extended elbows and knees. The placement of the transducer was perpendicular to the longitudinal axis of the limbs. The measurements will be obtained from the right thigh, namely at the midpoint between the anterior superior iliac spine and the proximal end of the patella, using the metric unit of centimeters (Fig. 2).

2.7. Assessment of patients' clinical prognosis using (APACHE II)

The APACHE-II scoring systems were developed by Knaus *et al*., in 1991.[11] The APACHE-II score is comprised of three constituent elements. The Acute Physiology Score (APS), which constitutes the primary component of the APACHE-II score, is calculated based on 12 clinical measurements that are collected within the first 24 h following admission to the ICU. The APS component of the APACHE-II score was derived by selecting the measurement that had the highest degree of abnormality. In cases when a variable was not subjected to measurement, it was allocated a value of zero points.

The factors assessed in the study included internal temperature, heart rate, mean arterial pressure, respiratory rate, oxygenation, and arterial pH.

The second component involved age adjustment, whereby patients aged 44 years and older were assigned an additional 1 to 6 points. The chronic health examination was the third component of APACHE-II. A supplementary modification was implemented to accommodate individuals experiencing severe and chronic organ failure encompassing the heart, lungs, kidneys, liver, and immune system.

The following data were carried out.

The patient demographic information includes variables such as age, sex, and cause of admission, as well as the duration of the patient's stay in the ICU. Additionally, the vital signs of the patient are also considered. The variables of heart rate, mean arterial blood pressure (MABP), internal temperature, and oxygen saturation (SpO_2) were measured and documented, and lab tests (complete blood count, coagulation profile. Arterial blood gases, serum sodium, serum potassium and renal functions) were done. Also, results were used to calculate APACHE II scoring for the study participants. Muscle thickness of rectus femoris and rectus abdominis measured by US was recorded in centimeters.

2.7.1. Primary outcome

Evaluation of the prognostic value of abdominis rectus muscle thickness and the measurement of rectus femoris muscle thickness guided by the US in ICU patients.

2.7.2. Secondary outcomes

Assessing the association of degree of muscle wasting assessed by US, and: ICU stay, need for mechanical ventilation, mortality incidence in ICU, and APACHE II score as a method of prognosis in ICU patients.

2.8. Statistical analysis

The data that was collected was analyzed using the statistical software package for social sciences, namely version 23.0 developed by SPSS Inc., based

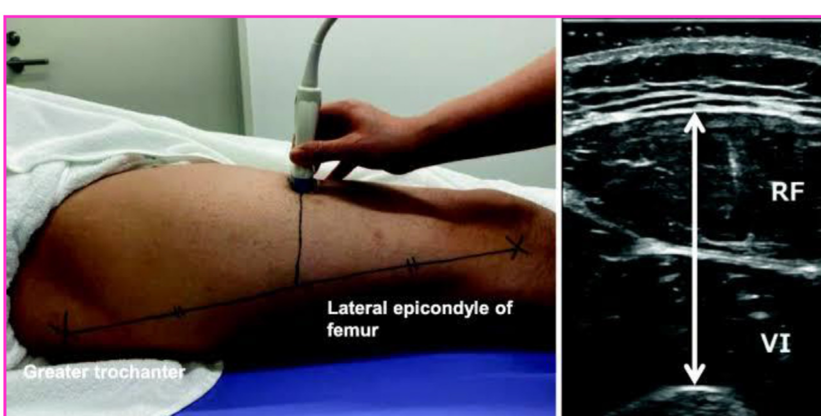

Fig. 2. Measurement of rectus femoris thickness by ultrasound.

in Chicago, Illinois, USA. The presentation of quantitative data followed a certain format. When the data had a parametric distribution (i.e., normal distribution), the mean value was reported along with the standard deviation and range. On the other hand, for variables that did not follow a normal distribution (i.e., nonparametric data), the median value was reported along with the inter-quartile range (IQR). Furthermore, the presentation of qualitative characteristics was expressed in numerical values and percentages. The normality of the data was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests.

The following tests were done.

The concept of paired samples refers to a statistical technique that involves comparing two sets of observations that are related or connected in some way. The *t*-test for significance was employed to compare similar samples.

The independent-samples *t*-test was employed to assess the significance of differences between two means.

When doing a statistical analysis to compare means among many groups, a one-way analysis of variance (ANOVA) is employed. The post hoc test is a statistical analysis method used to determine if there are significant differences between multiple groups after conducting an initial ANOVA. Tukey's test was employed to conduct multiple comparisons among distinct variables.

Repeated-measures ANOVA was used to compare multiple within-group measures. The Bonferroni correction was used to adjust the *P*-value for multiple within-group comparisons.

The comparison between groups with qualitative data was conducted by employing both the χ^2 test and Fisher's exact test. The Fisher's exact test was utilized in cases where the expected count in any cell was less than 5, as an alternative to relying solely on the χ^2 test.

The Pearson correlation coefficient (r) was employed to evaluate the extent of correlation between two sets of variables. A positive correlation indicates that an increase in the independent variable corresponds to an increase in the dependent variable, whereas a negative correlation suggests that an increase in the independent variable corresponds to a reduction in the dependent variable.

2.8.1. Scatter plot

A graphical representation is constructed by plotting the values of two variables on a set of orthogonal axes, wherein the arrangement of the resulting data points provides insights into the presence of correlation. The confidence interval was established at a 95% level, with a corresponding margin of error of 5%. The significance of the *P*-value was determined based on its probability (*P*-value). A *P*-value less than 0.05 was deemed significant, a *P*-value less than 0.001 was considered extremely significant, and a *P*-value greater than 0.05 was regarded as insignificant.

3. Results

We aimed our study to evaluate the prognostic value of rectus abdominis muscle thickness and rectus femoris muscle thickness guided by US in ICU patients and which of them undergoes more rapid changes and gives an earlier prognosis we applied our study to 70 patients, with the same inclusion and exclusion criteria.

Table 1 describes the age, sex, and cause of admission distribution of total study population. Age ranged from 25 to 90 years with mean ± SD of 52.74 ± 15.47. There were 34 (48.6%) patients who were '40–60 years'. As regards sex distribution, there were 35 (50%) females and 35 (50%) males; and cause of admission was 28 (40%) patients were surgical and 42 (60%) patients were medical (Fig. 3 and Table 2).

Table 1. Demographic data distribution among study group.

Baseline characteristics	Total (n = 70)
Age (y)	
Range	25–90
Mean ± SD	52.74 ± 15.47
Age Group	
<40 years	15 (21.4%)
40–60 years	34 (48.6%)
>60 years	21 (30.0%)
Sex	
Male	35 (50.0%)
Female	35 (50.0%)
Cause of admission	
Surgical	28 (40.0%)
Medical	42 (60.0%)

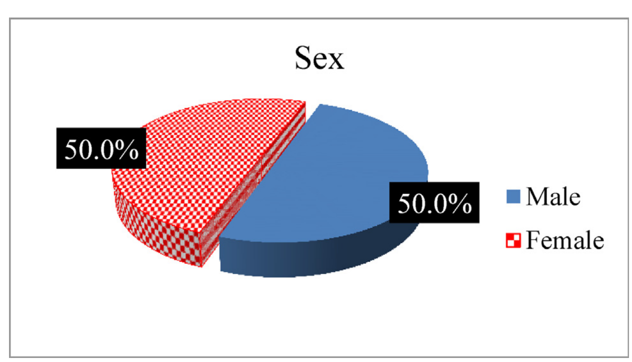

Fig. 3. Pie chart sex distribution among study groups.

Table 2. Comparison between day 1 at RF (cm) measurements (day 3 and day 7 among study group).

RF (cm)	Range	Mean ± SD	Paired sample *t*-test		
			MD±SE	*t*-test	*P*-value
Day 1	0.4–1.5	0.95 ± 0.27			
Day 3	0.4–1.5	0.88 ± 0.29	0.070 ± 0.097	6.018	<0.001**
Day 7	0.4–1.5	0.82 ± 0.29	0.126 ± 0.137	7.708	<0.001**

This table shows a statistically significant reduction mean value of RF on day 3 and day 7 comparing to day 1, with a *P*-value ($P < 0.001$) (Fig. 4 and Table 3).

This table shows a statistically significant reduction mean value of RA 'cm' in Day 7 comparing to Day 1, with a *P*-value ($P < 0.05$) (Fig. 5 and Table 4).

This table shows that the APACHE II score ranged of 1–44 with mean 13.86 ± 10.46 and mortality ranged was 1–85 with mean 22.49 ± 23.04 (Table 5).

This table shows that the hospital stay 'days' ranged from 7 to 45 with a mean of 12.14 ± 7.16; while there were 14 (20%) patients were in mechanical ventilation (Table 6).

This table shows that the patients outcome was 20 (28.6%) patients died and 50 (71.4%) patients were discharged (Table 7).

This table shows a statistically significant reduction mean value of RF in day 3 and day 7 compared with mean reduction value of RA in day 3 and day 7 among died group, with *P*-value ($P < 0.001$). As for the discharged group, there is no different time in RF and RA, with *P*-value ($P > 0.05$) (Figs. 6 and 7 and Table 8).

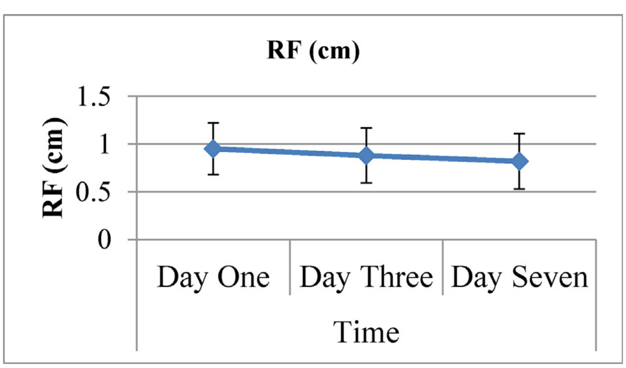

Fig. 4. Comparison between Day 1 at RF (cm) measurements (Day 3 and Day 7 among study group.

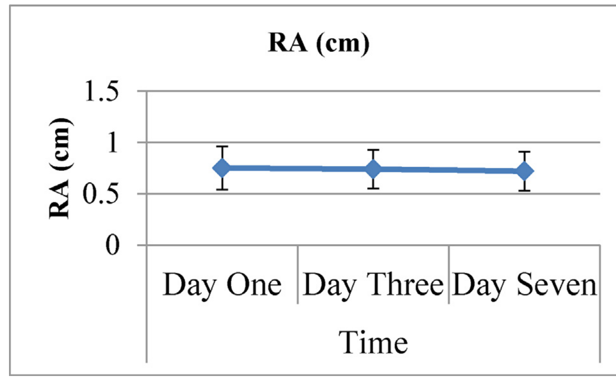

Fig. 5. Comparison between day 1 at RA (cm) measurements (day 3 and day 7 among study group).

Table 4. Acute Physiology and Chronic Health Evaluation II score and mortality rate% distribution among study group.

Acute Physiology and Chronic Health Evaluation II	Total (n = 70)
APACHE II Score	
Range	1–44
Mean ± SD	13.86 ± 10.46
Mortality rate%	
Range	1–85
Mean ± SD	22.49 ± 23.04

Table 5. Hospital stay and mechanical ventilation distribution among the study group.

	Total (n = 70)
Hospital stay (days)	
Range	7–45
Mean ± SD	12.14 ± 7.16
Mechanical ventilation	
No	56 (80.0%)
Yes MV	14 (20.0%)

Table 6. Patient outcome distribution among study group.

Patient outcome	Total (n = 70)
Died	20 (28.6%)
Discharged	50 (71.4%)

Table 3. Comparison between day 1 at RA (cm) measurements (Day 3 and day 7 among study group).

RA (cm)	Range	Mean ± SD	Paired sample *t*-test		
			MD±SE	*t*-test	*P*-value
Day 1	0–1.2	0.75 ± 0.21			
Day 3	0–1.2	0.74 ± 0.19	0.007 ± 0.010	0.634	0.528
Day 7	0–1.2	0.72 ± 0.19	0.030 ± 0.011	2.652	0.010*

Table 7. Different between times regarding RF and RA in the dead group and discharged group.

Times	Died	
	RF (cm)	RA (cm)
Day 1	0.86 ± 0.21A	0.68 ± 0.14
Day 3	0.74 ± 0.18B	0.64 ± 0.14
Day 7	0.64 ± 0.17C	0.60 ± 0.14
RMANOVA	**10.485**	**2.058**
P-value	**<0.001****	**0.367**
Times	**Discharged**	
	RF (cm)	**RA (cm)**
Day 1	0.98 ± 0.28	0.78 ± 0.22
Day 3	0.93 ± 0.30	0.78 ± 0.20
Day 7	0.89 ± 0.30	0.77 ± 0.19
RMANOVA	**2.346**	**2.675**
P-value	**0.349**	**0.331**

Using: RMANOVA Repeated measurements ANOVA for **Mean ± SD;** Different capital letters indicate significant difference at ($P < 0.05$) among means in the same row.
***P* value greater than 0.0: 5** is insignificant; ***P* value less than 0.05:** is significant; ****P* value less than 0.001:** is highly significant.

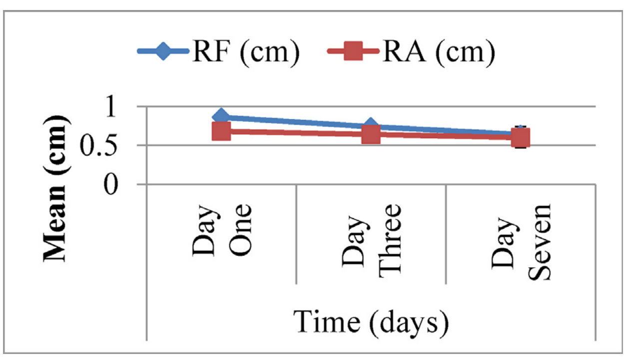

Fig. 6. Different between times regarding RF and RA in the dead group.

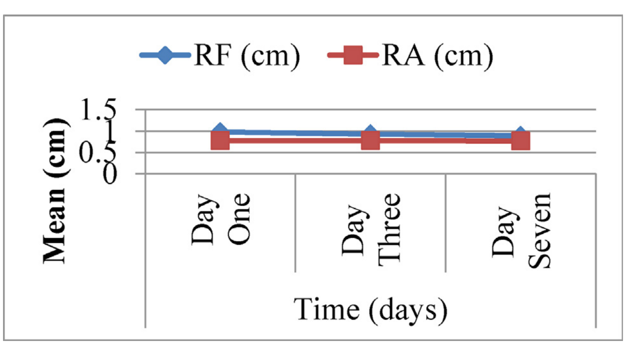

Fig. 7. Different between times regarding RF and RA in the discharged group.

This table shows a statistically significant reduction mean value of RF on day 3 and day 7 compared with the mean reduction value of RA on day 3 and day 7 among long-stay hospital group, with *P*-value ($P < 0.001$). As for the short-stay hospital, there is no different time in RF and RA, with *P*-value ($P > 0.05$) (Figs. 8 and 9).

Table 8. Different between times regarding RF and RA in long stay hospital and short-stay hospital.

	Long stay hospital greater than 10 days	
Times	RF (cm)	RA (cm)
Day 1	0.86 ± 0.23A	0.70 ± 0.16
Day 3	0.75 ± 0.24B	0.67 ± 0.16
Day 7	0.68 ± 0.21C	0.63 ± 0.16
RMANOVA	**9.437**	**1.852**
P-value	**<0.001****	**0.396**
Times	**Short stay hospital <10 days**	
	RF (cm)	**RA (cm)**
Day 1	1.03 ± 0.28	0.80 ± 0.24
Day 3	1.00 ± 0.27	0.82 ± 0.20
Day 7	0.96 ± 0.31	0.81 ± 0.19
RMANOVA	**2.111**	**2.408**
P-value	**0.377**	**0.357**

Using: RMANOVA Repeated measurements ANOVA for **Mean ± SD;** Different capital letters indicate significant difference at ($P < 0.05$) among means in the same row.
***P* value greater than 0.05:** is insignificant; ***P* value less than 0.05:** is significant; ****P* value less than 0.001:** is highly significant.

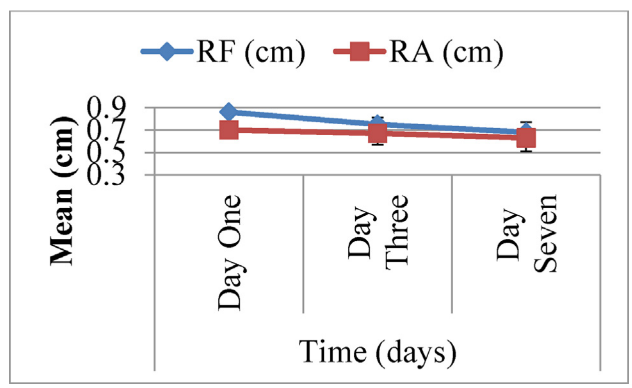

Fig. 8. Different between times regarding RF and RA in long-stay hospital.

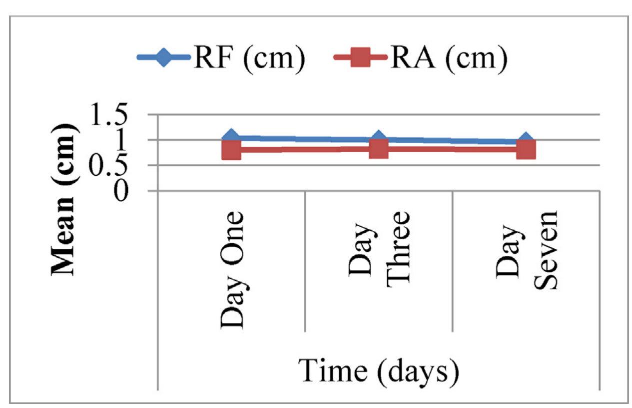

Fig. 9. Different between times regarding RF and RA in short-stay hospital.

4. Discussion

Sarcopenia exhibits associations with prolonged mechanical ventilation, extended hospital and ICU stays, postemergency surgical difficulties, challenges in waste management, and increased mortality rates.[10]

The findings of our research indicate that the use of ultrasound to evaluate the thickness of the rectus abdominis muscle and rectus femoris muscle can serve as a dependable and convenient quantitative approach for assessing morbidity and mortality concerns in the ICU. There was an observed association between a decrease in the mean value of rectus abdominis and rectus femoris muscle thickness, and an increase in the mean value of APACHE score, extended hospital stay, and elevated mortality rates. Additionally, a negative correlation was found between these variables.

Advanced age and female sex are commonly recognized as significant risk factors associated with an increased likelihood of requiring mechanical breathing, lower average measurements of rectus abdominis and rectus femoris muscles, higher average APACHE scores, and elevated mortality rates.

The utilization of mechanical ventilation was found to be correlated with an elevated mean value of the APACHE score, an extended duration of hospitalization, and increased rates of mortality.

In contrast to our findings, Yang and colleagues (2021) presented divergent results indicating a lack of connection between sarcopenia and outcomes. This discrepancy may be attributed to the very small sample size employed in their investigation.[10]

Against us[10] the study discovered that there is an association between the ratio of BMI to the average thickness of the rectus abdominis on both sides of the upper abdomen, known as the BMI-RA thickness ratio, and several clinical outcomes such as in-hospital mortality, duration of mechanical breathing, and length of hospital stay. Nevertheless, after conducting a multivariable analysis that accounts for APACHE and SOFA scores, it was observed that the BMI-RA thickness ratio exhibits a significant association alone with in-hospital mortality, whereas no significant association was found with prolonged mechanical ventilation.

4.1. The limitations of the study

After midline exploration, assessment of rectus abdominis muscle thickness was inapplicable with ultrasound. It is important to acknowledge the limitations of this study, as it was conducted within a hospital setting. Consequently, the number of patients included in the study was limited, resulting in a somewhat smaller sample size about the outcomes being investigated.

4.2. Conclusion and recommendations

From our study, we can conclude that this study showed that rectus abdominis muscle and rectus femoris muscle Ultrasound-based measurement of thickness represents a dependable and readily implementable quantitative approach for assessing morbidity and mortality concerns within the ICU setting.

In cases with prolonged ICU admission, the rectus femoris muscle was noticed to be deteriorated earlier and faster compared with rectus abdominis muscle so it could be used as an indicator of morbidity and mortality with higher accuracy.

The lower mean value of the rectus abdominis and femoris rectus muscles was associated and negatively correlated with higher mean value of APACHE score, prolonged hospital stay and higher mortality rates.

Old age and female gender could be considered as reliable risk factors of higher frequency of need for mechanical ventilation, lower mean values of rectus abdominis and rectus femoris muscles, higher mean value of APACHE score and mortality rates.

Mechanical ventilation was associated with a higher mean value of APACHE score, prolonged hospital stay, and higher mortality rates.

The current investigation has the potential to contribute to the existing body of knowledge and offer insights for future research endeavors that involve bigger sample sizes, thereby allowing for a reevaluation of our findings.

Conflicts of interest

There are no conflicts of interest.

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