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Evaluation of Sarcopenia by Ultrasound of the Rectus Femoris Muscle as a Predictor of Outcomes of Surgical Intensive Care Unit Patients, A Prospective, Observational Study

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Background: Muscle wasting is a frequent finding in critically ill patients and is associated with worse short- and long term outcomes. Loss of mass and function of skeletal muscles starts early - in the first 24 hours after admission to Intensive Care Unit (ICU) - and may persist for years 'Post-ICU syndrome'. Ultrasound of rectus femoris muscle is a valid and simple technique that could be used for longitudinal assessment of treatment success and facilitates the use of postoperative interventions that help in problems related to critical illness. The aim of this study is to evaluate sarcopenia by ultrasound of rectus femoris muscle as a predictor of outcomes of surgical intensive care unit.

Materials and Methods: This prospective observational study was performed on 40 patients admitted to the surgical ICU, Tanta University Hospitals, Egypt, after approval of the Institutional Ethical Committee, Tanta University. The study started from April 2019 till January 2020. An informed consent was taken from the nearest relatives of the patients. All data of the patients was

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confidential with secret codes and private files for each patient. All given data was used for the current medical research only. Any unexpected risks appeared during the course of the research were cleared to the participants and ethical committee at time.

Results: Cross-sectional area of rectus femoris muscle decreased significantly at all-time measurements as compared to the baseline at day 0 (within 24 hours from SICU admission), 5, 10, 15, 20, 25 and 30. There were negative correlations between delta cross-sectional area of rectus femoris muscle and age, height, weight, Body Mass Index and baseline cross-sectional area of rectus femoris muscle. There was a positive correlation between delta cross-sectional area of rectus femoris muscle and duration of mechanical ventilation, ICU length of stay and mortality.

Conclusion: Rectus femoris cross-sectional area measured by B-mode ultrasonography showed significant role in nutritional assessment as it decreases in critically ill patients with positive correlation with duration of mechanical ventilation and ICU stay.

Keywords: Mechanical ventilation; muscle wasting; sarcopenia; rectus femoris muscle; surgical intensive care unit, ultrasound.

1. INTRODUCTION

Muscle squandering is a regular finding in fundamentally sick patients and is related with more terrible short-and long haul results. Loss of mass and capacity of skeletal muscles begins early - in the initial 24 hours after admission to Intensive Care Unit (ICU) - and may endure for quite a long time 'Post-ICU syndrome'. Loss of muscle mass is a significant reason for ICU - obtained muscle shortcoming and is related with deferred weaning, delayed ICU and medical clinic stay and is an autonomous indicator of one year mortality [1-3].

Long-term muscle shortcoming might be capable of physical, mental and intellectual brokenness, which influences the personal satisfaction of ICU survivors and expands the expenses of the medical care services [1-3].

Muscle thickness squandering is more apparent and arrives at its top after the initial half a month of an intense stage catabolic situation [1-3]. Over the most recent couple of years, numerous creators have investigated to survey musculoskeletal quality and amount status in seriously catabolic patients, by examining distinctive muscle bunches at various minutes during the patients' ICU stays' [4,5].

It is notable the sonographic significance of considering the rectus femoris (RF) muscle, since it is the just anatomically bipennate muscle. It has a one of a kind intramuscular focal ligament that stretches out to the lower third of the muscle between the four quadriceps femoris muscles [6].

Several important factors contribute to the process of sarcopenia, such as a state of generalized inflammation, dysregulation of the endocrine system as well as an altered protein metabolism and gene articulation. An absence of standard active work and persistent ailing health causing a negative nitrogen balance further improve the deficiency of muscle mass [7].

Patients with sarcopenia had higher Acute Physiology and Chronic Health Evaluation II (APACHE II) score affirmation contrasted and patients without sarcopenia. Organ brokenness didn't contrast at Surgical ICU (SICU) confirmation, however was more extreme in sarcopenic contrasted and non sarcopenic patient on the third SICU day, stressing the significance of the biomarker sarcopenia as an indicator for the recuperation cycle in basic illness [8].

Sarcopenia can be used for hazard separation in SICU patients. Muscle ultrasound is a legitimate and straightforward procedure that could likewise be utilized for longitudinal evaluation of treatment achievement. Studies may utilize this strategy to individualize postoperative intercessions that may decrease the danger for an unfriendly release air identified with basic ailment, for example, early mobilization [9], streamlined wholesome help and decrease of sedation and narcotic dose [10].

The aim of this study is to evaluate sarcopenia by ultrasound of rectus femoris muscle as a predictor of outcomes of surgical intensive care unit.

2. MATERIALS AND METHODS

This prospective observational study was performed on 40 patients admitted to the surgical ICU (SICU), Tanta University Hospitals, Egypt, after approval of the Institutional Ethical Committee, Tanta University. The study started from April 2019 till January 2020. An informed consent was taken from the nearest relatives of the patients. All data of the patients was confidential with secret codes and private files for each patient. All given data was used for the current medical research only. Any unexpected risks appeared during the course of the research were cleared to the participants and ethical committee at time.

2.1 Inclusion Criteria

- Patients in age group 18-60 years
- Anticipated ICU stay time of more than 72 hours
- Well-nourished, previously healthy subjects (Nutric score=0-5) [11].

2.2 Exclusion Criteria

- Renal, liver or heart disease or COPD
- Previous immune abnormalities and patients treated with corticosteroids)
- Past history of nutritional problems, chronic use of drugs (as drugs inducing myopathies) or orthopedic problems (such as skeletal fractures or immobilization) in the previous 2 years
- Neuromuscular diseases and patients with amputated lower limbs
- Past or recent history of cancer
- Long-term critically ill patients shifted from other hospitals
- Pregnant patients

Patients admitted to SICU (who met the inclusion criteria and enrolled in our study) were attached to the 5 basic monitoring: ECG, NIBP, pulse oximety, capnogram and temperature probe). Each patient received nutrition according to our ICU protocol, either enteral or parentral nutrition. Rectus femoris cross-sectional area (RFCSA) ultrasound was done at day 0 (within 24 h from SICU admission), 5, 10, 15, 20, 25 and 30 days.

2.3 Muscle Ultrasound (Fig. 1)

Rectus femoris cross-sectional area was measured by B-mode ultrasonography using a 3 to 12 MHz transducer array. Patient was positioned supine in 30° upper body elevation, with legs extended and muscles relaxed. The point that represented 60% of the distance from the anterior superior iliac spine to the superior border of the patella was identified. The ultrasound probe was positioned perpendicularly along the superior aspect of the right thigh and transverse images of the rectus femoris were obtained.

A copious amount of gel was applied to minimize tissue compression. The inner echogenic line of the rectus femoris was traced manually on a frozen image and RFCSA was calculated by planimetric technique provided by the vendor (Phillips Medical Systems, Bothell, WA). All measurements were made on the screen of the ultrasound unit at the bedside.

The following clinical data were measured:

- **Demographics:** age, height, weight, BMI at time of admission
- **Ultrasound evaluation of** rectus femoris **muscle:** at day 0 (within 24 hours from SICU admission), 5, 10, 15, 20, 25 and 30 days
- Duration of mechanical ventilation, length of SICU stay and 30 days mortality rate in the SICU.

Primary Outcomes: The quantitative changes (cross-section diameter) of rectus femoris muscle in patients admitted more than 72 hours up to 30 days of SICU stay. **Secondary Outcomes:** It is to correlate sarcopenia with duration of mechanical ventilation, length of SICU stays, and 30 days' mortality rate in SICU.

2.4 Sample Size

The sample size calculation was performed using G. power 3.1.9.2. Forty patients were recruited based on the following considerations: 0.05 α error (95% confidence limit), 0.2 β error (80% power of the study), Rectus femoris cross-sectional area was 5.9±2.1 according to a previous study [12] with expected decrease 25% (mean difference 1.475) (the primary outcome) and 11 patients were added to each group to overcome drop out.

2.5 Statistical Analysis

Statistical analysis was done by SPSS v25 (SPSS Inc., Chicago, IL, USA). Normality of data

was checked with Shapiro-Wilks test and all data were normally distributed. Numerical variables were presented as mean, standard deviation (SD) and range and were compared by paired T test. Categorical variables were presented as frequency and percentage. Pearson's correlation coefficient (r) was used for detection of correlation between two quantitative variables in one group. P. value < 0.05 was considered significant.

3. RESULTS

The age of patients ranged from 19-60 years with a mean value ± SD 37.93 ± 13.68 years. In our study, 25 patients (62.5%) were males and 15 patients (37.5%) were females. The height of the patients ranged from 155-174 cm with mean ± SD 163.85 ± 6.2 cm. The weight of patients (predicted body weight) ranged from 55-118 kg with mean ± SD 83.23 ± 19.06 kg. BMI of patients ranged from 18.59-44.96 kg/m^2 with mean ± SD 31.05 ± 7.03 kg/m^2 (Table 1).

The CSA of rectus femoris at baseline ranged from 4.1-8.5 mm^2 with a mean ± SD 6.4 ± 1.3 mm^2. The CSA of rectus femoris at day 5 ranged from 3.9-8.4 mm^2 with a mean ± SD 6.25 ± 1.3 mm^2. The CSA of rectus femoris at day 10 ranged from 2.9-8 mm^2 with a mean ± SD 6.16 ± 1.28 mm^2. The CSA of rectus femoris at day 15 ranged from 4.5-8.1 mm^2 with a mean ± SD 6.25 ± 0.97 mm^2. The CSA of rectus femoris at day 20 ranged from 4.2-7.3 mm^2 with a mean ± SD 5.84 ± 0.98 mm^2. The CSA of rectus femoris at day 25 ranged from 4-7 mm^2 with a mean ± SD 5.48 ± 1.2 mm^2. The CSA of rectus femoris at day 30 ranged from 4-6.8 mm^2 with a mean ± SD 5.1 ± 1.49 mm^2. The CSA of rectus femoris decreased significantly at all-time measurements as compared to the baseline. Delta is the difference between day 30 and the baseline. It ranged from 0-1.4 mm^2 with mean ± SD 0.58 ± 0.41 mm^2 (Table 2).

The duration of MV ranged from 3-22 days with mean ± SD 12.38 ± 6.16 days. The ICU stay ranged from 6-30 days with mean ± SD 16.8 ± 7.09 days (Fig. 2). In our study, 5 patients (12.5%) died and 35 patients (87.5%) survived (Table 3).

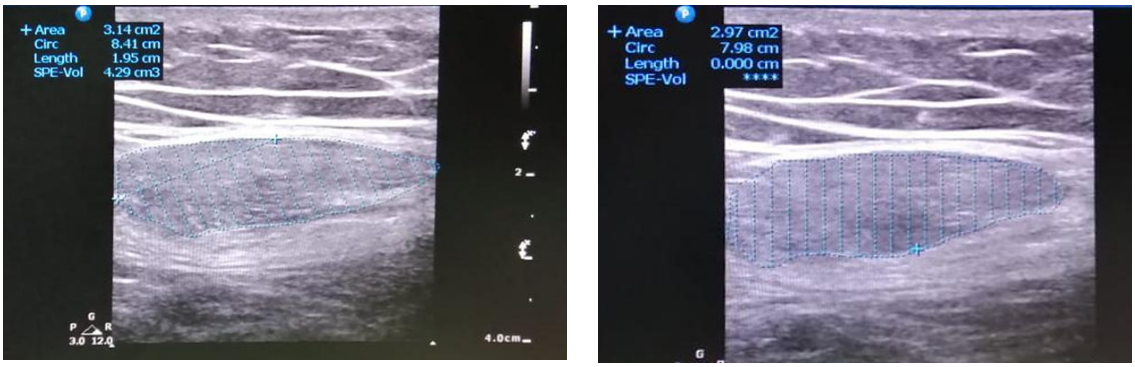
There were insignificant correlations between delta CSA of rectus femoris and age, height, weight, BMI and baseline CSA of RF. There was a positive moderate significant correlation between delta CSA of rectus femoris and duration of MV (r = 0.805, P <0.001). There was a positive moderate significant correlation between delta CSA of rectus femoris and ICU stay (r = 0.588, P <0.001) (Table 4).

Table 1. Age and sex of all studied patients

		Patients (n = 40)
Age (years)	Mean ± SD	37.93 ± 13.68
	Range	19-60
Sex	Male	25 (62.5%)
	Female	15 (37.5%)
Height (cm)	Mean ± SD	163.85 ± 6.2
	Range	155-174
Weight (kg)	Mean ± SD	83.23 ± 19.06
	Range	55-118
BMI (kg/m^2)	Mean ± SD	31.05 ± 7.03
	Range	18.59-44.96

Table 2. Cross-sectional area of rectus femoris muscle (mm^2) of all studied patients

	Mean ± SD	**Range**	**P. value**
Baseline (n = 40)	6.4 ± 1.3	4.1-8.5	
5d (n = 40)	6.25 ± 1.3	3.9-8.4	**<0.001***
10d (n = 31)	6.16 ± 1.28	2.9-8	**<0.001***
15d (n = 24)	6.25 ± 0.97	4.5-8.1	**<0.001***
20d (n = 15)	5.84 ± 0.98	4.2-7.3	**<0.001***
25d (n = 8)	5.48 ± 1.2	4-7	**<0.001***
30d (n = 3)	5.1 ± 1.49	4-6.8	**0.003***
Delta (n = 30)	0.58 ± 0.41	0-1.4	**-----**



(A) (B)

Fig. 1. Rectus femoris muscle cross-sectional area perpendicular to its longitudinal axis done to a 30-year-old patient at (A) day 0 (first day of admission) (B) at day 10

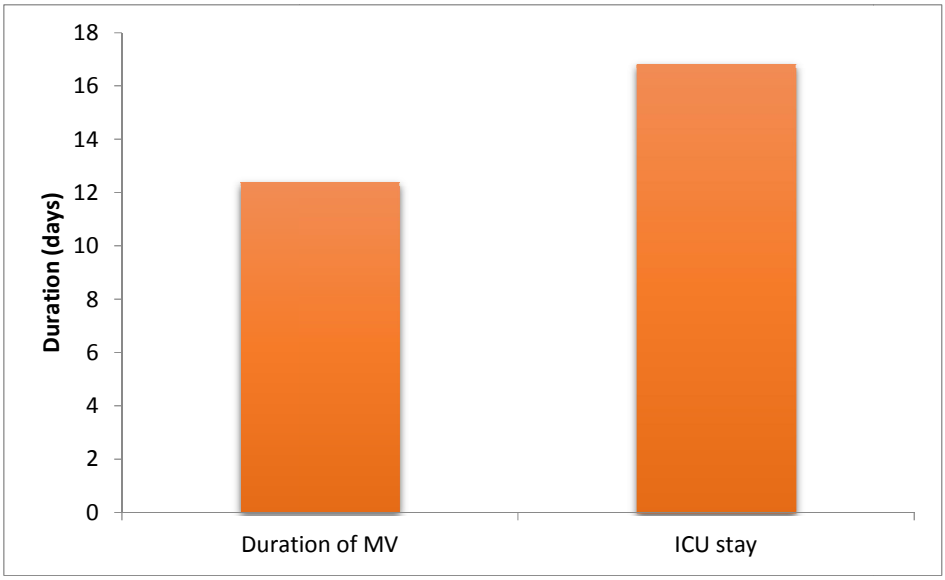


Fig. 2. Duration of mechanical ventilation and ICU stay of all studied patients

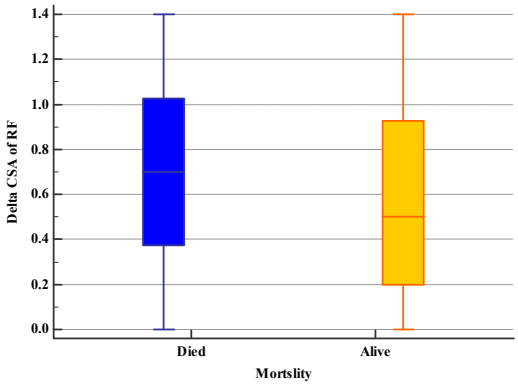


Fig. 3. Relationship between delta CSA of rectus femoris and mortality

Table 3. Mortality of all studied patients

		Patients (n = 40)
Mortality	**Dead**	5 (12.5%)
	Alive	35 (87.5%)

Table 4. Correlation between delta cross-sectional area of rectus femoris muscle and other parameters

	Delta CSA of rectus femoris (mm^2)	
	r	**P. value**
Age (years)	-0.130	0.426
Height (cm)	0.131	0.421
Weight (kg)	0.025	0.881
BMI (kg/m^2)	-0.003	0.983
Baseline CSA of rectus femoris (mm^2)	0.126	0.439
Duration of MV (days)	0.605	**<0.001***
ICU stay (days)	0.588	**<0.001***

4. DISCUSSION

The availability of reliable outcome predictors of surgical critically ill patients may help improve the value of care. Giving data on anticipated length of hospitalization, and danger for utilitarian reliance at release and mortality may help patients and family members settle on educated choices about their objectives regarding care. Prehospital practical status or physiological limit isn't ordinarily remembered for instruments we use to foresee results in fundamentally sick patients [13].

Muscle misfortune is much of the time saw in seriously sick patients conceded to intensive care units (ICUs), and factors like immobilization, foundational aggravation, diminished fringe blood stream, insulin opposition, and diminished food admission, particularly protein, can lead to a worsening of the nutrition status and reduction of muscle mass [14].

Unhealthiness, related with the negative nutrition balance between what patients require and what they receive, is related to reduced muscle mass and functionality, and it is common among ICU patients. Unhealthiness adversely impacts patients' guess, prompting expanded length of ICU and emergency clinic stay, demolishing the personal satisfaction after release, and connecting with higher mortality rates [15]. In this way, exact nourishment finding of these patients is fundamental to advancing satisfactory sustenance care. However, nutrition assessment is challenging in ICUs, especially when attempting to track nutrition status [16].

Ultrasonography is a convenient, non-intrusive, bedside apparatus equipped for qualifying and evaluating skeletal muscle and has been utilized as a guide to give sustenance analyze. One of the most beneficial aspects of ultrasound relative to other anthropometric instruments is its capacity to distinguish momentary changes, considering sequential measurements [(16)]. However, there are concerns regarding with respect to its utilization in this populace that ought to be thought of, for example, the liquid maintenance impact, the absence of cutoff focuses, and the shortfall of standards to decide if muscle follow-up evaluation is fitting when there is helpless picture quality, just as when it is preposterous to expect to envision and characterize the muscle sash edge [17].

The successive assessment of quantitative and qualitative changes of muscle mass by ultrasonography may help recognize basically ill patients with high risk of muscle dysfunction as verify the effects of different nutritional regimens. In this regard, B-mode ultrasonographic evaluation of skeletal muscles (in particular, rectus femoris muscle) is an arising and solid instrument to survey muscle changes over time [3]

There were negative correlations between delta CSA of rectus femoris and age, height, weight, BMI and baseline CSA of RF. Also, there was a positive correlation between delta CSA of rectus femoris and duration of MV. There was a positive correlation between delta CSA of RF, ICU length of stay and mortality.

In agreement with our results, Rodrigues et al. [18] found reductions in quadriceps thickness and rectus femoris cross-sectional area. Muscle mass loss by anthropometric measurements was similar between nourished and malnourished individuals. In contrast to our results, no significant changes between both were detected when using ultrasound muscle mass measurements. This could be identified to the high volume of fluid infusion on the first days of the critical illness, since the presence of edema might lead to the inadequate visualization of the muscles, according to patients' body composition especially in thin patients. They concluded that ultrasound is capable of detecting changes in the short term but not rapid changes and can add to the diagnosis of the nutrition assessment for patients in the ICU and that loss of muscle mass and a poor nutrition status has been associated with negative outcomes, such as long periods of MV, mortality, length of medical clinic stay, and length of stay in the ICU, notwithstanding more regrettable long-term outcomes after discharge.

Also, in agreement with our results, Palakshappa et al. [19] detailed that RF-CSA and thickness decline showed a positive connection with strength on day 7 of confirmation. They reasoned that muscle decay (as distinguished by the pace of progress in RF-CSA) can be emphatically related with strength multi week after ICU affirmation.

In agreement with our results, Hernández-Socorro et al. [20] exhibited that quadriceps rectus femoris muscle territory and thickness were appeared to altogether diminish in patients versus controls and that quadriceps rectus femoris muscle echogenicity and angiogenic action, muscle fasciculations, subcutaneous edema and intramuscular liquid were additionally fundamentally unique between the two gatherings. They reasoned that an all around planned ultrasound convention permitted them to survey the quantitative and subjective changes in quadriceps rectus femoris muscle in seriously sick, precisely ventilated patients and to relate quadriceps rectus femoris muscle squandering present in fundamentally sick patients with delayed MV.

Our results are supported by Nakanishi et al. [21] showed lower appendages squandering and shortcoming. They presumed that After ICU confirmation, recognizable decrease in muscle mass and huge practical incapacities start inside 3 days and from there on deteriorate logically.

In accordance with our results, Galindo Martín et al. [22] showed that lower appendage muscles exceptionally the RFCSA muscle thickness and cross-sectional zone were appeared to essentially diminish. They inferred that fundamentally sick patients create under-sustenance during their ICU stay and consequently this ultrasound strategy holds incredible guarantees because of its bedside materialness. It helps in formating a standardized protocol to reduce changes in measurements performed at different times.

Also, in agreement with the current study, Annetta et al. [23] assessed the quantitative and subjective changes of skeletal muscle young people (beforehand healthy) injury patients on enteral taking care of. Early appraisal of muscle changes by muscle ultrasonography was done to assess the morphological changes of rectus femoris muscle. The rectus femoris muscle mass changed fundamentally; Its AP width diminished and CSA of rectus femoris muscle logically diminished during the ICU stay, all patients considered. By this strategy, they had the option to measure the morphological changes of skeletal muscle in injury patients and consequently giving significant data about patient's outcome especially functional impairment. Ultrasound evaluation of skeletal muscles is inexpensive, non-invasive, simple and easily repeatable.

In concurrence with our study, Paris et al. [17] analyzed ultrasound based quadriceps muscle layer thickness (QMLT) with computed tomography (CT)– based muscle cross sectional area (CSA). They found that, while CT imaging (giving exact CSA measures) has been a significant measure in recognizing patients with low strength, a more functional methodology is expected to gauge strength in the ICU. They recommended that QMLT alone may not precisely anticipate muscle CSA or distinguish patients with low strength because of the edematous consequences for muscle thickness by maximally compacting hidden tissues. However, ultrasound-based QMLT with extra indicators (counting age, BMI, sex, Charlson Comorbidity Index, and affirmation type) might be significant in anticipating low strength in this gathering of ICU patients. What's more, because of its bedside materialness and moderately ease to reach and utilize, it can recognize the danger of ailing health and helpless ICU and post-ICU results just as to screen reaction to nourishment

and different intercessions focusing on muscle mass and capacity.

In agreement with our results, Mueller et al. [12] showed that ultrasound-estimations decline in muscle thickness was adversely connected with length of stay of immobilized ICU patients, sarcopenia didn't foresee term of SICU stay, and this can be clarified by: In their office, SICU release relies upon the two patients' conditions and bed accessibility. Their information showed that sarcopenia is related with higher requirement for institutional consideration after release, addressing higher sickness trouble, and practical reliance after hospitalization. They reasoned that sarcopenia measured effectively by bedside ultrasound strategies predicts helpless result of careful fundamentally sick patients as muscle ultrasound is a substantial and basic strategy that could likewise be utilized for longitudinal evaluation of therapy achievement and to individualize post-usable intercessions that may diminish the danger for helpless results identified with basic ailment, and to help early assembly, streamlined wholesome help, and decrease of sedation and narcotic portion.

In agreement with our results, Parry et al. [24] detailed 30% decrease of rectus femoris thickness and cross-sectional territory inside 10 days of affirmation. They reasoned that muscle squandering happens quickly in the ICU setting and ultrasonography is a helpful substitute measure for recognizing future impedance, practical result, dismalness, and mortality and to distinguish people for the most part in danger early will empower examination of interventional systems, which can be conveyed in the basic period to limit these progressions and their harmful useful outcomes.

Also, our results are supported by Weijs et al. [3] exhibited a positive relationship between's clinic length of stay and skeletal muscle mass, as assessed by stomach CT examine. In spite of the fact that CT examines are a significant apparatus to evaluate dietary status and muscle mass, CT checks are not regularly acted in ICU patients and can't be utilized as such due to X-beam openness, absence of time, aptitude, and significant expenses. Utilizing CT filters for longitudinal observing is unworkable, and for the concentrated consideration populace, choices for the CT scan should be explored such as ultrasound.

Also, in agreement with our results, Puthucheary et al. [25] demonstrated reduction in rectus femoris cross-sectional area in a group of ICU patients from day 1 to day 10, with the major loss occurring during the first 7 days. They concluded that in these critically ill patients, muscle wasting occurred early and rapidly during the first week of critical illness and was more severe among those with multi-organ failure compared with single organ failure.

Yet, in contrast with our results, Gruther et al. [26] discovered three potential clarifications: (I) muscle mass in bunch A was reported after a more limited LOS due to the examination setting (2 estimations, at gauge and following 28 days). The patients show edema all the more frequently toward the start of their visit at an ICU as a result of their positive water balance, (ii) Group B was a bigger gathering of patients, and (iii) Patients in bunch An experienced more serious infections then the patients in bunch B on account of various rejection measures (bunch A: LOS ≤ 28 days; bunch B: LOS ≤ 7 days). They presumed that deficiency of muscle mass shows a negative connection with length of stay, and it was higher during the initial 2-3 weeks of immobilization/ICU stay. They additionally discovered that ultrasound is a legitimate and down to earth estimation apparatus for reporting muscle mass (for example muscle layer thickness) as a feature of the day-by-day schedule at ICU.

5. LIMITATIONS OF THE STUDY

1- We need to assess the fluid status of the patient in ICU as it has affection on the measurement by US and to correlate RFCSA with other anthropometric especially mid arm circumference.
2- We did not assess the strength and function of the muscle in correlation with the reduction of RFCSA.
3- Some factors such as the complication and other therapeutic strategies during ICU stay related with muscle wasting weren't observed.

6. RECOMMENDATIONS

1- The fluid status of the patient in ICU should be assessed as it has the most affection on the measurement by US.
2- Assessing the strength and function of the muscle in correlation with the reduction of RFCSA should be considered in future studies.

3- Further studies should be considered to rely on this technique to evaluate the impact of different therapeutic strategies on muscle wasting and to improve patient outcomes.

7. CONCLUSION

Rectus femoris cross-sectional area measured by B-mode ultrasonography showed significant role in nutritional assessment as it decreases in critically ill patients with positive correlation with duration of mechanical ventilation and ICU stay.

CONSENT AND ETHICAL APPROVAL

This prospective observational study was performed on 40 patients admitted to the surgical ICU (SICU), Tanta University Hospitals, Egypt, after approval of the Institutional Ethical Committee, Tanta University. The study started from April 2019 till January 2020. An informed consent was taken from the nearest relatives of the patients.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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