



Feasibility of Upper Limb Muscle Ultrasound for Assessing Muscle Atrophy in ICU Patients: Evaluation of Biceps Brachii and Flexor Carpi Ulnaris

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Background

- For critically ill patients, muscle **atrophy** and muscle weakness are serious clinical issues, and they are key contributors to post-intensive care syndrome (PICS).

(Inoue S, et al. Acute Medicine & Surgery, 2019)

- In particular, patients admitted to the intensive care unit (ICU) experience marked lower-limb muscle **atrophy**. Previous studies have reported that the cross-sectional area of the rectus femoris decreases by 17.7% by day 10 after ICU admission .

(Puthuchery ZA, et al. JAMA, 2013; Hayes K, et al. Journal of Critical Care, 2018)

- However, most previous research has focused on lower-limb muscle **atrophy**, and studies examining upper-limb muscle **atrophy** remain limited (McNelly AS, et al. Chest, 2020). In contrast, upper-limb motor function is closely associated with activities of daily living (ADL) and quality of life (QOL), highlighting the need to clarify its clinical impact.

(Gustafson OD, et al. Acute Medicine & Surgery, 2020)

Background

ICU-acquired weakness (ICU-AW)



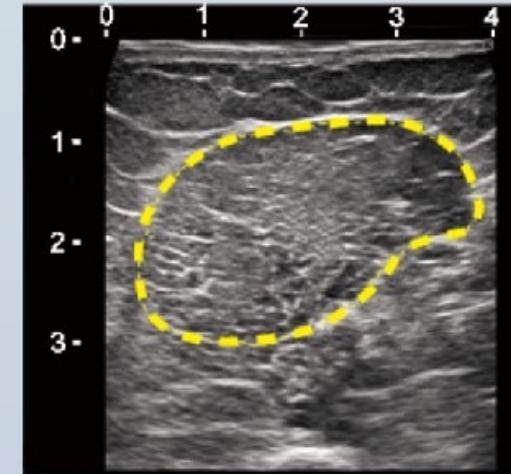
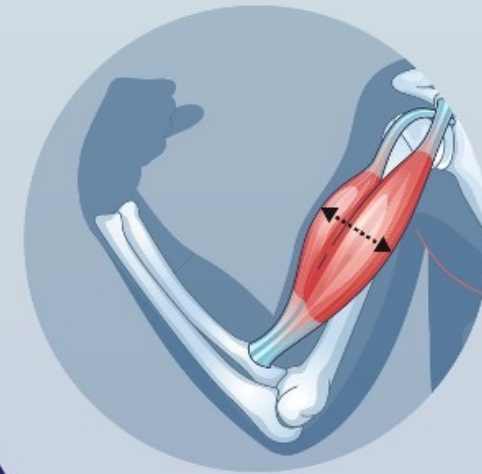
Critically-ill patients may experience rapid skeletal muscle atrophy during prolonged ICU stays, resulting in poor physical function and quality of life after discharge



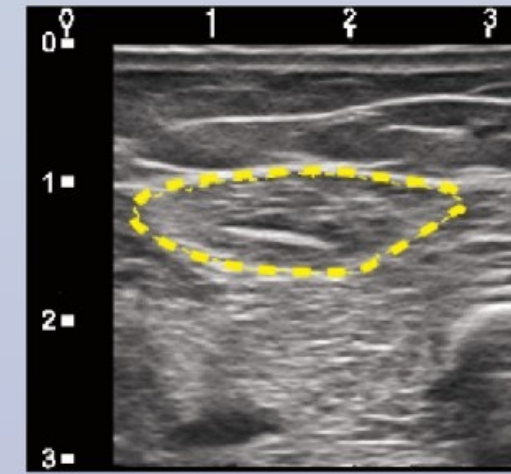
Accurate estimation of atrophy is necessary to mitigate ICU-AW

ICU: intensive care unit

Ultrasound evaluation of muscle cross-sectional area (CSA) to estimate ICU-AW



Biceps brachii (BB) CSA




Flexor carpi ulnaris (FCU) CSA



Purpose

The purpose of this study was to non-invasively evaluate changes in the muscle cross-sectional area of the BB, FCU, and Rectus femoris (RF) in ICU patients using ultrasonography, and to clarify the characteristics of muscle atrophy in these muscles.



Methods

- This prospective observational study was conducted at Showa Medical University Hospital and Showa Medical University Fujigaoka Hospital between January 2023 and November 2024.
- The study protocol was approved by the Institutional Review Board (Approval No. 2023-041-B).
- Oral informed consent was obtained from patients or their families and documented in medical records.

Participants

Inclusion criteria were as follows:

- Registered within 24 hours of ICU admission
- Judged by the attending physician to require ≥ 48 hours of mechanical ventilation
- Predicted ICU stay of ≥ 5 days
- Aged ≥ 18 years

Exclusion criteria included:

- Presence of limb trauma or amputation
- Diagnosis of primary neuromuscular disease
- Inability to acquire clear ultrasound images for measurement



**Showa Medical
University Hospital**



**Showa Medical University
Fujigaoka Hospital**

Ultrasound Measurement Protocol

BB:

Measurements were taken at a point located at the distal two-thirds of the line connecting the acromion and the antecubital crease.

Participants were positioned in the supine position with the elbow fully extended.

RF:

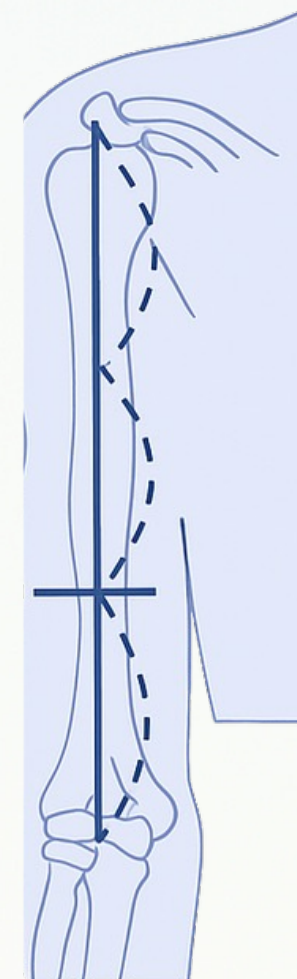
Measurements were performed at the midpoint between the anterior superior iliac spine (ASIS) and the superior border of the patella.

Participants were in the supine position with the knee fully extended.

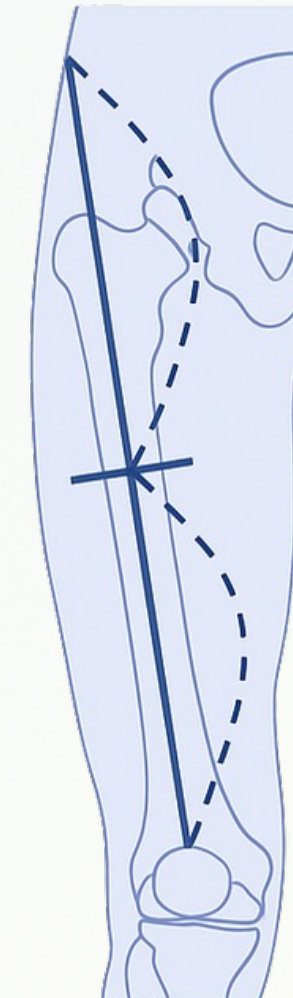
FCU:

Measurements were obtained at the midpoint of the line connecting the olecranon and the ulnar styloid process. Participants were in the supine position, with the elbow flexed at 90° and the forearm in a neutral position.

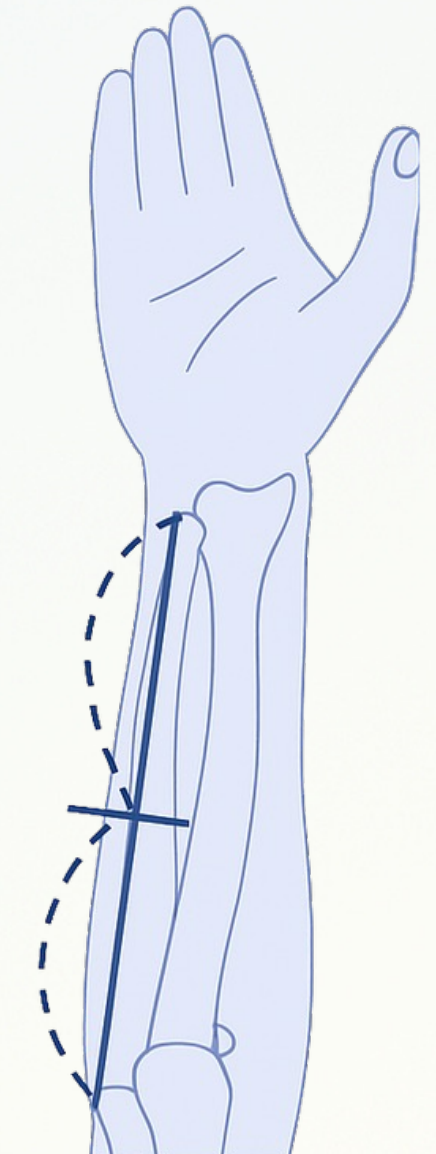
BB



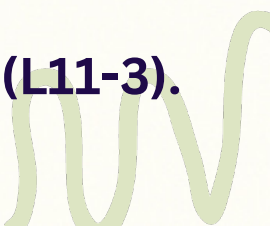
RF



FCU



CSA was measured using a SONIMAGE MX1 ultrasound system (Konica Minolta Japan) with a linear probe (L11-3).

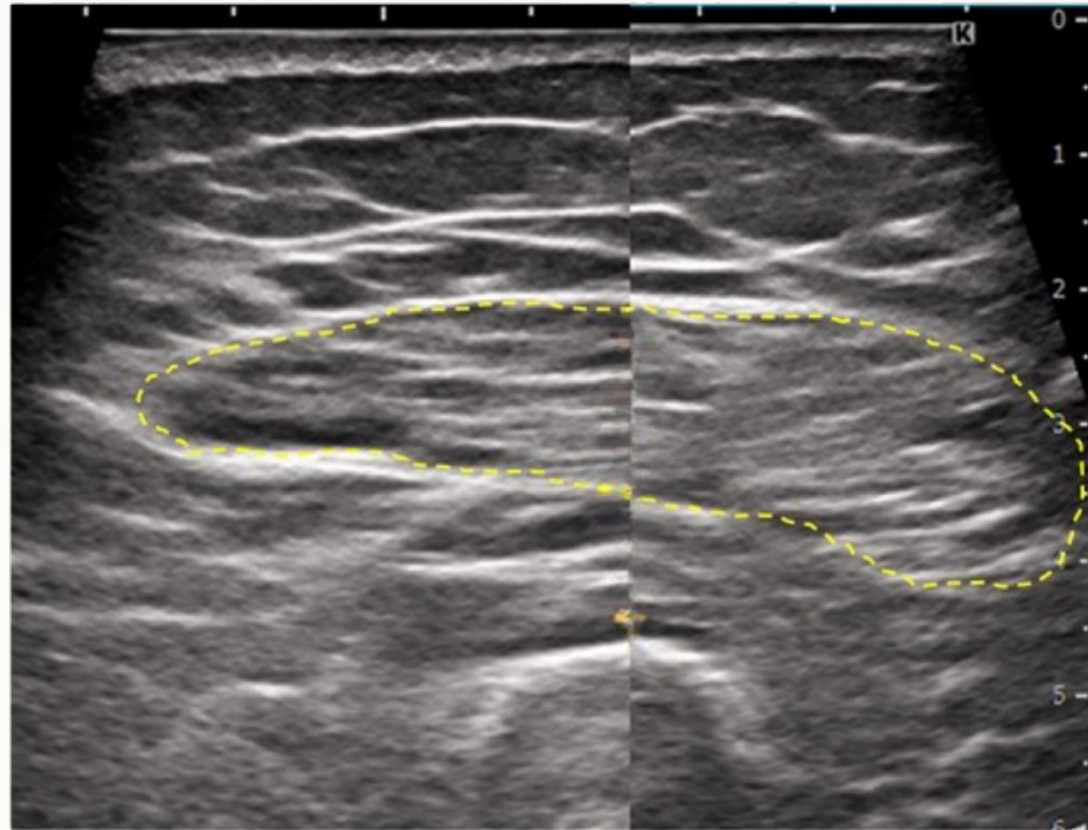


Ultrasound Measurement Protocol

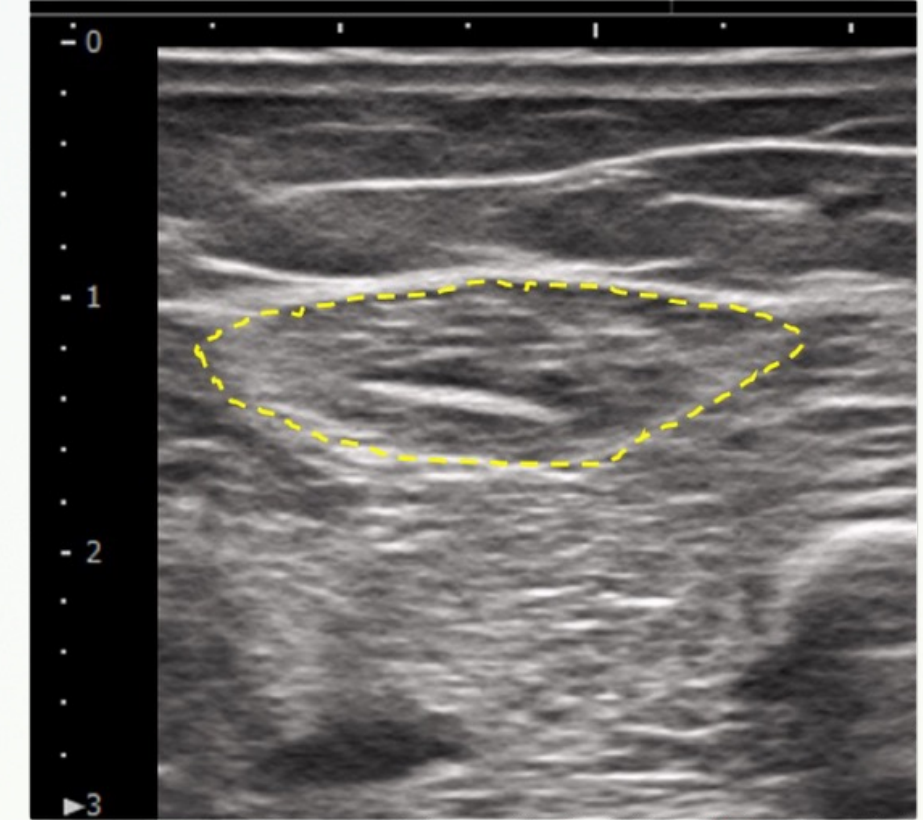
BB



RF



FCU



CSA was calculated by tracing the outer boundary of the muscle belly when clear ultrasound images were obtained. To ensure reproducibility, measurement sites were marked on the skin, and all measurements were taken from the same site. Each muscle was measured twice consecutively by a single evaluator, and the mean value was used for analysis.

Evaluation Items and Outcomes

Primary outcome:

The primary outcome was the longitudinal CSA of the BB, RF, and FCU measured on Days 0, 5, 7, and 14.

Secondary outcomes:

Secondary outcomes included ICU length of stay, SOFA score, Richmond Agitation–Sedation Scale (RASS) score, and duration of mechanical ventilation. Functional outcomes assessed within one week after initiation of rehabilitation included the Functional Status Score for the ICU (FSS-ICU), Barthel Index (BI), and ICU Mobility Scale (IMS). Discharge outcomes were categorized as discharge to home, transfer to another facility, or death.

Statistical analysis:

Statistical analyses were performed using JMP StudentEdition19 .The level of significance was set at $p < 0.05$.For the primary analysis of time-dependent changes in muscle atrophy, the Friedman test was used. Spearman’s rank correlation coefficient was applied for correlation analysis.

Assessment Items	At ICU Admission	5 Days After ICU Admission	7 Days After ICU Admission	14 Days After ICU Admission
Informed consent				
Background data collection	●			
Eligibility assessment	●			
Ultrasound examination	●	●	●	●
Secondary outcome assessment	●	●	●	●

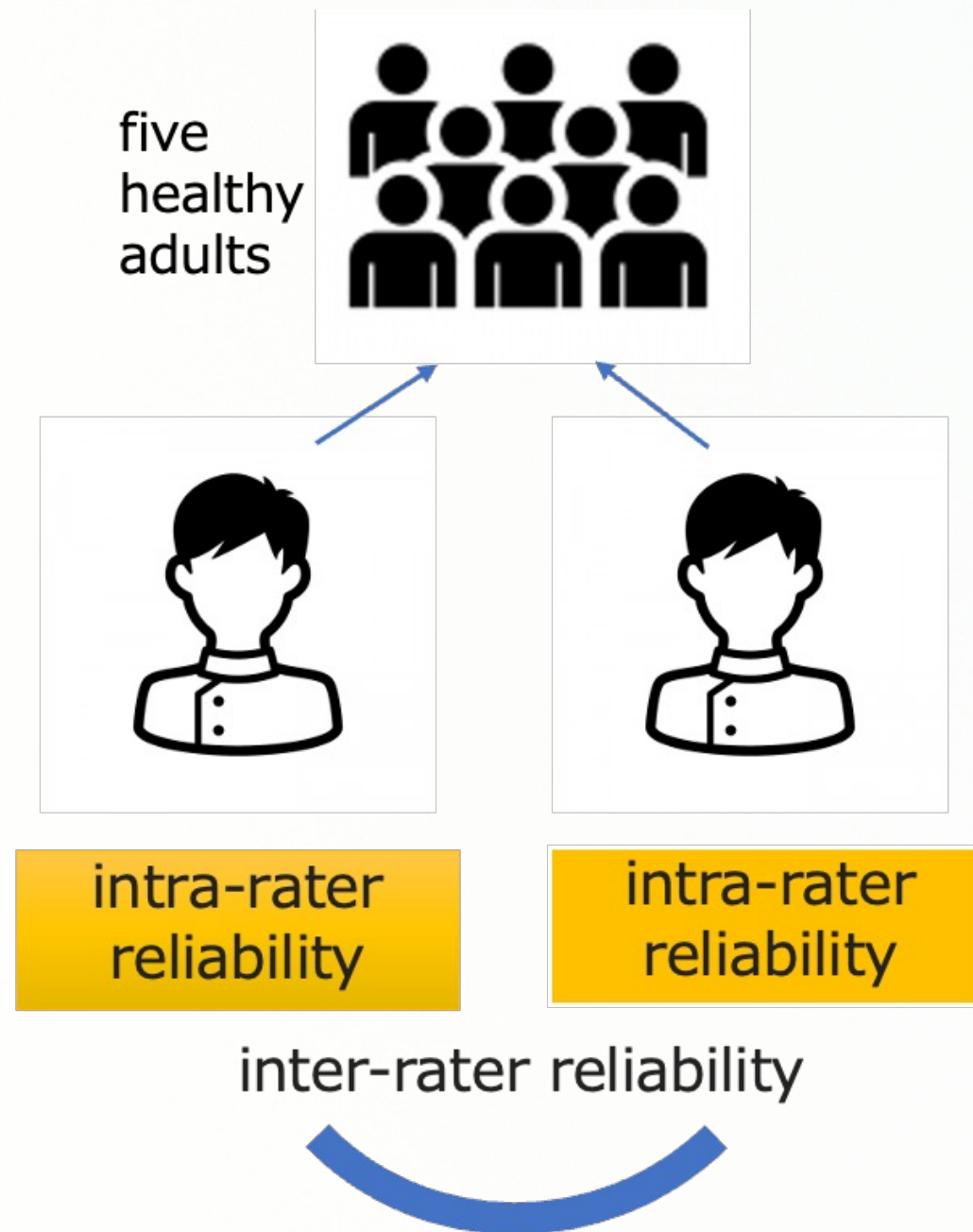
Results

Patient Characteristics (n = 15)

We enrolled 15 critically ill patients with a mean age of 56 years (range, 29–82 years). The median length of ICU stay was 15 days, and the median duration of mechanical ventilation was 8 days. The median SOFA score was 9, indicating the presence of multiple organ dysfunction. The mean time from ICU admission to initiation of rehabilitation was 1 day.

Variable	Value
Age, years	56 (29–82)
Sex, n	
Male	5
Female	10
Primary diagnosis, n	
Infectious / septic conditions	4
Neurological disorders / post-cardiac arrest	4
Cardiovascular diseases	4
Other	3
Height, cm	166 (150–190)
Weight, kg	68 (44–169)
Body mass index (BMI), kg/m ²	23 (18–53)
ICU length of stay, days	15 (7–44)
Hospital length of stay, days	24 (16–115)
SOFA score	9 (3–13)
Duration of mechanical ventilation, days	8 (5–44)
RASS score	–5
Time to rehabilitation initiation, days	1 (1–3)
FSS-ICU	1
Barthel Index (BI)	0

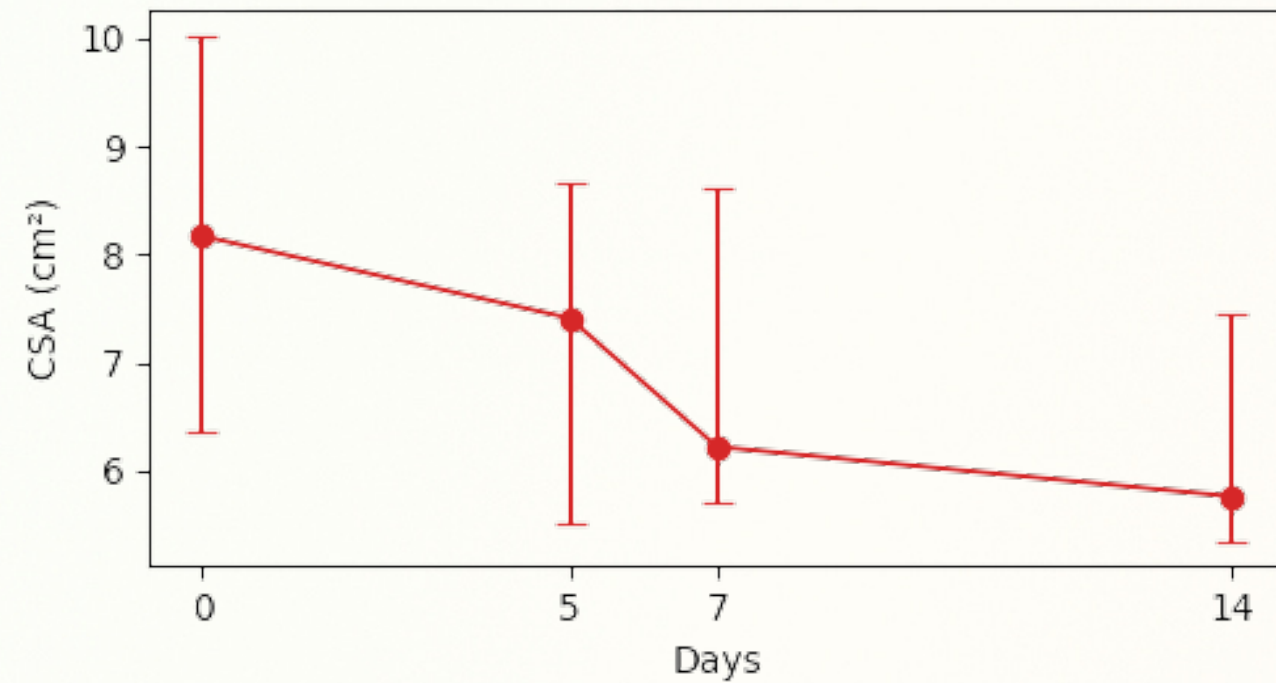
Reliability of Ultrasound Measurements



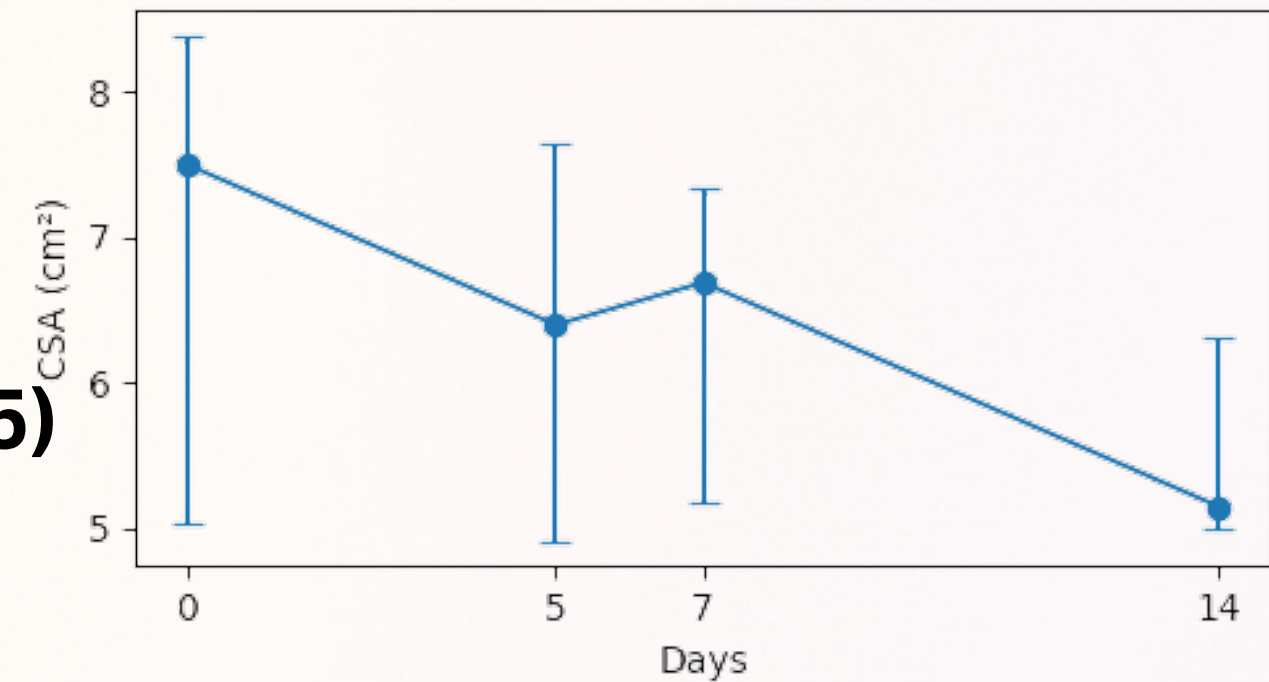
**All ICCs exceeded 0.95,
indicating excellent inter- and intra-rater reliability for BB and FCU.**

Time-course changes in muscle cross-sectional area during ICU stay (Friedman test).

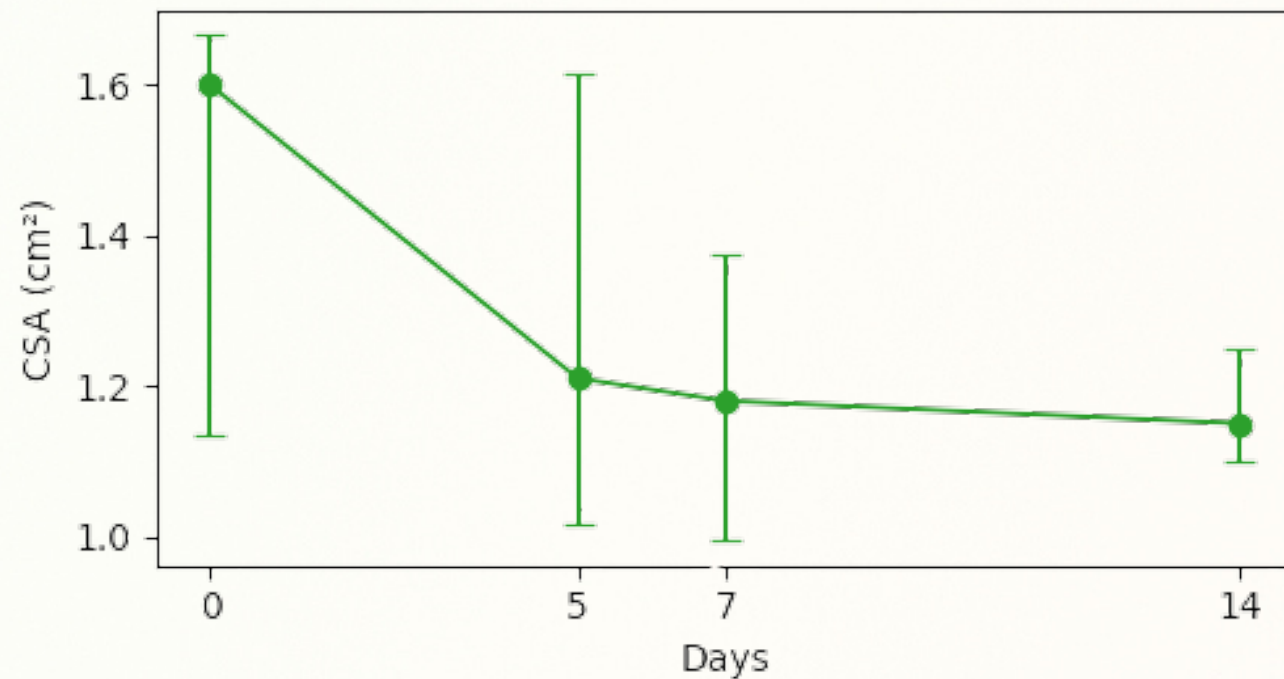
RF
($p < 0.05$)



BB
($p < 0.05$)

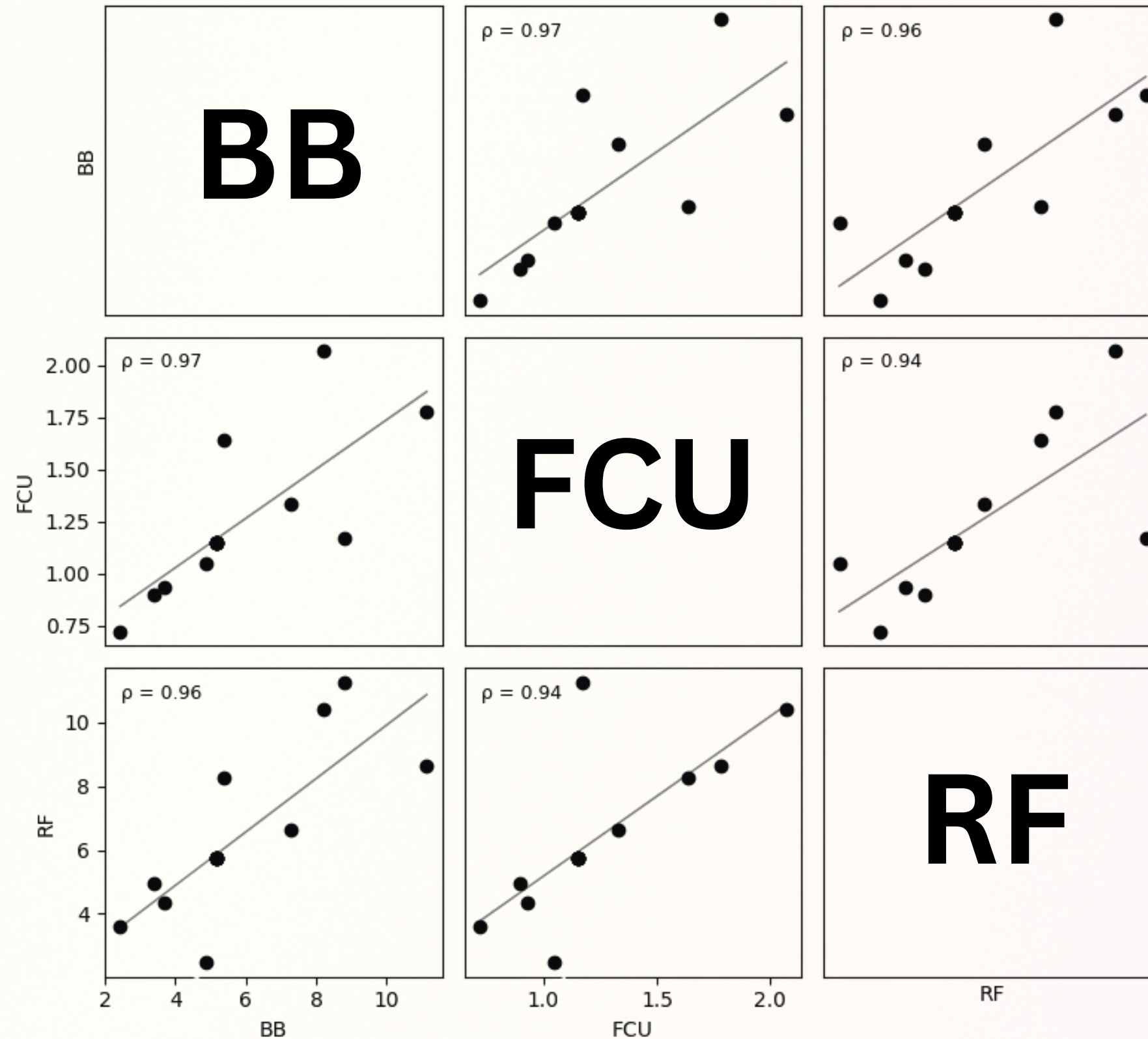


FCU
($p < 0.05$)



Significant reductions in muscle cross-sectional area were observed in all three muscles over 14 days.

Strong inter-muscle correlations at ICU Day 14

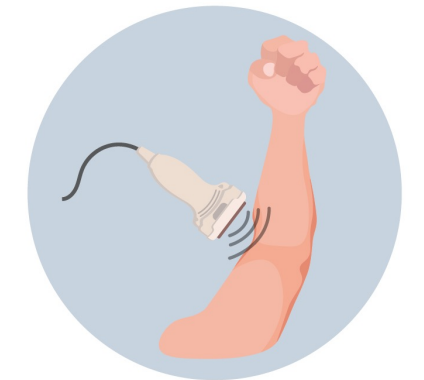


Spearman's rank correlation coefficient
All correlations $p < 0.05$

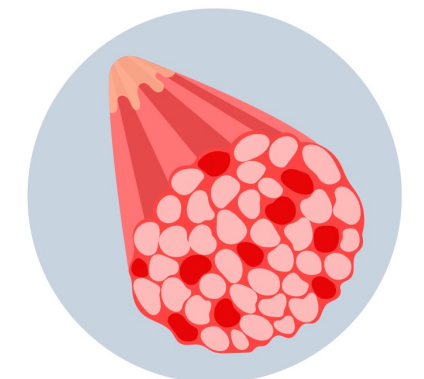
Discussion

- **Muscle CSA significantly decreased in RF, BB, and FCU over the 14-day ICU stay.** RF showed about 25% atrophy, consistent with previous reports in critically ill patients (Parry et al., 2013; Puthuchearry et al., 2013).
- **Upper-limb muscles (BB and FCU) also demonstrated significant CSA reductions.** These findings suggest that ICU-related muscle atrophy is not confined to weight-bearing muscles, but reflects a systemic and multifactorial process (Hermans & Van den Berghe, 2015).
- **Strong inter-muscle correlations were observed on ICU Day 14.** BB and FCU were strongly correlated with RF and with each other, indicating that upper-limb muscle changes may reflect global muscle wasting rather than isolated forearm changes.
- **Ultrasound assessment of BB and FCU may provide a simple and feasible bedside indicator of ICU-acquired weakness.** Among these, FCU may be particularly practical due to its superficial location and ease of measurement.

Advantages of estimating ICU-AW by FCU CSA measurement



Easier to orient and measure than BB



Higher density of fast-twitch muscle fibers allows earlier detection of atrophy



Conclusion

- **Skeletal muscle atrophy during ICU stay affects not only the lower limbs but also upper-limb and peripheral muscles, indicating a systemic and multifactorial process.**
 - **Ultrasound-based quantitative muscle assessment may facilitate early detection of ICU-acquired weakness and support individualized rehabilitation strategies.**
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