ORIGINAL ARTICLE

The Utility of Muscle Ultrasound as a Predictor of Outcome in Guillain–Barré Syndrome Patients in the Intensive Care Unit: A Prospective Cohort Study

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Abstract

Aims and background: Guillain–Barré syndrome (GBS) is associated with significant muscle loss, which can result in prolonged intensive care. The aim of this study was to evaluate muscle atrophy in GBS patients using serial ultrasound measurements of rectus femoris cross-sectional area (RFCSA).

Materials and methods: A prospective study was carried out among GBS patients admitted to the intensive care unit (ICU). All clinical and demographic variables were recorded at admission.

Ultrasound measurement of RFCSA was done at baseline and 3, 7, and 14 days after ICU admission. Clinical outcomes such as the ICU stay and duration of mechanical ventilation were studied at discharge.

Results: A total of 25 patients were studied. The mean age was 48.96 ± 14.82 years, 44% were female, and 25% experienced significant muscle atrophy in the first 72 hours. The percentage changes in the RFCSA were 5.21 (3.38–8.39), 9.18 (5.52–11.76), and 12.63 (8.65–15.09) on days 3, 7, and 14, respectively. A greater muscle atrophy rate was strongly positively correlated with longer ventilation periods [atrophy day 14 ($r = 0.88$, $p < 0.001$)] and atrophy day 7 ($r = 0.87$, $p < 0.001$) and total number of ICU days [atrophy day 14 ($r = 0.93$, $p < 0.001$)].

Conclusion: Muscle ultrasound (MUSG) shows potential as a tool for monitoring muscle atrophy in GBS patients. However, its ability to reliably identify patients at risk for prolonged ICU stays and mechanical ventilation requires cautious interpretation and further validation due to the absence of a comparator.

Clinical significance: The findings of this study highlight the utility of bedside MUSG as a non-invasive tool for monitoring muscle atrophy in neuromuscular diseases and critically ill patients.

Early identification of significant muscle loss allows for timely interventions, risk stratification, and resource optimization, ultimately improving ICU outcomes and patient recovery trajectories.

Keywords: Critical Care, Muscle ultrasound, Sarcopenia, Guillain–Barré syndrome.

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Highlight

- Muscle ultrasound effectively monitors muscle atrophy progression in Guillain–Barré syndrome (GBS) patients in the intensive care unit (ICU).
- Greater muscle atrophy rates strongly correlate with prolonged ICU stays and mechanical ventilation duration.

Introduction

Guillain–Barré syndrome is an autoimmune condition that specifically impacts the peripheral nerves and nerve roots. Pathophysiology involves an immune-mediated response, most commonly triggered by a preceding infection. The immune system, as a response to infection, generates antibodies that cross-react with the ganglioside on the nerve, causing damage, a phenomenon known as molecular mimicry.[1,2] The resulting impairment in nerve signaling causes muscle weakness and subsequent muscle atrophy with time.[3] Guillain–Barré syndrome is the leading cause of acute onset flaccid paralysis. Guillain–Barré syndrome can present with varied degrees of muscle involvement. In approximately 30% of GBS patients, significant respiratory muscle involvement and paralysis are observed, which require ICU management. In addition, ICU care is needed for mechanical ventilation, autonomic dysfunction, rapidly progressive weakness, or imminent respiratory failure.[4,5]

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The incidence of ICU-acquired weakness (ICUAW) ranges from 25 to 100%. Several factors increase the risk of developing this condition, including prolonged immobility, infections such as sepsis, ongoing inflammation, failure of multiple organ systems, high blood sugar levels, and the utilization of specific drugs, such as steroids and muscle relaxants. The exact mechanism is unknown.[6] In patients with GBS where there is already muscle weakness, this can have a compound effect on recovery.

Muscle loss is estimated to range from 15 to 30% per week at ICU admission.[7] Factors contributing to significant muscle loss and atrophy include prolonged ICU stays, patients requiring mechanical ventilation, or those with severe neuro-GBS.[8] Muscle loss can significantly affect recovery and prolong the rehabilitation time. The extent of muscle atrophy is a key factor that influences both short-term and long-term functional outcomes in ICU survivors.[9]

Guillain–Barré syndrome patients requiring ICU admission have the most severe form of the disease. These patients require a considerable amount of time in the ICU. In these patients, a reliable method to predict clinical outcomes, such as the need for tracheotomy, duration in the ICU, and duration of mechanical ventilation, is pertinent to planning treatment approaches.[3,10] In the past, conventional prognostic methods such as muscle power grading, nerve conduction studies, and cerebrospinal fluid analysis have been used. However, these methods are limited by their invasiveness, cost, and technicalities.[5,11]

Muscle ultrasound (MUSG) is a non-invasive, point-of-care, repetitive, and potentially cost-effective method that has been used in the ICU.[12] Muscle ultrasound allows clinicians to visualize muscle structure and measure muscle thickness, thereby providing valuable information about muscle atrophy and other pathophysiological changes.[12] Rapid muscle atrophy is observed in the ICU environment. Muscle ultrasound is a valuable method for predicting future disability.[13] There is empirical evidence supporting the association between muscle properties evaluated by MUSG and functional results. The effects of these modifications have been evaluated in several muscle groups during stays in the ICU, yet it remains uncertain whether they can serve as a prognostic indicator for recovery in GBS patients in the ICU.[14,15]

Rectus femoris MUSG has been demonstrated to be a dependable technique for evaluating muscle mass in critically ill patients.[13] Previous studies have shown the utility of MUSG in monitoring muscle atrophy in patients with ICUAW and myopathies.[15,16] However, substantial data on the specific role of MUSG in predicting outcomes for GBS patients in the ICU are lacking.

The primary objective of this study was to evaluate the progression of muscle atrophy in GBS patients through serial measurements of the rectus femoris cross-sectional area (RFCSA) using ultrasound. The secondary objectives included calculating the rate of muscle atrophy at specific time points. The exploratory objectives include correlating changes in muscle mass with clinical outcomes such as ICU days and ventilator days and comparing these outcomes between low and high-atrophy-rate groups.

Materials and Methods

This was a prospective cohort study conducted in a dedicated neurocritical care unit (NICU) between September 2023 and July 2024. Ethical approval was obtained before study initiation. The study was conducted in accordance with the Declaration of Helsinki, and written informed consent was obtained from all participants or their legal representatives. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement for reporting of results was complied with. The inclusion criteria were all adult patients who were diagnosed with GBS, according to the Brighton criteria, confirmed with electrophysiological studies, and admitted to the NICU. The exclusion criteria were a body mass index > 35 kg/m^2; previous neurological disease; previous chronic disability that affects muscle, such as stroke or neuromuscular disease; patients who didn't give consent; who had any previous trauma to the lower limbs; those who had poor image quality; and readmission to the ICU.

The following data were collected at NICU admission via a subject data sheet: Baseline demographics, including age, sex, and admission diagnosis. Laboratory data such as serum creatinine, hemoglobin, and sodium levels were recorded, along with vital signs (systolic blood pressure, heart rate, and body temperature). Illness severity was assessed via the acute physiology and chronic health evaluation (APACHE) II score, whereas nutritional status was evaluated via the modified nutrition risk in the critically Ill (mNUTRIC) score. Muscle strength was assessed via the Medical Research Council (MRC) scale at ICU admission. The duration of mechanical ventilation and ICU stay was collected at discharge from the NICU.

Ultrasound measurements were performed by a single well-trained investigator via a 6.5 MHz, 3.8 cm linear transducer probe connected to an ultrasound machine with B-mode imaging (Sonosite M turbo). Patients were placed in a supine position with their elbows and knees in passive extension. The RFCSA in cm^2 was measured following a standardized protocol as described in previous studies.[12,13] The average of three consecutive measurements within 10% variability was used for analysis. Measurements were taken on both thighs.

Ultrasound assessments were conducted on days 0, 3, 7, 14, or on the day of NICU discharge, whichever occurred first.

Muscle atrophy was calculated as a percentage via the following formula:

Atrophy on Day 3 = (RFCSA on Day 0 – RFCSA on Day 3)/(RFCSA on Day 0)* 100

Atrophy on Day 7 = (RFCSA on Day 0 – RFCSA on Day 3)/(RFCSA on Day 0)* 100

Atrophy on Day 14 = (RFCSA on Day 0 – RFCSA on Day 3)/(RFCSA on Day 0)* 100

Statistical Analysis

Baseline characteristics of the study population were summarized using descriptive statistics. Continuous variables are presented as means with standard deviations (SDs) or medians with interquartile ranges, while categorical variables are shown as frequencies and percentages. Data normality was evaluated using the Shapiro–Wilk test.

Linear and logistic regression analyses were utilized to identify key predictors of muscle atrophy rates, ICU duration, and ventilation days. Initially, univariate analysis was performed for each variable, and those with a $p < 0.05$ were incorporated into the multivariate regression models. Final models were selected using a backward stepwise method, applying a significance threshold of 0.05 for variable inclusion. The adjusted R-squared values and odds ratios (ORs) with 95% confidence intervals (CIs) are reported. All the statistical analyses were done via Statistical Package for Social Science (SPSS) version 21.0 (IBM Corp., Armonk, NY, USA) and R version 4.0.4.

A pilot study of 10 patients was done in our setup, which revealed that 60% of the patients had more than 10% atrophy

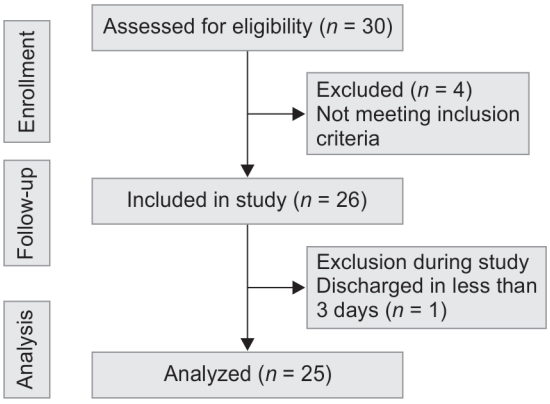


Fig. 1: Patient inclusion

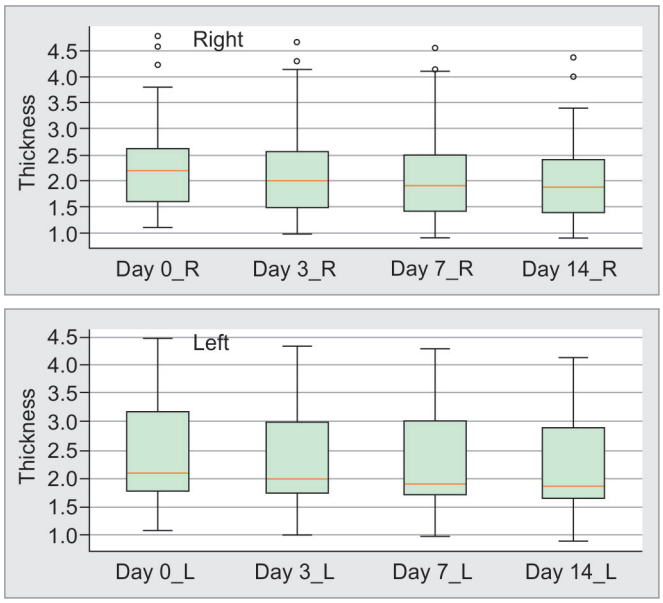


Fig. 2: Rectus femoris cross-sectional area on both sides across days

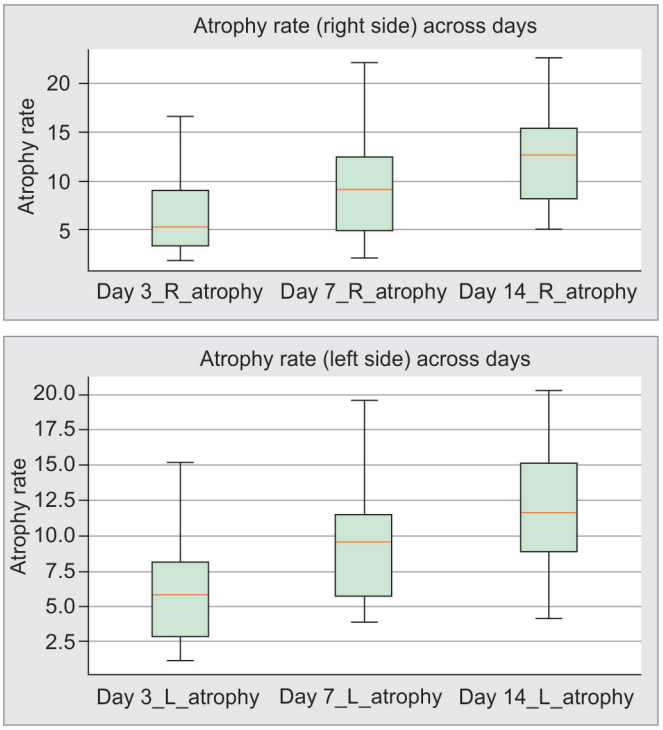


Fig. 3: Atrophy rates on both sides across days

Table 1: Demographic and clinical variables

Variable	*Mean ± SD*	*Median (25th–75th percentile)*
Age (years)	48.96 ± 14.82	48.0 (40.0–60.0)
Hemoglobin (gm/dL)	12.58 ± 1.99	12.3 (11.1–14.2)
Creatinine (mg/dL)	0.56 ± 0.17	0.6 (0.4–0.7)
Sodium (mEq/L)	135.48 ± 3.77	135.0 (134.0–138.0)
RFCSA Day 0 (cm^2)	2.4 ± 0.99	2.17 (1.68–2.85)
RFCSA Day 3 (cm^2)	2.25 ± 0.95	2.0 (1.62–2.65)
RFCSA Day 7 (cm^2)	2.18 ± 0.93	1.91 (1.59–2.64)

on day 14. The sample size was determined to be 24, based on an 80% power and a 5% alpha error. Ultimately, 25 patients were included in the final analysis.

Results

A total of 25 patients were included in this study (Fig. 1). The RFCSA and atrophy rates of the right and left sides are shown in Figures 2 and 3. The means of both sides were taken for further calculations. The baseline and clinical data of the patients are presented in Table 1. A total of 14 patients underwent tracheostomy, and two patients died in the ICU.

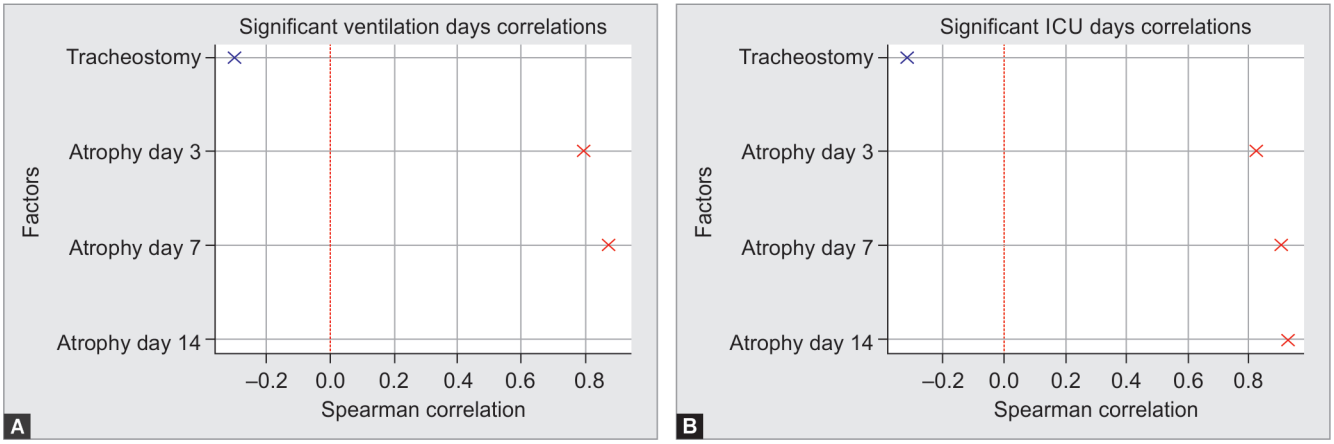
There was a significant decrease in muscle thickness with time. The average RFCSA values on days 0, 3, 7, and 14 were 2.4 + 0.9, 2.25 + 0.95, 2.18 + 0.93, and 2.11 + 0.92, respectively (Table 1, Fig. 2).

The median atrophy rates were 5.21 (3.38–8.39) on day 3, 9.18 (5.52–11.76) on day 7, and 12.63 (8.65–15.09) on day 14. The maximum degree of atrophy was observed on day 14 (Table 1, Fig. 3).

There was a very strong correlation between ventilation days and ICU days ($r = 0.98$, $p < 0.001$). Additionally, a greater muscle atrophy rate was strongly positively correlated with longer ventilation periods (atrophy day 14 ($r = 0.88$, $p < 0.001$) and atrophy day 7 ($r = 0.87$, $p < 0.001$)). Interestingly, there was a moderate negative correlation between days of ventilation and tracheostomy ($r = -0.30$, $p = 0.04$), suggesting that patients who undergo tracheostomy tend to have shorter ventilation periods. Similarly, total ICU stay was strongly positively correlated with atrophy day 14 ($r = 0.93$, $p < 0.001$) and moderately negatively correlated with tracheostomy ($r = -0.32$, $p = 0.04$) (Fig. 4).

Multiple linear regression models were employed, incorporating interaction terms between atrophy at different time points (day 3, day 7, and day 14). For ICU days, the final model explained 86% of the variance ($R^2 = 0.860$), identifying atrophy on day 14 as a significant predictor. Greater atrophy on day 14 was associated with longer ICU stays ($\beta = 2.20$, $p = 0.041$). The interaction between atrophy on day 7 and day 14 did not contribute significantly to the number of ICU days.

In contrast, for ventilation days, the model explained 87% of the variance ($R^2 = 0.871$). The interaction effect between atrophy on days 7 and 14 was a significant factor associated with longer ventilation days ($\beta = 0.869$, $p = 0.013$). While individual atrophy measurements did not reveal significant effects on their own, the combined muscle atrophy between days 7 and 14 clearly affected



Figs 4A and B: Correlation factors. (A) Correlation with ventilation days; (B) Correlation with the number of ICU days

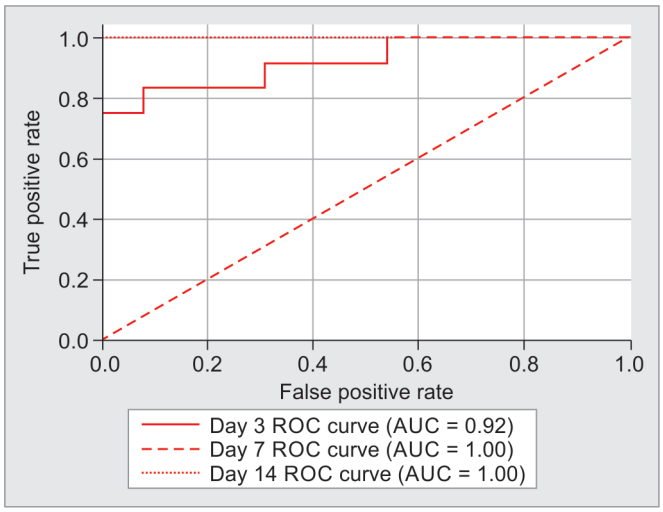


Fig. 5: Receiver operating characteristic curve for prolonged ICU stays

prolonged ventilation, suggesting that the progression of muscle atrophy during this period plays a critical role in determining the duration of mechanical ventilation.

A receiver operating characteristic (ROC) curve was generated to identify the optimal cutoff for predicting a prolonged ICU stay, which was defined as an ICU stay exceeding 26 days. This threshold was determined based on the median ICU stay in the study cohort [26 (13–33) days]. Figure 5 displays the ROC curves based on the RFCSA atrophy rate between D0 and D3, between D0 and D7, and between D0 and D14. The cutoff values for prolonged ICU stay were determined to be 6.5%, 9.7%, and 12.7%, respectively. The atrophy rate on day 3 demonstrated a sensitivity of 83% and specificity of 92% (AUC = 0.92). The atrophy rates at days 7 and 14 had 100% sensitivity and specificity for prolonged ICU stays (Fig. 5).

The relationships between muscle atrophy rates at three different time points (day 3, day 7, and day 14) and the total number of ventilation days and ICU days were the highest, with the initial days of atrophy. The strength of the association decreases with time.

Discussion

This study demonstrates that significant muscle atrophy occurs in GBS patients during the first 14 days of ICU admission, as measured by serial ultrasound assessments of RFCSA. The rate of muscle loss was highest between days 7 and 14, underscoring the need for early monitoring and potential interventions. The effects of these changes on clinical outcomes, such as ICU days and ventilation days, were also explored. The findings of this study provide insights into the progression of muscle atrophy in GBS patients and highlight the predictive value of early muscle thickness measurements for patient outcomes.

The average RFCSA in this study was 2.4 ± 0.9 cm^2 on the day of admission to the ICU. These values are significantly lower than the values reported in ICU patients.[13,16,17] Patients with GBS admitted to the ICU are more likely to have severe GBS, which could explain the low values observed. The low muscle mass observed in this study is consistent with the known pathophysiology of GBS, where acute inflammatory demyelination leads to muscle denervation and a subsequent reduction in muscle mass.[5]

In our study, the number of patients whose atrophy rate was at least 10% in the first 3 days was 25%, which increased to 44% by day 7 and 56% by day 14 of ICU admission. These rates are comparable with those of other studies. Ultrasound measurements of the RFCSA in 31 patients were performed to identify significant muscle atrophy of more than 10%. The study reported an incidence of 58%.[18] Hrdy et al., in their study of critically ill patients with significant muscle wasting, reported an incidence of 59.6% on day 7.[19] There are no previous studies on GBS. Regardless of the type of population, muscle wasting occurs as early as 72 hours in patients admitted to the ICU.

Kangalgil et al., in their study of patients with acute brain injury, reported an atrophy rate of 15.8% in the first week after ICU admission.[17] Yao et al., in their study of mechanically ventilated patients, reported that an atrophy rate of approximately 7% on day 3 was predictive of the occurrence of ICUAW.[20] In our study, the atrophy rates were approximately 5%, 9%, and 12% on days 3, 7, and 14, respectively.

Parry et al. performed sequential measures at admission and at 3, 7, and 10 days in a cohort of 22 patients with severe diseases who were receiving mechanical ventilation. The range of average muscle mass decrease in the RFCSA varied from 0.2 to 9% in the first 72 hours.[13] An analysis of muscle mass reduction on day 7 revealed a reported muscular atrophy rate ranging from 12.1 to 23.2% relative to the baseline value.[21] A comprehensive review and meta-analysis conducted by Fazzini et al. revealed that, at a 14-day follow-up in the ICU, there was a significant muscle mass loss of 24.5–29.4%, as evaluated by the cross-sectional area (CSA).[7] As seen in our study

population, the day 7 to day 14 trophy rate is the maximum, and early assessment is imperative to identify muscle loss and provide for early interventions.

In addition to GBS per se, factors previously shown to contribute to ICUAW have the potential to further worsen muscle weakness.[22] Previous studies have shown that mechanical ventilation, prolonged immobilization, the use of steroids, and neuromuscular blocking drugs are important contributors to muscle weakness in the ICU. A recent systematic review revealed that ventilation days, age, APACHE II score, blood lactate level, and length of ICU stay were the top predictors of ICUAW.[23] Severity scores have been shown to be a good predictor of muscle loss in critical care patients.[24] In our study, the usual predictors of disease severity, such as the APACHE II score and the mNUTRIC score, did not correlate with clinical outcomes, such as the number of ventilation days or ICU days. Previous studies have demonstrated good predictability of these scores with respect to mortality and morbidity in the ICU.[25,26] The mNUTRIC score is recommended for nutritional scoring in the ICU and is a good predictor of mortality.[27,28] Patients with GBS are usually younger, have fewer comorbidities, and do not have multiorgan failure, which could explain the lack of predictability of conventional ICU severity scoring, which uses multiorgan dysfunction in the model for the prediction of outcomes.

Malnutrition in the ICU results from various factors, ranging from increased catabolism, infections, and nutritional deficiencies to overall reduced intake. It is associated with high mortality and morbidity.[29] The assessment of nutrition in the ICU is challenging, and there are many methodological and estimation difficulties in the ICU.[30] Sarcopenia, which is defined by skeletal muscle loss, has emerged as an important predictor of outcomes in ICU. Studies have shown that sarcopenia is associated with worse clinical outcomes.[31]

It is important to differentiate muscle loss as a result of catabolism resulting in weakness and ICUAW as a result of critical illness, immobilization, inflammation, and drugs.[3,6,16] The rapid muscle atrophy observed in this study is consistent with the known pathophysiology of GBS, where acute inflammatory demyelination leads to muscle denervation and subsequent atrophy.[1,2] The use of MUSG in this context provides a noninvasive, real-time assessment of muscle changes, which can be crucial for timely intervention. Our study aligns with previous research indicating that MUSG is an effective tool for monitoring muscle health in ICU patients.[15,32]

One of the significant findings of this study is the correlation between the atrophy rate on day 14, ICU days, and ventilation days. A significant interaction effect was observed between days 7 and 14 atrophy rates and the number of ventilation days. However, the present study did not find any association between muscle atrophy and mortality. These findings are similar to those of a previous study in which the predictability of 28-day mortality was poor with MUSG.[9,18] However, The study was exploratory, not powered to evaluate definitive clinical endpoints, and intended to be hypothesis-generating. Larger, multicentric studies are needed to confirm these associations and validate the findings.

In patients with GBS, early identification of patients at risk for significant muscle loss could facilitate targeted interventions, such as physical therapy and nutritional support, aimed at preserving muscle function and improving outcomes.

The limitations of the study include the following: First, it is a single-center study with a small sample size, limiting the study's generalizability and statistical power for detecting smaller effect sizes. Second, only one muscle group was evaluated, and other variables, such as muscle thickness and echogenicity, were not studied. There is an absence of a direct comparator for MUSG. Third, nutritional intake during the ICU stays and the rehabilitation program were not included in the study. Fourth, biomarkers of muscle health and inflammation have not been studied. Finally, the impact of muscle mass loss on physical capacity and functionality post-discharge was not analyzed. While the findings of this study are promising, they also point to the need for larger, more comprehensive studies to validate these results.

Conclusion

This prospective study highlights the potential utility of MUSG as a non-invasive tool for monitoring muscle atrophy in GBS patients in the ICU. While early measurements of muscle thickness were associated with trends in clinical outcomes such as ICU and ventilation days, these findings should be interpreted with caution given the small sample size and absence of a comparator. Larger, multicenter studies are needed to validate the predictive value of MUSG and explore its role in guiding clinical interventions.

Clinical Significance

This study demonstrates the value of MUSG as a noninvasive and cost-effective tool for monitoring muscle atrophy in GBS patients requiring ICU care. The findings establish that early muscle atrophy, particularly within the first 14 days of ICU admission, strongly correlates with prolonged ICU stays and mechanical ventilation duration. By identifying at-risk patients through ultrasound-based muscle assessments, clinicians can implement timely, targeted interventions such as optimized nutrition and physical therapy to mitigate muscle loss, enhance recovery, and improve clinical outcomes in critically ill GBS patients.

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