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THE IMPACT OF PROLONGED ICU BED REST ON INTERCOSTAL MUSCLE THICKNESS AND FUNCTION: A LONGITUDINAL ULTRASOUND STUDY

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Abstract

Introduction: Prolonged intensive care unit (ICU) stays often lead to significant muscle atrophy, potentially impacting patient outcomes. While diaphragm dysfunction has been well-studied, the effects on intercostal muscles remain poorly understood. This study aimed to investigate the impact of prolonged ICU bed rest on intercostal muscle thickness and function using longitudinal ultrasound measurements.

Methods: In this prospective, observational study, 100 mechanically ventilated patients were followed for up to 28 days. Intercostal muscle thickness was measured via ultrasound at three standardized points on days 0, 3, 7, 14, and 28.

Respiratory function was assessed through Maximal Inspiratory Pressure (MIP), Rapid Shallow Breathing Index (RSBI), and diaphragm excursion. Clinical outcomes, including extubation success and mortality, were recorded.

Results: Intercostal muscle thickness decreased progressively, with a 23% reduction at the 4th intercostal space by day 28. This decline correlated strongly with deterioration in respiratory function parameters ($r=0.65$-0.68 for MIP, $p<0.001$). Logistic regression analysis revealed that changes in intercostal muscle thickness were significant predictors of successful extubation (OR 1.08, 95% CI 1.03-1.13, $p=0.001$). The ICU mortality rate was 18%, with a hospital mortality rate of 25%.

Conclusion: This study demonstrates a significant association between intercostal muscle atrophy and declining respiratory function in critically ill patients.

The strong correlation with extubation outcomes suggests that monitoring intercostal muscle thickness could provide valuable prognostic information. These findings underscore the need for strategies to preserve respiratory muscle mass in ICU patients and highlight the potential of ultrasound as a non-invasive monitoring tool.

Keywords: Intercostal muscles, Critical care ultrasound, Mechanical ventilation, Muscle atrophy, Respiratory function

Introduction:

Intensive Care Units (ICUs) play a crucial role in modern healthcare, providing life-saving interventions for critically ill patients. However, prolonged ICU stays, often necessitating extended

periods of bed rest, can lead to significant physiological changes in patients' bodies. One area of particular concern is the impact on muscle structure and function, which can have far-reaching consequences for patient recovery and long-term outcomes (Hermans & Van den Berghe, 2015).

While the effects of prolonged immobilization on major muscle groups, such as those in the limbs, have been well-documented, less attention has been paid to the impact on respiratory muscles, particularly the intercostal muscles. These muscles, located between the ribs, play a vital role in breathing by helping to expand and contract the chest cavity. Any compromise in their function could potentially affect respiratory mechanics and overall patient recovery (De Jonghe et al., 2002).

The intercostal muscles are uniquely positioned to be affected by prolonged bed rest in ICU patients. Unlike limb muscles, which may experience some passive movement during patient care activities, the intercostal muscles may be subject to even more profound inactivity, especially in mechanically ventilated patients. This could lead to accelerated atrophy and functional decline, potentially contributing to difficulties in weaning from mechanical ventilation and increased risk of respiratory complications (Levine et al., 2008).

Recent advancements in imaging technology, particularly in ultrasound techniques, have made it possible to assess muscle structure and function non-invasively and repeatedly over time. Ultrasound has been successfully used to measure muscle thickness and cross-sectional area in various muscle groups, providing valuable insights into muscle atrophy and recovery (Puthucheary et al., 2013). Applying these techniques to intercostal muscles could offer a unique window into the effects of prolonged ICU stays on respiratory muscle integrity.

Understanding the impact of prolonged ICU bed rest on intercostal muscle thickness and function is not merely an academic exercise. It has significant clinical implications for patient care and outcomes. If substantial changes in intercostal muscle structure and function are observed, it could inform the development of targeted interventions to preserve muscle integrity, potentially improving respiratory function and facilitating faster recovery (Schepens et al., 2015).

Moreover, this research could contribute to our broader understanding of the physiological effects of critical illness and prolonged immobilization. It may help bridge the gap between the known systemic effects of bed rest and the specific challenges faced in respiratory function and weaning from mechanical ventilation in long-term ICU patients (Goligher et al., 2012).

The use of ultrasound as a primary assessment tool in this study offers several advantages. It is non-invasive, can be performed at the bedside, and allows for repeated measurements over time without exposing patients to radiation or requiring their transfer out of the ICU. This makes it an ideal modality for longitudinal studies in critically ill patients (Zambon et al., 2010).

Furthermore, by correlating changes in intercostal muscle thickness with functional outcomes, this study could provide valuable prognostic information. It may help clinicians identify patients at higher risk of prolonged mechanical ventilation or difficult weaning, allowing for earlier intervention and more personalized care plans (Dres et al., 2012).

The potential implications of this research extend beyond the ICU setting. Insights gained from this study could inform rehabilitation strategies for patients recovering from critical illness, both in the hospital and after discharge. It may also have relevance for other patient populations experiencing prolonged periods of immobility, such as those with spinal cord injuries or prolonged hospital stays for other reasons (Needham et al., 2012).

In the context of the ongoing global health challenges, including the COVID-19 pandemic, which has seen unprecedented numbers of patients requiring prolonged ICU care and mechanical ventilation, this research takes on added significance. Understanding the specific impacts of prolonged ICU stays on respiratory muscle function could inform care strategies for these patients and potentially contribute to improved outcomes (Kress & Hall, 2007).

The aim of this study was to investigate the impact of prolonged ICU bed rest on intercostal muscle thickness and function using longitudinal ultrasound measurements, and to correlate these changes with clinical outcomes in critically ill patients.

Methodology:

Study Design:
This study employed a prospective, observational, longitudinal design. It was conducted in the intensive care unit of a tertiary care hospital over a period of six months. The study protocol was approved by the institutional ethics committee prior to commencement.

Study Site:
The research was conducted in the medical and surgical ICUs of Major SD Singh Medical College & Hospital, a 1000-bed tertiary care academic medical center located in Farrukhabad, Uttar Pradesh. This hospital serves as a major referral center for complex cases in the region and has a 50-bed ICU facility equipped with state-of-the-art medical technology and staffed by experienced critical care specialists.

Study Duration:
The study was conducted over a period of six months.

Sample Size Calculation:
Based on previous studies of muscle atrophy in ICU patients, we estimated that a sample size of 100 patients would provide 80% power to detect a 10% change in muscle thickness over time, assuming a standard deviation of 20% and an alpha level of 0.05.

Inclusion Criteria:
The study included patients who met the following criteria:
1. Age 18 years or older
2. Admitted to the ICU with an expected length of stay of at least 7 days
3. Requiring mechanical ventilation for at least 48 hours
4. Able to lie in a supine position for ultrasound examination
5. Provided informed consent (either directly or through a legally authorized representative)

Exclusion Criteria:
Patients were excluded from the study if they met any of the following criteria:
1. Pre-existing neuromuscular disorders affecting respiratory function
2. History of chronic respiratory failure or long-term oxygen therapy
3. Recent thoracic surgery (within the past 3 months)
4. Presence of chest wall deformities or injuries that would interfere with ultrasound measurements
5. Pregnant women
6. Patients with a body mass index (BMI) > 40 kg/m^2
7. Unable to obtain informed consent

Data Collection Tools and Techniques:

Ultrasound Measurements:
Intercostal muscle thickness was measured using a high-frequency linear transducer (10-15 MHz) connected to a portable ultrasound machine. Measurements were taken at three standardized points:
1. The second intercostal space at the midclavicular line
2. The fourth intercostal space at the anterior axillary line
3. The eighth intercostal space at the midaxillary line

At each point, the thickness of the internal and external intercostal muscles was measured separately. Three measurements were taken at each point and averaged to ensure reliability. The

ultrasound probe was placed perpendicular to the chest wall, and care was taken to apply minimal pressure to avoid compression of the muscles.
Measurements were performed by trained sonographers who were blinded to the patient's clinical status. Inter-observer reliability was assessed by having a second sonographer repeat measurements in a subset of patients.

Functional Assessments:
To correlate muscle thickness with function, the following assessments were performed when clinically appropriate:
1. Maximal Inspiratory Pressure (MIP): Measured using a handheld pressure meter connected to the patient's endotracheal or tracheostomy tube.
2. Rapid Shallow Breathing Index (RSBI): Calculated as the ratio of respiratory rate to tidal volume during a spontaneous breathing trial.
3. Diaphragm Excursion: Measured using M-mode ultrasound at the zone of apposition of the diaphragm.

Clinical Data Collection:
Relevant clinical data were collected from patients' electronic medical records, including:
1. Demographic information (age, sex, BMI)
2. Admission diagnosis and severity scores (APACHE II, SOFA)
3. Duration of mechanical ventilation
4. ICU and hospital length of stay
5. Incidence of ventilator-associated pneumonia
6. Success or failure of extubation attempts
7. ICU and hospital mortality

Data Collection Schedule:
Ultrasound measurements and functional assessments were performed according to the following schedule:
1. Within 24 hours of ICU admission (baseline)
2. On days 3, 7, and 14 of ICU stay
3. Weekly thereafter until ICU discharge or day 28, whichever came first
4. At ICU discharge
5. At hospital discharge (if different from ICU discharge)

Data Management and Statistical Analysis:
All data were entered into a secure, password-protected electronic database. Double data entry was performed to minimize errors, and regular data quality checks were conducted throughout the study period. Missing data were handled using multiple imputation techniques where appropriate. Statistical analysis was performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). A p-value < 0.05 was considered statistically significant for all analyses. Continuous variables were presented as means and standard deviations or medians and interquartile ranges, depending on the distribution of the data. Categorical variables were presented as frequencies and percentages. Changes in intercostal muscle thickness over time were analyzed using linear mixed-effects models, which account for repeated measures and missing data. Time, ICU length of stay, and relevant clinical variables were included as fixed effects, with patient ID as a random effect. Pearson's or Spearman's correlation coefficients were calculated to assess the relationship between changes in muscle thickness and functional outcomes (MIP, RSBI, diaphragm excursion). Logistic regression models were constructed to evaluate whether changes in intercostal muscle thickness could predict clinical outcomes such as successful extubation, development of ventilator-associated pneumonia,

and ICU mortality. Models were adjusted for relevant confounders such as age, severity of illness, and comorbidities.

Results:

Table 1: Baseline Characteristics of Study Participants (N=100)

Characteristic	Value
Age, years (mean ± SD)	62.5 ± 15.3
Sex, male (n, %)	58 (58%)
BMI, kg/m² (mean ± SD)	27.3 ± 4.8
APACHE II score (median, IQR)	22 (18-26)
SOFA score (median, IQR)	8 (6-10)
Admission diagnosis (n, %)	
- Sepsis	35 (35%)
- Respiratory failure	28 (28%)
- Post-operative	20 (20%)
- Trauma	12 (12%)
- Other	5 (5%)

Table 2: Changes in Intercostal Muscle Thickness Over Time (mm, mean ± SD)

Measurement Site	Baseline	Day 3	Day 7	Day 14	Day 28
2nd ICS, MCL	4.8 ± 0.9	4.6 ± 0.9	4.3 ± 0.8	4.0 ± 0.8	3.7 ± 0.7
4th ICS, AAL	5.2 ± 1.0	5.0 ± 1.0	4.7 ± 0.9	4.3 ± 0.9	4.0 ± 0.8
8th ICS, MAL	4.5 ± 0.8	4.3 ± 0.8	4.1 ± 0.7	3.8 ± 0.7	3.5 ± 0.6

Table 3: Respiratory Function Parameters Over Time (mean ± SD)

Parameter	Baseline	Day 7	Day 14	Day 28
MIP, cmH_2O	-65 ± 15	-58 ± 14	-52 ± 13	-48 ± 12
RSBI, breaths/min/L	75 ± 25	82 ± 28	88 ± 30	92 ± 32
Diaphragm Excursion, cm	1.8 ± 0.4	1.6 ± 0.4	1.5 ± 0.3	1.4 ± 0.3

Table 4: Correlation Between Intercostal Muscle Thickness and Respiratory Function

Muscle Thickness Site	MIP (r)	RSBI (r)	Diaphragm Excursion (r)
2nd ICS, MCL	0.65	-0.58	0.62
4th ICS, AAL	0.68	-0.61	0.64
8th ICS, MAL	0.63	-0.56	0.6

Table 5: Clinical Outcomes

Outcome	Value
Duration of mechanical ventilation, days	12 (7-18)
ICU length of stay, days	15 (9-23)
Hospital length of stay, days	24 (16-35)
Successful extubation, n (%)	78 (78%)
Ventilator-associated pneumonia, n (%)	22 (22%)
ICU mortality, n (%)	18 (18%)
Hospital mortality, n (%)	25 (25%)

Table 6: Logistic Regression Analysis for Predicting Successful Extubation

Variable	Odds Ratio	95% CI	P-value
Age (per year increase)	0.98	0.96-1.00	0.08
APACHE II score (per point)	0.94	0.89-0.99	0.02
Baseline MIP (per cmH_2O)	1.03	1.01-1.05	0.01
% change in 4th ICS thickness	1.08	1.03-1.13	0.001
Diaphragm excursion at day 7 (cm)	2.45	1.56-3.85	<0.001

Discussion:

The baseline characteristics of our study population are consistent with typical ICU cohorts reported in previous studies. The mean age of 62.5 years and predominance of male patients (58%) align with the findings of Puthucheary et al. (2013), who reported a median age of 59 years with 59% male participants in their study of acute skeletal muscle wasting in critical illness. The median APACHE II score of 22 indicates a cohort with severe illness, similar to that reported by Dres et al. (2012) in their study of ICU-acquired weakness. The distribution of admission diagnoses, with sepsis (35%) and respiratory failure (28%) being the most common, reflects the typical case mix in many ICUs. This is comparable to the findings of Hermans et al. (2014), who reported sepsis and respiratory failure as predominant admission diagnoses in their study of ICU-acquired weakness. Our data show a progressive decrease in intercostal muscle thickness across all measurement sites over the 28-day period. The rate of decline appears to be most rapid in the first 14 days, with a slower rate of atrophy thereafter. This pattern is consistent with the findings of Schepens et al. (2015) in their study of diaphragm atrophy, where they observed the most significant changes in the first two weeks of mechanical ventilation. The magnitude of muscle loss in our study (approximately 23% decrease at the 4th intercostal space by day 28) is comparable to the diaphragm atrophy reported by Grosu et al. (2012), who found a 6% decrease in diaphragm thickness per day of mechanical ventilation. Our findings suggest that intercostal muscles may be affected similarly to the diaphragm during prolonged ICU stays.

The decline in Maximal Inspiratory Pressure (MIP) from -65 cmH_2O at baseline to -48 cmH_2O by day 28 represents a significant loss of inspiratory muscle strength. This is in line with the findings of Dres et al. (2017), who reported that 63% of their cohort had inspiratory muscle weakness at the time of liberation from mechanical ventilation. The increase in Rapid Shallow Breathing Index (RSBI) over time suggests a deterioration in respiratory function, potentially due to respiratory muscle weakness. This aligns with the work of Yang and Tobin (1991), who established RSBI as a predictor of weaning outcomes. The decrease in diaphragm excursion from 1.8 cm to 1.4 cm is consistent with the findings of Zambon et al. (2010), who reported significant reductions in diaphragm excursion in mechanically ventilated patients.

The strong positive correlations between intercostal muscle thickness and MIP ($r = 0.65$-0.68) suggest that intercostal muscle atrophy is associated with reduced inspiratory muscle strength. This relationship has not been extensively studied for intercostal muscles, but it aligns with findings related to diaphragm thickness and strength (Goligher et al., 2014). The negative correlation with RSBI indicates that as muscle thickness decreases, patients tend to exhibit more rapid, shallow breathing patterns. This novel finding extends our understanding of the relationship between respiratory muscle structure and function in critically ill patients.

The median duration of mechanical ventilation (12 days) and ICU length of stay (15 days) in our cohort are comparable to those reported in other studies of critically ill patients (Needham et al., 2012). The successful extubation rate of 78% is within the range typically reported in ICU studies, though direct comparisons are challenging due to variations in patient populations and extubation protocols. The incidence of ventilator-associated pneumonia (22%) is consistent with rates reported in the literature, such as the findings of Papazian et al. (2020) in their study of ventilator-associated pneumonia in COVID-19 patients. The ICU mortality rate of 18% and hospital mortality rate of 25% are comparable to those reported in large-scale studies of critically ill patients, such as the LUNG SAFE study by Bellani et al. (2016).

The logistic regression model identifies several significant predictors of successful extubation, including baseline MIP, change in intercostal muscle thickness, and diaphragm excursion at day 7. These findings extend the work of Ferrari et al. (2014), who found that diaphragm dysfunction was associated with extubation failure. The strong association between change in intercostal muscle thickness and extubation success (OR 1.08, 95% CI 1.03-1.13, $p=0.001$) is a novel finding that highlights the potential importance of preserving intercostal muscle mass in mechanically ventilated patients.

Conclusion:

This study provides compelling evidence for the significant impact of prolonged ICU bed rest on intercostal muscle thickness and respiratory function. Our findings demonstrate a progressive decline in intercostal muscle thickness over time, which correlates strongly with deterioration in respiratory function parameters. The observed changes in muscle thickness and function have important clinical implications, as evidenced by their association with extubation outcomes. The study highlights the potential value of monitoring intercostal muscle thickness as a predictor of respiratory function and clinical outcomes in ICU patients. The strong correlations between muscle thickness, respiratory function parameters, and extubation success suggest that interventions aimed at preserving intercostal muscle mass could potentially improve patient outcomes. These results underscore the need for early mobilization and rehabilitation strategies in the ICU to mitigate muscle atrophy. They also suggest that ultrasound assessment of intercostal muscles could be a valuable tool for monitoring patients and guiding clinical decision-making. Future research should focus on developing and testing interventions to preserve intercostal muscle mass and function in critically ill patients, as well as exploring the long-term consequences of ICU-acquired intercostal muscle weakness.

References:

1. De Jonghe, B., Sharshar, T., Lefaucheur, J. P., Authier, F. J., Durand-Zaleski, I., Boussarsar, M., ... & Bastuji-Garin, S. (2002). Paresis acquired in the intensive care unit: a prospective multicenter study. Jama, 288(22), 2859-2867.
2. Dres, M., Dubé, B. P., Mayaux, J., Delemazure, J., Reuter, D., Brochard, L., ... & Demoule, A. (2012). Coexistence and impact of limb muscle and diaphragm weakness at time of liberation from mechanical ventilation in medical intensive care unit patients. American journal of respiratory and critical care medicine, 195(1), 57-66.
3. Goligher, E. C., Dres, M., Fan, E., Rubenfeld, G. D., Scales, D. C., Herridge, M. S., ... & Ferguson, N. D. (2014). Mechanical ventilation–induced diaphragm atrophy strongly impacts clinical outcomes. American journal of respiratory and critical care medicine, 197(2), 204-213.
4. Hermans, G., & Van den Berghe, G. (2015). Clinical review: intensive care unit acquired weakness. Critical care, 19(1), 274.
5. Kress, J. P., & Hall, J. B. (2007). ICU-acquired weakness and recovery from critical illness. New England Journal of Medicine, 382(14), 1314-1331.
6. Levine, S., Nguyen, T., Taylor, N., Friscia, M. E., Budak, M. T., Rothenberg, P., ... & Shrager, J. B. (2008). Rapid disuse atrophy of diaphragm fibers in mechanically ventilated humans. New England Journal of Medicine, 358(13), 1327-1335.
7. Needham, D. M., Davidson, J., Cohen, H., Hopkins, R. O., Weinert, C., Wunsch, H., ... & Harvey, M. A. (2012). Improving long-term outcomes after discharge from intensive care unit: report from a stakeholders' conference. Critical care medicine, 40(2), 502-509.
8. Puthucheary, Z. A., Rawal, J., McPhail, M., Connolly, B., Ratnayake, G., Chan, P., ... & Montgomery, H. E. (2013). Acute skeletal muscle wasting in critical illness. Jama, 310(15), 1591-1600.
9. Schepens, T., Verbrugghe, W., Dams, K., Corthouts, B., Parizel, P. M., & Jorens, P. G. (2015). The course of diaphragm atrophy in ventilated patients assessed with ultrasound: a longitudinal cohort study. Critical Care, 19(1), 422.
10. Zambon, M., Beccaria, P., Matsuno, J., Gemma, M., Frati, E., Colombo, S., ... & Bellani, G. (2010). Mechanical ventilation and diaphragmatic atrophy in critically ill patients: an ultrasound study. Critical care medicine, 44(7), 1347-1352.
11. Bellani, G., Laffey, J. G., Pham, T., Fan, E., Brochard, L., Esteban, A., ... & LUNG SAFE Investigators. (2012). Epidemiology, patterns of care, and mortality for patients with acute respiratory distress syndrome in intensive care units in 50 countries. Jama, 315(8), 788-800.

12. Dres, M., Dubé, B. P., Mayaux, J., Delemazure, J., Reuter, D., Brochard, L., ... & Demoule, A. (2011). Coexistence and impact of limb muscle and diaphragm weakness at time of liberation from mechanical ventilation in medical intensive care unit patients. American journal of respiratory and critical care medicine, 195(1), 57-66.
13. Ferrari, G., De Filippi, G., Elia, F., Panero, F., Volpicelli, G., & Aprà, F. (2014). Diaphragm ultrasound as a new index of discontinuation from mechanical ventilation. Critical ultrasound journal, 6(1), 8.
14. Goligher, E. C., Dres, M., Fan, E., Rubenfeld, G. D., Scales, D. C., Herridge, M. S., ... & Ferguson, N. D. (2012). Mechanical ventilation–induced diaphragm atrophy strongly impacts clinical outcomes. American journal of respiratory and critical care medicine, 197(2), 204-213.
15. Grosu, H. B., Lee, Y. I., Lee, J., Eden, E., Eikermann, M., & Rose, K. M. (2012). Diaphragm muscle thinning in patients who are mechanically ventilated. Chest, 142(6), 1455-1460.
16. Hermans, G., Van Mechelen, H., Clerckx, B., Vanhullebusch, T., Mesotten, D., Wilmer, A., ... & Van den Berghe, G. (2014). Acute outcomes and 1-year mortality of intensive care unit–acquired weakness. A cohort study and propensity-matched analysis. American journal of respiratory and critical care medicine, 190(4), 410-420.
17. Needham, D. M., Davidson, J., Cohen, H., Hopkins, R. O., Weinert, C., Wunsch, H., ... & Harvey, M. A. (2012). Improving long-term outcomes after discharge from intensive care unit: report from a stakeholders' conference. Critical care medicine, 40(2), 502-509.
18. Papazian, L., Klompas, M., & Luyt, C. E. (2003). Ventilator-associated pneumonia in adults: a narrative review. Intensive care medicine, 46(5), 888-906.
19. Puthucheary, Z. A., Rawal, J., McPhail, M., Connolly, B., Ratnayake, G., Chan, P., ... & Montgomery, H. E. (2013). Acute skeletal muscle wasting in critical illness. Jama, 310(15), 1591-1600.
20. Schepens, T., Verbrugghe, W., Dams, K., Corthouts, B., Parizel, P. M., & Jorens, P. G. (2015). The course of diaphragm atrophy in ventilated patients assessed with ultrasound: a longitudinal cohort study. Critical Care, 19(1), 422.
21. Yang, K. L., & Tobin, M. J. (1991). A prospective study of indexes predicting the outcome of trials of weaning from mechanical ventilation. New England Journal of Medicine, 324(21), 1445-1450.
22. Zambon, M., Beccaria, P., Matsuno, J., Gemma, M., Frati, E., Colombo, S., ... & Bellani, G. (2016). Mechanical ventilation and diaphragmatic atrophy in critically ill patients: an ultrasound study. Critical care medicine, 44(7), 1347-1352.