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Original Research Article

Assessment of Respiratory Muscle Strength in Mechanically Ventilated Patients

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ABSTRACT

Background: Respiratory muscle weakness is a prominent and well-recognized problem among mechanically ventilated patients, contributing significantly to delayed weaning, prolonged intensive care unit (ICU) stays, and reduced overall quality of life. Maximal Inspiratory Pressure (MIP) serves as a reliable and non-invasive indicator of respiratory muscle strength and can be easily assessed at the bedside using the end-expiratory occlusion technique. Recognizing its clinical value, this study aimed to measure the MIP of mechanically ventilated patients and examine its association with the duration of ventilator dependence.

Methods: An observational study was conducted among 75 patients receiving mechanical ventilation in the ICU who met the predefined inclusion criteria. MIP was measured using the end-expiratory occlusion method, and the value was calculated using the formula: MIP = Total PEEP – Maximal Negative Pressure. Demographic data were analyzed using descriptive statistics, while respiratory muscle strength was assessed in terms of median and interquartile range (IQR).

Results: The respiratory muscle strength of the study population, represented by MIP, showed a median value of 28 cm H_2O with an interquartile range of 26 to 29 cm H_2O. Patients who were on SIMV and CPAP mode of ventilation had an average MIP of 26.44 and 28.3 cm of H_2O. The correlation coefficient between length of stay on ventilator and MIP is -0.610 with a significant p value of <0.001. These findings indicate reduced inspiratory muscle strength among mechanically ventilated patients.

Conclusion: The study demonstrated that respiratory muscle strength in mechanically ventilated individuals is diminished, and a longer duration of ventilator support is associated with progressively lower MIP values. This negative correlation highlights the importance of routine monitoring of respiratory muscle strength and early rehabilitation strategies to facilitate timely weaning and improved patient outcomes.

Keywords: Intensive Care Unit Acquired Weakness (ICU-AW); Respiratory muscle strength; Mechanical ventilator; Maximal Inspiratory Pressure; Ventilator-induced Diaphragm Dysfunction; Modes of Ventilator

Key Message:

- MIP is an accurate and non-invasive method for assessing respiratory muscle strength in mechanically ventilated patients, aiding in early detection of respiratory muscle weakness.

- Regular MIP assessment helps to monitor muscle strength over time.
- Low MIP values are associated with difficulty in weaning from a mechanical ventilator, as it is a valuable predictor of extubation and weaning outcomes.

INTRODUCTION

ICU-acquired weakness (ICUAW) is a common neuromuscular complication associated with patients in the Intensive Care Units (ICU). It is characterized by diffuse, symmetrical muscle weakness that develops during critical illness and is frequently associated with prolonged mechanical ventilation, sepsis, or multiorgan failure and can affect both limb and respiratory muscles [1]. Annually about 13 to 20 million patients throughout the world are admitted to the Intensive Care Unit (ICU), out of which 750,000 patients need mechanical ventilation, and nearly 300,000 of them requires long-term support[2]. ICUAW is one of the most common neuromuscular conditions, identified by skeletal muscle weakness caused by various factors such as sepsis, immobilization, hyperglycaemia, and the use of glucocorticoids or other medications with neuromuscular blocking action [3]. It mainly involves the respiratory muscles (diaphragm, intercostal) and proximal muscles of the limb-girdle (quadriceps, biceps, and deltoid). The pathophysiology of ICU-AW is multifaceted with complex interactions between diverse physiological processes. Prolonged bed rest and immobilisation in the ICU lead to muscular atrophy and muscle wasting which is characterized by reduced protein synthesis and increased protein breakdown termed as disuse atrophy [4]. A critical illness neuropathy (CIN) refers to peripheral neuropathy of axonal degeneration, characterized by demyelination of peripheral nerves and secondary changes in the motor or sensorimotor nerve trunks which produce muscular weakness with decreased reflexes. Critical Illness Myopathy (CIM) induces muscle damage and dysfunction like fiber necrosis, inflammation, and atrophy. The pathogenesis of CIM is related to systemic inflammation, oxidative stress, and mitochondrial dysfunction [5]. Sepsis and Systemic Inflammatory Response Syndrome (SIRS) are two main factors for the development of the weakness which forms a cascade-like inflammatory response that causes muscle proteolysis, poor muscle regeneration, and mitochondrial dysfunction [6]. Microvascular dysfunction in skeletal muscle reduces oxygen delivery and nutrients to the muscle fibers, leading to tissue hypoxia with metabolic disturbances. Electrolyte imbalances such as hypokalemia, and hypocalcemia influence muscle contractions, induce an alteration in nerve impulse transmission, and reduce neuromuscular function and thus cause muscle weakness. In addition, many medications like neuromuscular blocking agents, corticosteroids, and sedatives will aggravate muscle weakness by reducing neuromuscular transmission and promoting muscular damage [7].

ICU-AW can lead to prolonged dependence on mechanical ventilation and extended hospital stays. Patients frequently report a poor prognosis, restricted mobility, and a reduced quality of life [8]. Patients in ICU are frequently affected by respiratory muscle weakness, which is reported to be more than twice as frequent in comparison with limb muscles and associated with poor short- and long-term outcomes [9]. It also prolongs the need for mechanical ventilation, prevents the extubation process, and extends the ICU stay [10]. Additionally, the weakness may further increase the complications including ventilator-associated pneumonia, respiratory distress, and Ventilator-induced lung injury (VILI) [11]. Ventilator dependency increases the progression and severity of the muscle weakness which impacts the patient's quality of life and reduces functional outcomes [12]. Early diagnosis and management of respiratory muscle weakness are essential to alleviate the weakness and improve outcomes in ICU patients [13]. Measurement

of the respiratory muscle strength is useful to detect the weakness and quantify its severity. Various methods are used to assess the respiratory muscle strength in ventilated patients which includes manometry, Twitch pressure measurement (Twitch Pdi), Ultrasound [6], Electromyography (EMG), trans-diaphragmatic pressure (Pdi), Maximal Inspiratory Pressure (MIP) [14].
Maximal Inspiratory Pressure (MIP) is an accurate and convenient parameter for respiratory muscle strength assessment by end-expiratory occlusion technique [15]. It is non-invasive and time-efficient as compared to other tests. It becomes crucial to assess respiratory muscle strength in ventilated patients and there is minimal literature about this in the Indian context and globally also. This study is undertaken with a demanding need to evaluate the respiratory muscle strength in ventilated patients and to determine the length of ventilator stay based on MIP values.

MATERIALS & METHODS

The study was approved by the Ethical Review Board No (MSRMC/EC/PG-04/06-2023) of the Ramaiah Medical College, Bangalore. It was then registered with the Clinical Trial Registry of India (CTRI/2023/10/059176). Written informed consent was obtained from the patient's attendant.

Study participants: From July 2023 to July 2024, this observational research was conducted in the adult ICU of a tertiary care hospital in Bangalore. During this period, 125 patients were assessed for eligibility, 75 of them met the inclusion criteria and guardians provided informed written consent. 50 patients were excluded from the study as they did not meet the inclusion criteria. (Figure 1). Mechanically ventilated patients on Synchronized Intermittent Mandatory Ventilation (SIMV), or Continuous Positive Airway Pressure (CPAP) mode of ventilation, over 18 years of age who were alert and able to follow simple commands were included in the study. Patients having a history of arrhythmias and acute myocardial infarction, unconscious patients, presence of flail chest or rib fractures, patients with neurological impairment, muscular dystrophy, and cognitive impairment that affects the ability to follow commands, were excluded from the research.

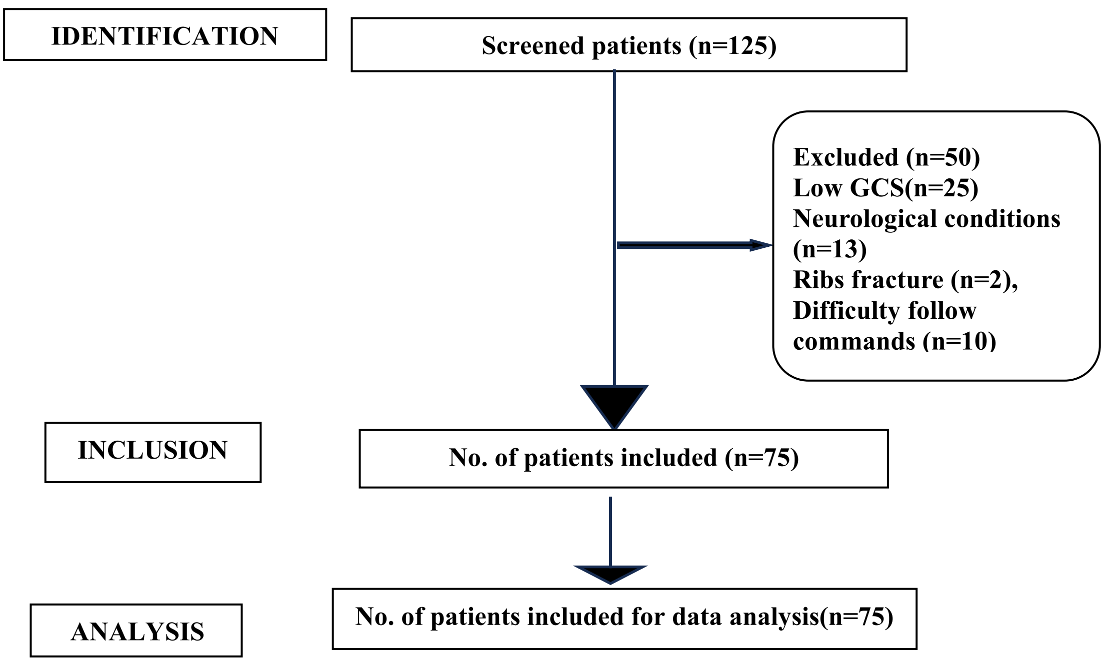

Figure 1: STROBE Flow Chart

Study Procedure

The Department of Critical Care Medicine of a tertiary care hospital was approached and explained the nature of the study. After screening for inclusion criteria, and getting the informed consent filled, the participants were recruited from the ICU. Dräger and Maquet ventilators were used in the study. Respiratory muscle strength was assessed in ventilated patients using maximal inspiratory pressure (MIP). This was done by asking the patient to make inspiratory efforts, the expiratory hold knob was held for 10 seconds and a drop in maximum negative pressure from the ventilator was noted. Maximal Inspiratory Pressure was calculated by the difference between the total PEEP and the maximal negative pressure drop. (Figure 2). The formula used to calculate MIP was:

MIP=TOTAL PEEP – MAXIMAL NEGATIVE PRESSURE

The respiratory muscle strength was measured every day till the patient was extubated (Figure 3)

FIGURE 2: Assessment of Respiratory Muscle Strength in ventilated patients in ICU

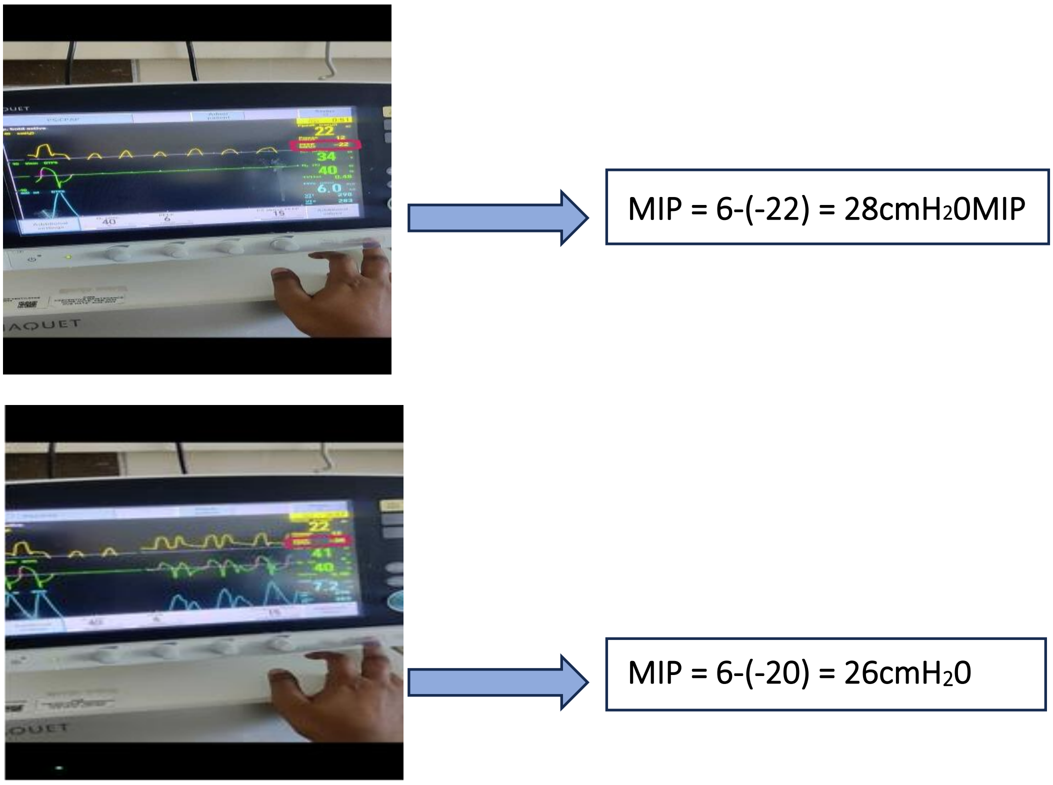

FIGURE 3: Representation of MIP from ventilator
MIP=TOTAL PEEP – MAXIMAL NEGATIVE

Statistical Analysis

Descriptive statistics were done for demographic data. Continuous data such as age were represented in mean ± SD. Categorical data such as gender and mode of ventilation were represented as frequency. The normality of the collected data was tested using the Shapiro-Wilk normality test, it was found that data were not normally distributed, hence non-parametric test was used to analyze the data. Average MIP was found by median and interquartile range. Also, Spearman correlation was done for MIP and length of ventilator stay.

RESULT

The study included 75 patients, table 1 represents the mean age of 54.69±15.32, in which 54.7% were males and 45.3% were female. The median and interquartile range of respiratory muscle strength i.e., MIP was found to be 28(26,29) cmH2O represented in table 2.

Table 3 represents data categorized into age in a decade and mode of ventilation. Age distribution in decade revealed that 25.3% (n=19) patients were in the range of 60-70, 21.3% (n=16) patients in the range of 50-60, 20% (n=15) patients in the range of 40-50, 17.3% (n=13) patients in the range 70-80, 8% (n= 6) patients in the range of 20-30 and 8% (n= 6) patients in the range of 30-40. Based on the mode of ventilation 61 %(n=139) were classified under the CPAP mode of ventilator and 39% (n=89) were under the SIMV mode of the ventilator. Representation of average MIP values corresponding to the length of ventilator stay is addressed. Also, a correlation of MIP with length of stay on the ventilator was done and it is shown in table 4.

Table 1: Age in mean ±SD and gender in percentage

Age(years)	54.69±15.32
Gender	
Male (%)	41(54.7%)
Female (%)	34(45.3%)

Table 2: Statistical Analysis (Inter quartile range)

Respiratory Muscle Strength	Median (IQR)
MIP (cm H2O)	28(26,29)

MIP: Maximal Inspiratory Pressure, IQR: Inter quartile Range

Table 3: MIP values of ventilated patients in decade of age, mode of ventilator, determination of length of stay on the ventilator

Age range (Years)	**%(n)**	**Average MIP (cmH2O)**
20-30	8%(n=6)	28.0
30-40	8%(n=6)	27.7
40-50	20%(n=15)	26.9
50-60	21.3%9(n=16)	25.3
60-70	25.3%(n=19)	24.5
70-80	17.3%(n=13)	23.8
Mode of ventilator	**%(n)**	**Average MIP (cmH2O)**
SIMV		26.44
CPAP	61%(n=139)	28.5
Number of patients	**Length of ventilator stay(days)**	**Average MIP (cmH2O)**
17	2	29.38
40	3	27.52
15	4	26.85
2	5	23.90
1	6	18.33

Table 4: Correlation of MIP with the length of ventilator stay

Correlation			
Spearman's rho		**Ventilator stay**	**MIP**
Length of ventilator stay	Correlation Coefficient	1.000	-.610**
	Sig. (2- tailed)	.	<.001
	N	75	75
MIP	Correlation Coefficient	-.610**	1.000
	Sig. (2- tailed)	<.001	.
	N	75	75

****. Correlation is significant at the 0.01 level (2-tailed).**

DISCUSSION

In this study, the assessment of respiratory muscle strength in mechanically ventilated patients using MIP was determined. MIP is widely recognized as the most accurate predictor of respiratory muscle strength in patients on ventilator. It can be measured at the bedside by non-invasive techniques. The calculation of MIP was done in accordance with the study done by Spadaro S et al. where MIP was measured by occluding the expiratory hold knob of the ventilator concluding that this method delivers accurate, non-invasive measures 16. MIP predicts effective weaning, with greater values signifying strong respiratory muscles. Also, this predicts respiratory muscle weakness and allows for early intervention to prevent complications associated with prolonged ventilator stays. The current study assessed MIP value in ventilated patients and it was found to be 28(26,29) cm H2O and also determined that MIP levels decreased with age. Subsequently, the CPAP mode was associated with a greater MIP value than the SIMV mode of the ventilator. Mabrouk AA et al. showed the efficacy of various modes of ventilators for weaning predictors. The findings revealed that the CPAP group had the highest success rate, while the SIMV group had the highest failure rate for extubation respectively based on MIP values 17. The current study also observed a significant decline in MIP as the length of the ventilator extended. According to Tanzis G et al., greater MIP values correspond to reduced stay on ventilators in ICU patients and MIP has a predictive value for weaning 18. Spearman's correlation analysis revealed a significant negative correlation between MIP and ventilator stay, indicating that longer duration on the ventilator was associated with reduced MIP values. Implementing this approach of measuring the MIP in ventilated patients is beneficial in assessing muscular strength at the bedside. The advantage of this method is less time-consuming and performed using ventilatory parameters without the use of equipment. Pedro Caruso et al. addressed variations in MIP over time during mechanical ventilation and investigated the association between MIP progression and limb muscle strength, the study revealed that around 40% of patients receiving mechanical ventilation showed a reduction in MIP 19. De Jonghe et al assessed respiratory muscle weakness during an ICU stays in ventilated patients, they identified low maximum inspiratory pressure and maximal expiratory pressure as independent predictors of delayed extubation20.

CONCLUSION

The current study concluded that as the length of stay on a ventilator increases, there is a corresponding decrease in Maximum Inspiratory Pressure (MIP) value. This inverse relationship indicates that a prolonged stay on a ventilator result in lower MIP readings.

Limitations of the current study were the considerations, such as age group, gender differentiation, comorbidities, and specific case conditions were not taken into account in this analysis, but they are likely to affect MIP.

Declaration by Authors

Ethical Approval: Approved

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