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INNOVATIVE USE OF DIAPHRAGMATIC ULTRASOUND TO ENHANCE PREDICTION OF WEANING SUCCESS FROM MECHANICAL VENTILATION IN INTENSIVE CARE UNITS

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ABSTRACT

Background: Mechanical ventilation (MV) is a critical intervention in ICUs, but timely and successful weaning from MV is a challenging process. Accurate prediction of weaning outcomes can significantly improve patient management and resource utilization. Ultrasound measured Diaphragmatic excursion (DE) has emerged as a promising predictor of weaning success. The purpose of this study is to evaluate the effectiveness of DE measurements in predicting weaning outcomes in mechanically ventilated patients. **Methodology:** This analytical cross-sectional study included 30 patients undergoing spontaneous breathing trials (SBT) as part of their weaning process from MV in an ICU setting. DE was measured using ultrasound during the SBT. Independent sample T test was done to know the mean difference between the variables. Receiver Operating Characteristic (ROC) curve analysis was done to evaluate the predictive power of DE. Statistical significance was determined using p-values, with $p < 0.05$ considered significant. **Results:** The mean DE among weaning success patients was 2.5±0.62 cm and of weaning failure patients was 1.5± 0.37 cm. The mean difference of DE between success and failure patients was found to be significant [$p = 0.0008$] .ROC curve analysis yielded an AUC of 0.932 at a cutoff of 1.8cm with sensitivity of 81.8% and specificity of 87.5%, demonstrating good predictive power of DE for weaning outcomes. **Conclusion:** Diaphragmatic excursion measured via ultrasound has a real potential for predicting weaning success in mechanically ventilated patients. Its regular assessment can assist clinical decision-making, potentially improving patient outcomes and ICU efficiency.

Keywords: Diaphragmatic Excursion, Ultrasound, Mechanical Ventilation, Weaning, Intensive Care Units

INTRODUCTION

Weaning from mechanical ventilation is done after the recovery of underlying conditions when the patient has sufficient gas exchange, good neurological and hemodynamic stability. But about 20% patients might need to undergo reintubation.[1] In some cases where the disease is still prevalent, weaning failure might occur if we extubate too early. Delay in weaning increases the inherent risks such as ventilator-associated Pneumonia, Diaphragmatic atrophy.[2]

That's why there is a NEED for some reliable pointers when to exactly extubate to predict weaning success. Accurate prediction of weaning outcomes can significantly impact the patient's prognosis.

Since the movement of diaphragm plays an important role in spontaneous respiration, observation of diaphragm kinetics seems essential.[3] It can be done with Fluoroscopy, CT but they have risks of radiation. It can also be done with Diaphragmatic electromyography, Phrenic nerve stimulation, MRI but these are complex and costly procedures. Therefore, we have selected Ultrasonography for our study as it is radiation free, real-time, repeatable, reliable, non-invasive, fast, easy and an accurate measure.[4]

AIM

To determine the efficacy of diaphragmatic excursion as a predictive tool for successful weaning from mechanical ventilation.

OBJECTIVES

1. To Measure Diaphragmatic Excursion [DE] in Patients Undergoing Spontaneous Breathing Trials.
2. To Correlate DE Measurements with Weaning Outcomes.
3. To Assess the Predictive Cutoff Value of DE In Successful Extubation.

MATERIALS AND METHODOLOGY

- **Study Design**

An analytical cross-sectional study was carried out on 30 patients who were on mechanical ventilator in ICUs of ASRAM Medical College and Hospital, Eluru in coordination with critical care physicians, from April 2023 to June 2024.

- **Inclusion Criteria**

Patients on mechanical ventilator, aged 18-75 years , ready for spontaneous breathing trails.

- **Exclusion Criteria**

We have excluded the cases of Pneumothorax, Pleural effusion, Ascites, Neuromuscular diseases, Thoracic injuries, Suspicious diaphragmatic paralysis [Raised cupola sign in X ray].

1. Initial Ventilator Management

Patients were initially stabilized on mechanical ventilation (either on Control or Support mode) with settings adjusted based on their respiratory needs. Continuous monitoring of vital signs, blood gases, and respiratory parameters is essential to ensure patient stability.

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2. Timing of SBT (Spontaneous Breathing Trials)

Typically, SBTs are not performed in the first 1-2 days as patients need time for stabilization. Once the patient shows clinical signs of improvement and stability (E.g., Improved oxygenation, Reduced need for ventilation), they may be considered for SBT.

3. Conducting The First Spontaneous Breathing Trial [SBT]

- **Criteria For SBT Initiation**:[5]
    - Improvement in underlying condition for which the patient needed mechanical ventilation.
    - Adequate oxygenation (e.g., $FiO_2 \leq 0.4$, PEEP ≤ 5-8 cmH_2O).
    - Patient is hemodynamically stable.
    - Ability to initiate spontaneous breaths.
- **SBT Procedure**:
    - The ventilator is set to a minimal support mode (e.g., PSV with low pressure support) and SBT is performed.
    - Duration of SBT: Typically, 30-120 minutes, depending on the patient's tolerance.

4. Use of Ultrasound for DE Measurement

A 5MHz Curvilinear probe of Esaote Ultrasound [MyLab Sigma model] was used to measure diaphragmatic excursion (DE) during the first and subsequent SBTs and DE values were recorded 20 mins after initiating SBT.

DE is measured as the vertical movement of the diaphragm during inspiration and expiration. A curvilinear probe was placed in the subcostal region parallel to the intercostal space in the mid clavicular line in B mode to locate the diaphragm which looks like a bright hyperechogenic line[6]. Then the range of the diaphragmatic movement was measured using the M-mode with the cursor crossing the diaphragm as perpendicularly as possible (as shown in Fig 4). The maneuver was repeated at least three times, and the average measurements were taken.[7]

5. Criteria For SBT Success and Failure

- **Success Criteria**:
    - Stable vital signs (heart rate, blood pressure).
    - Adequate oxygenation without respiratory distress.
    - Patient remains comfortable and cooperative.
- **Failure Criteria**:
    - Signs of respiratory distress (E.g., increased respiratory rate, use of accessory muscles).
    - Hemodynamic instability (E.g., significant changes in blood pressure or heart rate).
    - Poor oxygenation (e.g., drop in SpO_2).
    - Patient discomfort or agitation.

6. Post-SBT Management

- **Success**:

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    - If the patient successfully completes the SBT with stable clinical status, they may be considered for extubation .
    - Close monitoring for any signs of respiratory distress post-extubation .
- **Failure**:
    - If the patient fails the SBT, the ventilator support is continued at previous settings or adjusted based on clinical needs.
    - Re-evaluation and subsequent SBTs are planned after addressing the causes of failure (E.g., optimizing fluid balance, treating infections)

7. Subsequent SBTs and Weaning

Patients who have failed the initial SBT were re-evaluated daily and subsequent SBTs were conducted once the patient meets the criteria again, with ultrasound DE measurements done 20 mins after initiation of SBT.

Criteria of Weaning[8]

- Positive end-expiratory pressure (PEEP) ≤ 5 cm H2O
- Fraction of inspired oxygen (FiO2) < 0.4
- Respiratory rate (RR) < 35 breaths/ min
- Blood pressure (BP) ≥ 100/60 mmHg without inotropic supports
- PaO2/ FiO2 (P/F ratio) > 250, and
- Rapid shallow breathing index (RSBI)< 105.
- Patients were followed up for 48hrs after extubation
- They received oxygen through venturi mask / face mask / nasal prongs

Even after 48 hours following extubation if the patient has stable vitals, with aabsence of respiratory distress and if he/she is spontaneously breathing then it is considered as a SUCCESSFUL EXTUBATION.

STATISTICS

- This analytical cross-sectional study included 30 patients from undergoing spontaneous breathing trials (SBT) as part of their weaning process from MV in an ICU setting.
- Independent sample T test was done to know the difference between the variables by using SPSS 29 software.
- Receiver Operating Characteristic (ROC) curve analysis was done to evaluate the predictive power of DE by using MD CALC software.
- Statistical significance was determined using p-values, with $p < 0.05$ considered significant.

RESULTS

- This study has almost equal sex distribution as shown in Fig 1 and most of the patients were in the age group of 40-60 years as shown in Fig 2.
- The mean DE among
    - weaning success patients was 2.5±0.62 cm and of
    - weaning failure patients was 1.5±0.37 cm.
- The mean difference of DE between success and failure patients was found to be significant [$p = 0.0008$] as shown in Table 1.
- ROC curve analysis yielded an AUC of 0.932 at a cutoff of 1.8cm as shown in Fig 3.

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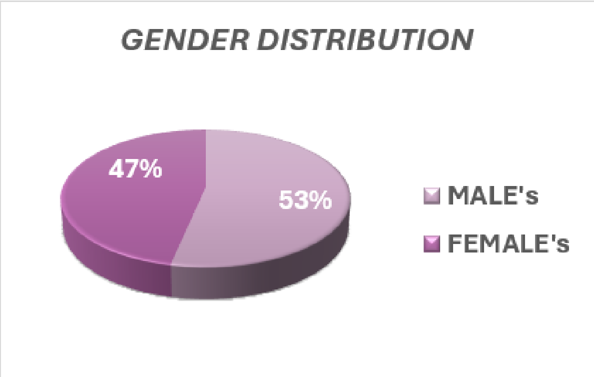
- At this threshold, the sensitivity was found to be 81.8%, meaning that the model correctly identified 81.8% of patients who were successfully weaned.
- The specificity was 87.5%, indicating that 87.5% of patients who failed to wean were correctly classified.
- This demonstrates good predictive power of DE for weaning outcomes.



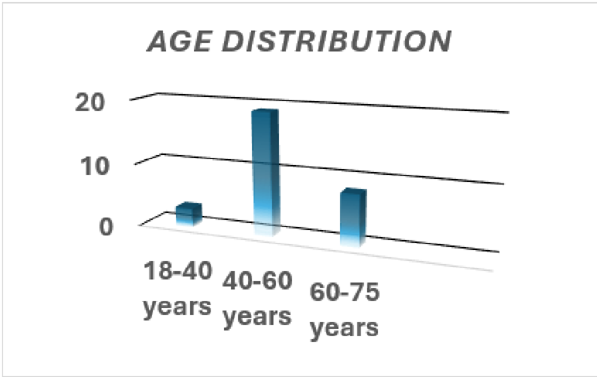


Figure 1: Represents the gender distribution; Figure 2: Represents the age distribution

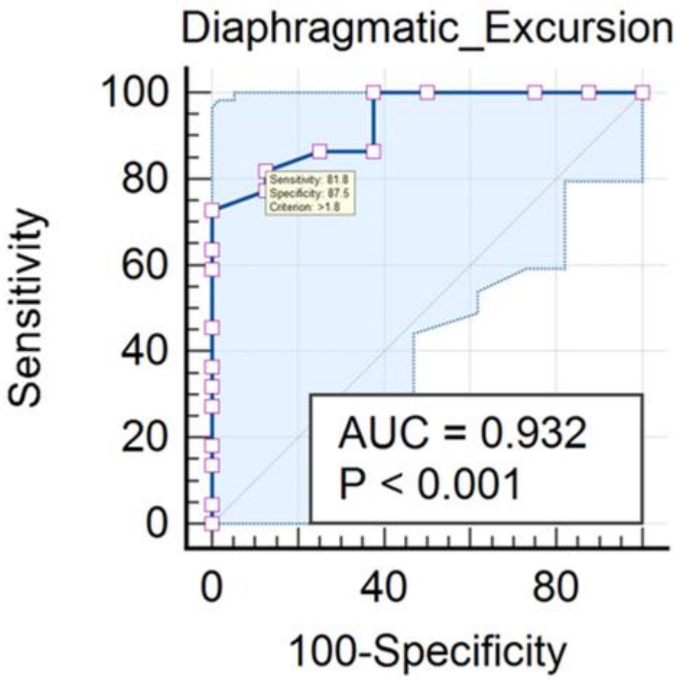


Figure 3: Represents Receiver operator characteristic [ROC] curve analysis

Table 1: Represents the standard deviation and P value

Weaning Outcome	N	Mean DE	Std. Deviation	T -value	P-value
Success	22	2.582	0.6246	4.583	0.0008
Failure	8	1.500	0.3703		

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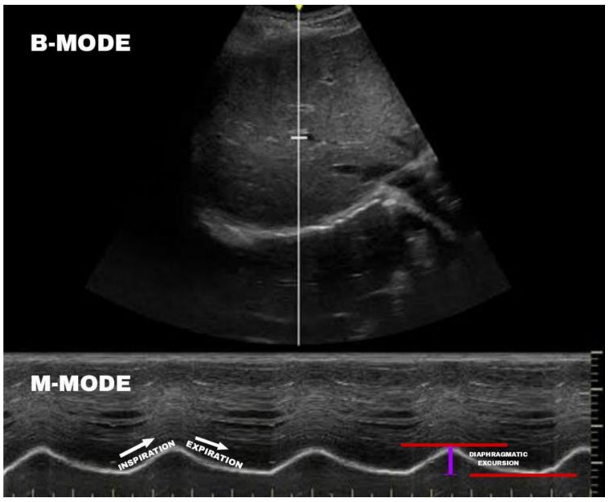

Figure 4: Shows diaphragmatic excursion measure in M mode

DISCUSSION

- The study demonstrates that higher diaphragmatic excursion values are significantly associated with successful weaning from mechanical ventilation with a mean DE of 2.5cm compared to 1.5 cm in those who failed weaning.
- The significant p-value (0.0008) between successful and unsuccessful weaning groups highlights the strong association between higher DE and weaning success, emphasizing the potential of DE as a predictive tool.
- ROC curve analysis yielded an area under the curve (AUC) of 0.932, demonstrating the high predictive power of DE for weaning outcomes, with a sensitivity of 81.8% and specificity of 87.5%.
- Excursion is known to positively correlate with lung inspiratory volumes.[9]
- DE, measured via ultrasound, provides a non-invasive, reliable indicator of diaphragmatic function and patient readiness for extubation.[10]
- Incorporating DE measurements into weaning protocols can reduce weaning failure rates and associated complications, potentially improving patient outcomes.[11]

Future Directions

- As ultrasound technology progresses, it may be possible for clinicians to estimate diaphragmatic measures quickly for weaning using portable, hand-held devices.
- Automated speckle tracking is developed to enhance accuracy and reduce operator variability.
- Further studies with larger sample sizes are required to potentially establish DE as a standard criterion in weaning protocols worldwide.
- Some devices like RESPINOR DXT are already under development which gives us real time diaphragmatic excursion measures.[12]

CONCLUSION

Diaphragmatic excursion measured via ultrasound has a real potential for predicting successful ventilator weaning. Its regular assessment can enhance clinical decision-making, potentially improving patient outcomes .

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