Diaphragm ultrasound: A predictor of extubation in head injury patients

Anusha Rao Uchila1, Aafaque Ahmad Anjum2, Naresh Tirpude3

1Senior Resident, Department of Neuroanaesthesia and Neuro Critical Care, NIMHANS, Bengaluru, Karnataka, 2Senior Resident, Department of Critical Care Medicine, DrNB Critical Care Medicine, Jehangir Hospital, Pune, 3Consultant Anesthesiologist, Ex-Head, Department of Anesthesiology, Government Medical College and Hospital, Nagpur, Maharashtra, India

ABSTRACT

Background: Timing is critical when determining if a patient can be successfully extubated. The criteria for obtaining the optimal time for extubation are bare minimum and subject to variability. There are not many studies that are done to use diaphragm function or diaphragm thickness (Tdi) to have any role in extubation outcome as success or failure. Aims and Objectives: The aims and objectives of the study are to apply diaphragmatic ultrasound as a predictor of extubation to reduce morbidity and mortality in these patients. Materials and Methods: This study was conducted as a prospective single-blind study among patients admitted in post-anesthesia care unit and surgical intensive care unit, Department of Anesthesiology at Trauma care Centre during the study period of June 2019–November 2021. The ultrasonographer was informed of the intensivist’s decision to start weaning. Tdi is measured at end expiration and end inspiration. The percent change in Tdi between end expiration and end inspiration (ΔTdi%) was calculated as (Tdi end inspiration−Tdi end expiration/Tdi end expiration) ×100. Results: Mean age was 46.2±15.2 years, ranging from 18 to 66 years. Tdi was above 30 in 64% cases, whereas Tdi% at end of expiration was above 0.17 cm in 62% cases. Weaning was successful in 78% cases whereas weaning failed in 22% cases. Weaning success rate was significantly associated with higher Tdi at end expiration (≥0.17 cm) (P<0.05). Conclusions: Timely weaning off is very important. Delayed weaning may lead to further infection and complications. Diaphragmatic ultrasound plays a vital role in extubating the patient. Ultrasound-guided Tdi and diaphragm motion can be used as a predictor for timely extubation. Diaphragmatic thickness reflects the strength of diaphragm and hence would help us to estimate a successful extubation.

Key words: Diaphragmatic ultrasound; Diaphragmatic thickness; Inspiration; Expiration; Weaning; Extubation

INTRODUCTION

General anesthesia with endotracheal intubation and intermittent positive pressure ventilation is one of the most frequently performed practices in the field of anesthesia. Endotracheal intubation (insertion of endotracheal tube [ETT] into the trachea) and extubation (translaryngeal removal of ETT) are a part of general anesthesia and both are associated with hemodynamic responses. Endotracheal extubation is associated with hemodynamic changes due to reflex sympathetic discharge and cough caused by pharyngeal and laryngeal stimulation. Increase in sympathetic-adrenal activity results in tachycardia, hypertension, and arrhythmias. This increase in heart rate and blood pressure are usually for a short period of time and unpredictable. This response is more detrimental to patients with systemic hypertension, coronary artery disease, or cerebrovascular diseases. Therefore, hemodynamic response to extubation has always been a challenge to anesthesiologist and intensivist as weaning is an important concern in intensive care unit (ICU). Thus, it is important to extubate at the right time to prevent failed weaning, increased hospital stay, and mortality. Patients who have a history of difficult weaning and very long intubation period have increased readmission rates in ICU.
Timing is critical when determining if a patient can be successfully extubated. Premature discontinuation of ventilator may cause cardiovascular and respiratory distress leading to \( CO_2 \) retention and hypoxemia with up to 25% of patients requiring re-intubation and reinstatement of ventilatory support.\(^3,4\) Similarly, unnecessary delay in weaning from mechanical ventilation can also be deleterious. Complications such as ventilator-associated pneumonia and ventilator-induced diaphragm atrophy can be seen even with short periods of mechanical ventilation thereby prolonging the need for mechanical ventilation.\(^5\)

Criteria available for determining the optimal timing of extubation are limited. Subjective decisions are often wrong. Stroetz and Hubmayr\(^6\) found that clinical criteria to extubate were often incorrect with the decision to extubate being biased toward ventilator dependency. Measures such as breathing frequency (respiratory rate), minute ventilation, and negative inspiratory force have done little to improve the timing of successful extubation.\(^7,8\) A more recent parameter, i.e., rapid shallow breathing index that can be defined as ratio of respiratory rate to tidal volume (\( V_t \)) provides an idea to time the extubation with spontaneous breathing trials but its value is limited when used to predict successful extubation in pressure support trials.\(^10,11\)

Direct measures of diaphragm function for extubation have not been extensively evaluated. Motion of the diaphragm dome has been assessed using M-mode ultrasound\(^12,13\) and found to be useful in predicting extubation outcomes;\(^14,15\) however, imaging the dome does not directly visualize the diaphragm muscle itself. Factors such as breath size, impedance of neighboring structures, abdominal muscle compliance, rib cage, abdominal muscle activity, and ascites affect regional and global diaphragm motion of the tendinous dome of the diaphragm.\(^16\) This drawback can be overcome by ultrasonography of the diaphragm in the zone of apposition (ZAP) as this approach allows for direct visualization of the diaphragm muscle and assessment of its activity with minimal impedance.\(^17-20\) We thus conducted this study to apply the above data to conclude that the best possible approach was to manage these cases to reduce morbidity and mortality in these patients.

**Aims and objectives**

To apply diaphragmatic ultrasound as a predictor of extubation in order to reduce morbidity and mortality in these patients.

**MATERIALS AND METHODS**

This study is conducted as a prospective single-blind study among patients admitted in post-anesthesia care unit (PACU) and surgical ICU (SICU), Department of Anesthesiology at Trauma care Centre during the study period of June 2019–November 2021. All the patients with a fraction of inspired oxygen of <50%, hemodynamically stable patients in the absence of vasopressors, alert patients, patients with no specific disease process other than the presence of respiratory failure, patients on ventilator support with tracheal intubation, and head injury patients who are on ventilator support at PACU and SICU were included in our study. Pregnant women on ventilator support, patients whose age is <18 years, and patients with surgical dressings over the right lower rib cage which can preclude ultrasound examination were excluded from this study.

**Sample size estimation**

Sample size was determined considering sensitivity of Tdi% as the main outcome measure. In a study conducted by DiNino et al.,\(^21\) sensitivity of Tdi% was 87%. Taking the absolute precision of 10% and desired confidence level of 95%, using the formula \( n = \frac{z^2pq}{d^2} \), the sample size was estimated to be 43. However, we included a total of 50 patients.

Approval from the Institutional Ethics Committee was sought. Permission was taken from the Head of the Department of Anesthesiology. The purpose of the study was explained to the study subjects/relatives. Informed written consent in local language was taken before enrollment for study. Subjects were recruited 6–24 h before the first weaning trial.

The sonographer was notified of the intensivist’s decision to start weaning. Diaphragm thickness (Tdi) is measured using a 7–10 MHz linear ultrasound probe set in B mode (LOGIQ Book, GE Healthcare, Waukesha, Wisconsin, USA). The right hemidiaphragm was imaged at the ZAP and rib cage in the mid-axillary line between the 8\(^{th}\) and 10\(^{th}\) intercostal spaces as previously described. All patients were studied with the head of bed elevated between 20\(^{\circ}\) and 40\(^{\circ}\).

The Tdi was measured at end expiration and end inspiration. A flowmeter (Hamilton Flow Sensor H) was placed in the ventilator circuit and flow was recorded simultaneously with ultrasound images to confirm end expiration and end inspiration on the ultrasound images. The percent change in Tdi between end expiration and end inspiration (\( \Delta \)Tdi%) is calculated as (Tdi end inspiration – Tdi end expiration/ Tdi end expiration) \times 100.

The intensivist was blinded to the ultrasound result and the research team had no role in deciding about extubating the patient. Tdi at end expiration has been shown to reflect diaphragm strength in healthy individuals. A sufficiently strong diaphragm would promote successful extubation, therefore, we evaluated if Tdi end expiration itself can be useful for determining extubation outcome. Since the
diaphragm shortening contributes to Vt, we combined ΔTdi% with parameters such as Vt and respiratory rate (f).

**Statistical analysis**

Data were entered in Microsoft Excel sheet and coded. Analysis of data was done using a statistical software Stata version 10.1 (2011). Descriptive statistics were used to summarize quantitative variables with mean and standard deviation. Frequency and percentage were used to summarize qualitative or categorical variables. Chi-square test was applied for categorical data. P<0.05 was considered statistically significant.

**RESULTS**

In the present study, a total of 50 cases fulfilling the inclusion criteria were enrolled. The mean age was 46.2±15.2 years, ranging from 18 to 66 years. Majority of patients were to 40 to 60 years of age (40%) and about 70% of patients with head injury were males. Mean weight and height were 65.08±11.2 kg and 162.4±8.7 cm, respectively. About 40% patients with head injury had extradural hemorrhage and 26% patients had subdural hemorrhage. Mean duration of ventilation in our study population was 23.24±9.9 h, and majority of patients received ventilation for <24 h (62%) (Table 1).

Table 2 represents the mean weaning index among the study population. Mean thickening fraction was 29.18±9.09. Mean Tdi at end of inspiration and expiration was 1.03±0.27 and 0.80±0.39, respectively. Maximum inspiratory flow was 0.92±0.45.

In the present study, Tdi was above 30 in 64% cases, whereas Tdi/f and Tdi×Vt were >0.008 and >80 in 60% and 62% cases, respectively. Tdi% at end of expiration was above 0.17 cm in 62% cases (Table 3).

Figure 1 represents the final outcome. Out of 50 cases, weaning was successful in 78% cases whereas weaning failed in 22% cases.

In the present study, weaning success rate was significantly associated with higher Tdi at end expiration (≥0.17 cm). However, weaning failure was noted in 8 out of 19 cases with Tdi% at end expiration of <0.17 cm (P<0.05) (Table 4).

**DISCUSSION**

Following endotracheal intubation, the timing of extubation is critical for determining successful weaning as premature weaning as well as delay in weaning has been associated with adverse consequences. Various methods have been used for determining the optimal time of extubation with their own advantages and disadvantages. Recently, the role of ultrasound-guided measurement of diaphragm function has been suggested. We aimed to assess the role of diaphragmatic ultrasound for the assessment of weaning index and its association with weaning outcome. Mean age was 46.2±15.2 years and the majority of patients with head injury were above 40 years of age. We observed
male predominance in our study, with male: female ratio of 2.33:1. Our study findings were concordant with the findings of Mowafy and Abdelgalel, in which the mean age of patients with head injury was 35.77±9.56 years, with 66% patients being male. Males due to their outdoor activities are at higher risk of head injuries due to road traffic accidents. The mean weight of patients in this study was 65.08±11.17 kg whereas mean height was 162.4±8.7 cm. Similarly, mean weight and height of patients in study of Mowafy and Abdelgalel were 83.18±9.1 kg and 165.75±6.44 cm, respectively.

On weaning index, the mean diaphragmatic thickening fraction was 29.18±9.09, and 64% patients had Tdi% above 30. However, Tdi at end of inspiration was 1.03±0.27 cm whereas Tdi at end of expiration was 0.8±0.39 cm and maximum inspiratory pressure was 0.92±0.45. About 62% of patients in our study had Tdi at end of inspiration above 0.17 cm. Tdi/f ratio and Tdi×Vt ratio were above 0.008 and 80 in 60% and 62% cases, respectively.

A study by Ferrari et al., found that a diaphragm thickening fraction (DTF) of 36% predicted successful weaning in patients requiring long-term ventilator support. Farghaly and Hasan have shown that DTF% ≥34.2% was associated with successful extubation. In the present study, weaning success rate was 78% and only 22% failed. Our study findings were similar to the findings of Mowafy and Abdelgalel and colleagues demonstrated that 73.6% of patients experienced successful weaning, while 26.4% encountered failure. Both early and delayed weaning strategies are associated with numerous complications, including higher mortality rates and prolonged stays in the intensive care unit (ICU). The outcome of weaning can be influenced by various factors such as hemodynamic stability, muscle weakness, electrolyte imbalances, pulmonary dysfunction, and the patient's ability to effectively cough and clear endotracheal secretions. Study by Xue et al., showed that 39 had weaning success and 11 had failure. Among the 50 patients of this study, the rate of successful weaning is 78% (39/50) and the rate of failed weaning is 22% (11/50) which is much lower than the previous study (30%).

**Limitations of the study**

The study has been done on patients who were extubated within 24 h (62% of patients). The diaphragm function is affected in patients who require prolonged ventilation. Hence, this study cannot be extrapolated in patients with prolonged mechanical ventilation.

**CONCLUSION**

This study shows that timely weaning is very important. Delayed weaning may lead to further infection and complications. Diaphragmatic ultrasound thus plays a vital role in extubating the patient. Diaphragmatic thickness and motion detected by ultrasound can be used as a predictor for timely extubation. Diaphragmatic thickness reflects the strength of diaphragm and hence would help us to predict a successful extubation.

**ACKNOWLEDGMENT**

Nil.

**REFERENCES**

https://doi.org/10.4037/ajcc2010273

https://doi.org/10.1164/ajccrm.152.3.7663780

https://doi.org/10.1186/s12890-019-1034-0

https://doi.org/10.1007/s00134-004-2230-8

https://doi.org/10.1056/NEJM199105233242101

https://doi.org/10.1378/chest.105.2.540

https://doi.org/10.1016/s0009-9260(05)82897-3

https://doi.org/10.7863/jum.2001.20.6.597

https://doi.org/10.1378/chest.126.1.179

https://doi.org/10.1097/CCM.0b013e3182266408

https://doi.org/10.2214/ajr.101.4.961

https://doi.org/10.1164/ajccrm.155.5.9154859

https://doi.org/10.1378/chest.07-2200

https://doi.org/10.1056/NEJMra1007236

https://doi.org/10.1164/ajccrm.155.4.9105075

https://doi.org/10.1164/rccm.200706-893OC

https://doi.org/10.1136/thoraxjnl-2013-204111

https://doi.org/10.1186/2036-7902-6-8

https://doi.org/10.1016/j.aucc.2016.03.004

24. Thille AW. Simple, difficult, or prolonged weaning: the most important factor is the success or failure of the first weaning trial. Respir Care. 2011;56(5):716-717.
https://doi.org/10.4187/respcare.01317

Authors’ Contributions:
ARU- Definition of intellectual content, prepared first draft of manuscript, implementation of study protocol, data collection, data analysis, manuscript preparation, and submission of article; AAA- Concept, design, clinical protocol, manuscript preparation, editing, and manuscript revision; NT- Design of study, statistical analysis and interpretation, review manuscript.

Work attributed to:
Department of Anesthesiology, Government Medical College and Trauma care Centre, Nagpur, Maharashtra, India.

Orcid ID:
Dr. Anusha Rao Uchila - https://orcid.org/0009-0000-2920-2413
Dr. Aafaque Ahmad Anjum - https://orcid.org/0000-0003-3542-8229
Dr. Naresh Tirpude - https://orcid.org/0000-0003-7081-1394

Source of Support: Nil, Conflicts of Interest: None declared.