ORIGINAL ARTICLE
ASIAN JOURNAL OF MEDICAL SCIENCES

Diaphragm ultrasound: A predictor of extubation in head injury patients

Anusha Rao Uchila[1], Aafaque Ahmad Anjum[2], Naresh Tirpude[3]

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

Submission: 03-02-2024 Revision: 29-03-2024 Publication: 01-05-2024

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) $\times 100$. **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

Access this article online

Website:

http://nepjol.info/index.php/AJMS

DOI: 10.3126/ajms.v15i5.62510

E-ISSN: 2091-0576

P-ISSN: 2467-9100

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.[1] 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.[2]

Address for Correspondence:
Dr. Anusha Rao Uchila, Senior Resident, Department of Neuroanaesthesia and Neuro Critical Care, NIMHANS, Bengaluru, Karnataka, India. **Mobile:** +91-9663170112, **E-mail:** anushauchila@gmail.com

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 reinstitution 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.[7-9] A more recent parameter, i.e., rapid shallow breathing index that can be defined as ratio of respiratory rate to tidal volume (Vt) 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 $n=z^2pq/d^2$, 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 8th and 10th intercostal spaces as previously described. All patients were studied with the head of bed elevated between 20° and 40°.

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 (ΔTdi%) is calculated as (Tdi end inspiration–Tdi end expiration/ Tdi end expiration) ×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).

Table 1: Distribution of patients according to baseline variables

Baseline variables	Frequency (n=50)	Percentage
Age (years)		
18–25	6	12
25–40	11	22
40–60	20	40
>60	13	26
Sex		
Male	35	70
Female	15	30
Anthropometry		
Weight	65.08±11.2 kg	
Height	162.4±8.7 cm	
Diagnosis		
EDH	20	40
SDH	13	26
Hemorrhagic contusion	6	12
Cerebral edema	11	22
Duration of ventilator		
<24 h	31	62
>24 h	19	38

EDH: Extradural hemorrhage, SDH: Subdural hemorrhage

Table 2: Mean weaning index in study population

Index	Mean	Standard deviation
Diaphragmatic thickening fraction	29.18	9.09
Diaphragm thickness at end of inspiration	1.03	0.27
Diaphragm thickness at end of expiration	0.80	0.39
Maximum inspiratory pressure	0.92	0.45

Table 3: Distribution of diaphragm thickness and its fraction with breathing parameters such as tidal volume (Vt) and respiratory rate (f)

Tdi	Frequency (n=50)	Percentage
Tdi%		
>30	32	64
<30	18	36
Tdi%/f		
>0.008	30	60
<0.008	20	40
Tdi%/VT		
>80	31	62
<80	19	38
Tdi% at end expiration		
>0.17 cm	31	62
<0.17 cm	19	38

Tdi: Diaphragm thickness

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.[3,5] Various methods have been used for determining the optimal time of extubation with their own advantages and disadvantages.[7-9] 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

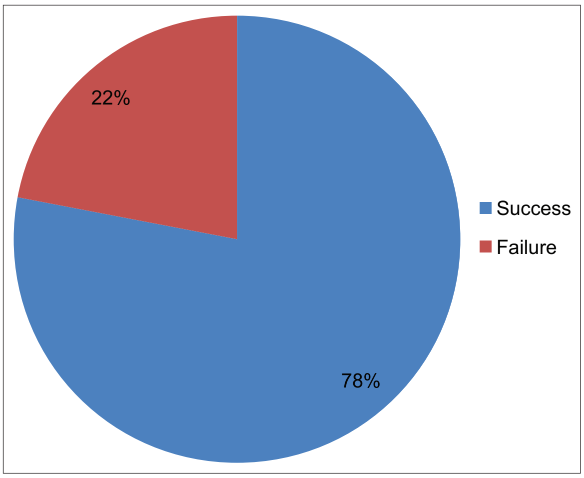

Figure 1: Distribution according to weaning outcome

Table 4: Association of weaning outcome with Tdi at end expiration

Tdi at end expiration	Success	Failure	Total
≥0.17 cm	28	3	31
<0.17 cm	11	8	19
P-value		0.001	

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,[1] 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.[1]

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.[22] Farghaly and Hasan have shown that DTF% ≥34.2% was associated with successful extubation.[23] 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.[1,3,5] Study by Xue et al., showed that 39 had weaning success and 11 had failure.[7] 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%).[24]

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

1. Mowafy SM and Abdelgalel EF. Diaphragmatic rapid shallow breathing index for predicting weaning outcome from mechanical ventilation: Comparison with traditional rapid shallow breathing index. Egypt J Anaesth. 2018;35(1):9-17.
   https://doi.org/10.1016/j.egja.2018.10.003
2. Banerjee A and Mehrotra G. Comparison of lung ultrasound-based weaning indices with rapid shallow breathing index: Are they helpful? Indian J Crit Care Med. 2018;22(6):435-440.
   https://doi.org/10.4103/ijccm.IJCCM_331_17
3. Epstein SK, Ciubotaru RL and Wong JB. Effect of failed extubation on the outcome of mechanical ventilation. Chest. 1997;112(1):186-192.
   https://doi.org/10.1378/chest.112.1.186
4. Kulkarni AP and Agarwal V. Extubation failure in intensive care unit: Predictors and management. Indian J Crit Care Med. 2008;12(1):1-9.
   https://doi.org/10.4103/0972-5229.40942
5. Burns SM, Fisher C, Tribble SS, Lewis R, Merrel P, Conaway MR,

et al. Multifactor clinical score and outcome of mechanical ventilation weaning trials: Burns Wean Assessment Program. Am J Crit Care. 2010;19(5):431-439.

https://doi.org/10.4037/ajcc2010273

6. Stroetz RW and Hubmayr RD. Tidal volume maintenance during weaning with pressure support. Am J Respir Crit Care Med. 1995;152(3):1034-1040.

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

7. Xue Y, Zhang Z, Sheng CQ, Li YM and Jia FY. The predictive value of diaphragm ultrasound for weaning outcomes in critically ill children. BMC Pulm Med. 2019;19(1):1-8.

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

8. Conti G, Montini L, Pennisi MA, Cavaliere F, Arcangeli A, Bocci MG, et al. A prospective, blinded evaluation of indexes proposed to predict weaning from mechanical ventilation. Intensive Care Med. 2004;30(5):830-836.

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

9. Yang KL and Tobin MJ. A prospective study of indexes predicting the outcome of trials of weaning from mechanical ventilation. N Engl J Med. 1991;324(21):1445-1450.

   https://doi.org/10.1056/NEJM199105233242101

10. Lee KH, Hui KP, Chan TB, Tan WC and Lim TK. Rapid shallow breathing (frequency-tidal volume ratio) did not predict extubation outcome. Chest. 1994;105(2):540-543.

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

11. Houston JG, Fleet M, Cowan MD and McMillan NC. Comparison of ultrasound with fluoroscopy in the assessment of suspected hemidiaphragmatic movement abnormality. Clin Radiol. 1995;50(2):95-98.

    https://doi.org/10.1016/s0009-9260(05)82987-3

12. Gerscovich EO, Cronan M, McGahan JP, Jain K, Jones CD and McDonald C. Ultrasonographic evaluation of diaphragmatic motion. J Ultrasound Med. 2001;20(6):597-604.

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

13. Jiang JR, Tsai TH, Jerng JS, Yu CJ, Wu HD and Yang PC. Ultrasonographic evaluation of liver/spleen movements and extubation outcome. Chest. 2004;126(1):179-185.

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

14. Kim WY, Suh HJ, Hong SB, Koh Y and Lim CM. Diaphragm dysfunction assessed by ultrasonography: Influence on weaning from mechanical ventilation. Crit Care Med. 2011;39(12):2627-2630.

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

15. Miller WT and Talman EA. Subphrenic abscess. Am J Roentgenol Radium Ther Nucl Med. 1967;101(4):961-969.

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

16. Gottesman E and McCool FD. Ultrasound evaluation of the paralyzed diaphragm. Am J Respir Crit Care Med. 1997;155:1570-1574.

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

17. Summerhill EM, El-Sameed YA, Glidden TJ and McCool FD. Monitoring recovery from diaphragm paralysis with ultrasound. Chest. 2008;133(3):737-743.

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

18. McCool FD and Tzelepis GE. Dysfunction of the diaphragm. N Engl J Med. 2012;366(10):932-942.

    https://doi.org/10.1056/NEJMra1007236

19. McCool FD, Conomos P, Benditt JO, Cohn D, Sherman CB and Hoppin FG Jr. Maximal inspiratory pressures and dimensions of the diaphragm. Am J Respir Crit Care Med. 1997;155(4):1329-1334.

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

20. Esteban A, Ferguson ND, Meade MO, Frutos-Vivar F, Apezteguia C, Brochard L, et al. Evolution of mechanical ventilation in response to clinical research. Am J Respir Crit Care Med. 2008;177(2):170-177.

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

21. DiNino E, Gartman EJ, Sethi JM and McCool FD. Diaphragm ultrasound as a predictor of successful extubation from mechanical ventilation. Thorax. 2014;69(5):431-435.

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

22. Ferrari G, De Filippi G, Elia F, Panero F, Volpicelli G and Aprà F. Diaphragm ultrasound as a new index of discontinuation from mechanical ventilation. Crit Ultrasound J. 2014;6(1):1-6.

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

23. Farghaly S and Hasan AA. Diaphragm ultrasound as a new method to predict extubation outcome in mechanically ventilated patients. Aust Crit Care. 2017;30(1):37-43.

    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/0009-0003-7081-1394

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