



Original Article

Effectiveness of Ultrasound Guided Diaphragm Excursion Vs Diaphragm Thickening Fraction as A Guidance for Extubating Patients Under General Anaesthesia

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ABSTRACT

Background: Extubation, like intubation, is a critical component of airway management for anaesthesiologists. Diaphragmatic function plays a vital role in predicting extubation success, as diaphragm dysfunction can lead to postoperative ventilation, delayed weaning, and respiratory complications. Ultrasound, being a non-invasive, radiation-free, and readily available tool, allows real-time assessment of diaphragm movement and thickness. This study compares the effectiveness of Ultrasound-Guided Diaphragm Excursion (DE) and Diaphragm Thickening Fraction (DTF) in predicting successful extubation in patients under general anaesthesia.

Methods: A prospective randomised control study was conducted at Coimbatore Medical College Hospital from March 2022 to December 2024, after institutional ethical committee approval (Ref. No. 053/2023). Sixty ASA I–II patients aged 20–60 years undergoing elective surgery under general anaesthesia were enrolled and randomly divided into two groups: Group A (n=30) – Diaphragm Excursion (DE) measured, and Group B (n=30) – Diaphragm Thickening Fraction (DTF) measured. Standard anaesthetic techniques were followed. Diaphragm parameters were recorded at baseline, before extubation (T0), and at 10, 20, and 30 minutes after extubation using ultrasound. Data were analysed using t-test, Chi-square test, and Repeated Measures ANOVA, with $p < 0.05$ considered statistically significant.

Results: The mean age (41.2 ± 9.4 years) and gender distribution were comparable between groups. Hemodynamic parameters showed no significant difference. In the DE group, mean baseline excursion was 2.1 ± 0.25 cm, showing a statistically significant increase over time ($p < 0.0001$). In the DTF group, mean baseline DTF was $37.2 \pm 8.8\%$, with no significant variation over time. Diaphragm excursion values showed better correlation with extubation success compared to DTF.

Conclusion: Ultrasound-guided diaphragm assessment is a reliable tool for predicting extubation readiness. Among the two parameters studied, Diaphragm Excursion proved to be a more effective and consistent predictor of successful extubation than Diaphragm Thickening Fraction. Incorporating diaphragm ultrasound as an adjunct to clinical criteria can enhance the safety and accuracy of extubation decisions.

Keywords: Diaphragm excursion, diaphragm thickening fraction, ultrasound, extubation.

INTRODUCTION

How intubation plays an important part in airway management; similarly, extubation is an art and a main component of airway management for anaesthesiologists. The main muscle of respiration is the diaphragm. It is said that 60 to 70% of

the work done in respiration is by the diaphragm. Diaphragm dysfunction leads to postoperative mechanical ventilation, difficulty in weaning, prolonged hospital stays, and associated complications. If residual blockade is present postoperatively, it can lead to respiratory complications, including airway obstruction, hypoxia, reintubation, and a prolonged stay in the PACU. Therefore, postoperative residual curarisation is a concern before extubation. Ultrasound has emerged as a cheap, widely available, radiation-free, bedside tool for assessing diaphragmatic movements such as amplitude, force, velocity of contraction, specific motion patterns, and changes in diaphragm thickness during inspiration and expiration. The main diaphragm parameters we observe are Diaphragmatic excursion (DE) and Diaphragm thickening fraction (DTF). These parameters reflect inspiratory nasal pressure and transdiaphragmatic pressure during spontaneous respiration. Although many invasive methods exist to evaluate diaphragm function, diaphragm ultrasound plays a crucial role in direct visualisation and assessment. The purpose of this study is to assess diaphragm parameters intraoperatively in the operating theatre to support successful extubation as a non-invasive approach, through direct visualisation of diaphragm movements and the detection of abnormalities. It can also serve as an additional criterion, along with other extubation parameters, in the future. The main goal of this study is to determine whether the degree of diaphragmatic excursion and diaphragm thickening fraction measured by ultrasound can predict extubation success on the table.

MATERIAL & METHODS

After obtaining proper ethical committee approval from our institution [053/2023], this Prospective randomised control study was carried out in the Department of Anaesthesiology at Coimbatore Medical College Hospital, from March 2022 to December 2024.

INCLUSION CRITERIA:

- 1) ASA 1 and 2,
- 2) Mallamapatti 1 and 2,
- 3) Aged between 20 and 60,
- 4) Willing to give informed written consent,
- 5) 5. Elective surgeries.

EXCLUSION CRITERIA:

- 1) Patient Refusal ,
- 2) ASA 3 or more,
- 3) Mallampatti 3 or 4. Anticipating difficult intubation,
- 4) Patients with COPD/TB/Other lung pathologies, with Electrolyte abnormalities
- 5) Patients with cardiac, Hepatic, and Renal disorders.
- 6) Patients with neuromuscular diseases
- 7) Patients with coagulopathy.

After obtaining informed written Consent, we included 60 patients aged between 20 and 60 years who were scheduled for elective surgery under general anaesthesia. Sample size was calculated using the following formula: $N = 2(z\alpha + z\beta)^2 (\delta/\sigma)^2$ with 90% confidence interval and 0.05 significance. After getting the informed consent, 60 patients were divided into two groups of 30 each, Group A- DE is seen and Group B- DTF is seen, each patient was randomly allocated using a variable lock randomisation method 1:1 to distribute the patients equally to each group.

TECHNIQUE: The anaesthetic technique is standardised for all patients. Premedication was done with an injection. glycopyrrolate 10 mcg/kg and inj. midazolam 0.05mg/kg and inj. fentanyl 1mcg/kg. Before induction of anaesthesia, the baseline Diaphragm Excursion and Diaphragm thickening values are measured using ultrasound. Then Induction was done using injection. propofol 2 mg/kg and injection. Atracurium 0.5 mg/kg and maintained with sevoflurane 1-2%, 33% N2O and 66% O2. Patients were monitored with Standard ASA monitors. In Group A, diaphragm excursion was measured as follows -

- Baseline value
- Just before. extubation (t0)
- 10 mins after extubation (T10)
- 20 mins after extubation (T20)
- 30 mins after extubation (T30). [After the surgery is over, we look for the clinical criteria for extubation. Once the clinical criteria for extubation were met, the patient was reversed, and then the Diaphragm excursion was seen]. In the supine position, a 2 to 5 MHZ ultrasound probe was placed over one of the lower intercostal spaces in the Right anterior Axillary line for the right diaphragm and the liver serving as an acoustic window. 2D mode was used to view to right diaphragm. First 2D mode is used, followed by M Mode to directly visualise the movement of diaphragm along the selected line. A complete breathing cycle should be included in one image. In the M-mode, the lowest point represents the end of inspiration and the highest point represents the end of expiration. The excursion amplitude was measured on the vertical axis tracing for the lowest point to the point of maximum height of inspiration.

DIAPHRAGMATIC EXCURSION DURING EVENTS OF	NORMAL VALUES
1. Quiet breathing	1.78cm to 2.86cm
2. Deep breathing	4.28cm to 6.8cm
3. During sniffing	2.01cm to 3.93cm

In group2 Patients, diaphragm thickening fraction was measured as follows.

- Baseline value
- Just before extubation (T0)
- 10 mins after extubation (T10)
- 20 mins after extubation (T20)
- 30 mins after extubation (T30). , Diaphragm thickness during inspiration and expiration is measured and finally the Diaphragm thickening fraction is calculated using the formula. The probe was placed below the Right costal margin near the anterior or the mid-axillary line at the eighth or the ninth intercostal space. There appear to be three-layered structures, namely

- o The diaphragmatic pleura
- o The peritoneal fascia
- o The diaphragm is between them. The intercostal space that provides the best visualisation of the diaphragm was chosen, and the probe was positioned in that intercostal space parallel to it. Once the perfect view is obtained, the picture is frozen and the thickness measured. The diaphragm thickness was measured as the distance from the inner edge of the pleural fascia to the inner edge of the peritoneal fascia. They are measured at the end of expiration and at the end of inspiration during quiet breathing. The percentage of change it (tdi%) between end-expiration and end-inspiration was calculated as follows: $DTF = \frac{[Thickness\ at\ end\ inspiration - Thickness\ at\ end\ expiration]}{Thickness\ at\ the\ end\ expiration} \times 100$.

The normal diaphragmatic thickening fraction during quiet breathing ranged from 24.5% to 53.2% • In deep breathing, it is around 11%. These values were compared with the individual baseline parameter, and we see how it varies. If the values seem to be increasing from the baseline parameter, it means the patient is taking adequate breath with no residual block and good Diaphragm function. The patient is ready for extubation and doesn't need postop ventilation.



Fig 1- Probe In Rt Anterior Axillary Line.



Fig 2-Visualisation Of Diaphragm In B Mode With Liver As An Acoustic Window.

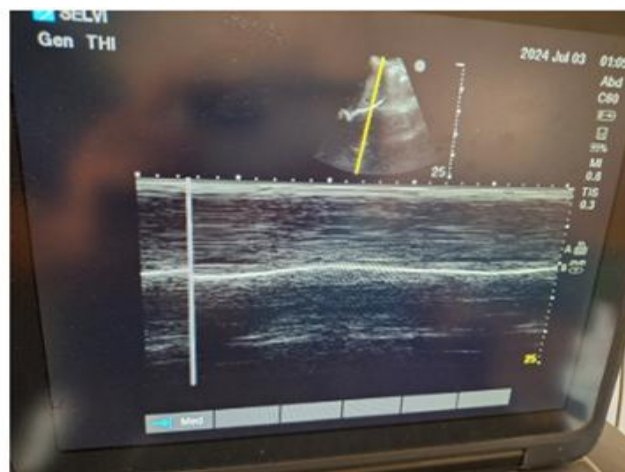


Fig 3- Visualisation Of Diaphragm In M Mode.

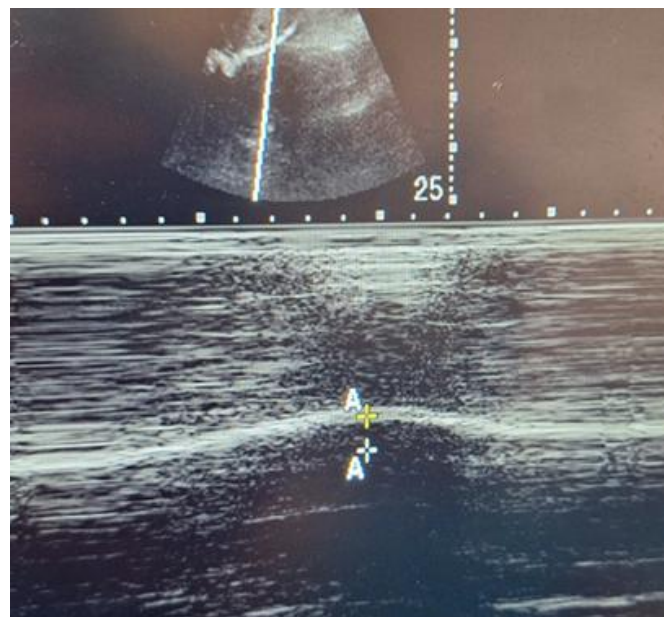


Fig 4-Excursion Amplitude Measured From Baseline To Maximum Height Of Inspiration.



Fig 5-. Probe Is Placed In Eighth Or Ninth Intercostal Space In Mid Axillary Line.



Fig 6-. Diaphragm Thickness Measured At Inspiration



Fig7-Diaphragm Thickness Measured At Expiration.

STATISTICAL ANALYSIS:

All figures are expressed in numbers and percentages. Descriptive statistics are presented as mean $\pm$ 1SD. Appropriate graphs were drawn. Error Bar charts were drawn for the mean of variables that were repeatedly measured (HR, SBP, DBP, SPO2) along with their 95% confidence intervals. Mean values were compared using an Independent t test. Chi-Square test was used to compare two categorical variables. A General Linear Model with Repeated Measures analysis (as the outcomes were measured repeatedly over time) was employed to observe rate of change over time and between the two USG monitored groups (DE and DTF). A p-value less than 0.05 is considered statistically significant.

RESULTS

Presented are the results of the two USG-guided extubating methods – Diaphragm Excursion (n=30) and Diaphragm Thickening Fraction (n=30). Age and Gender Overall, the patients were aged 41.2 ± 9.4 years, ranging from 22 to 58 years.

Figure1 . Age Distribution of the Patients by Extubating Method

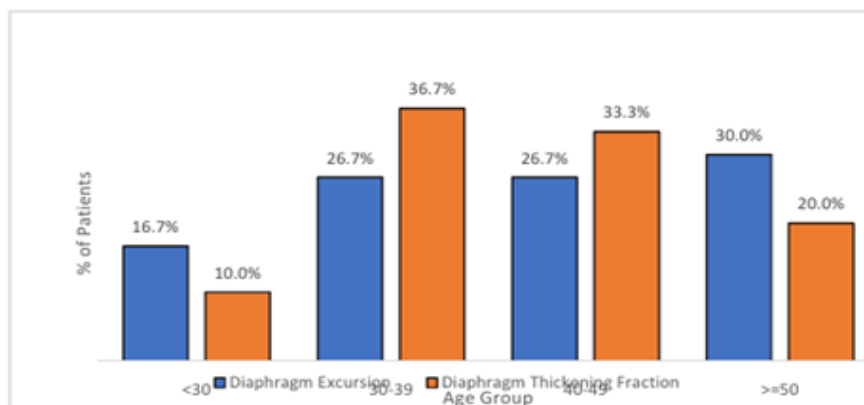
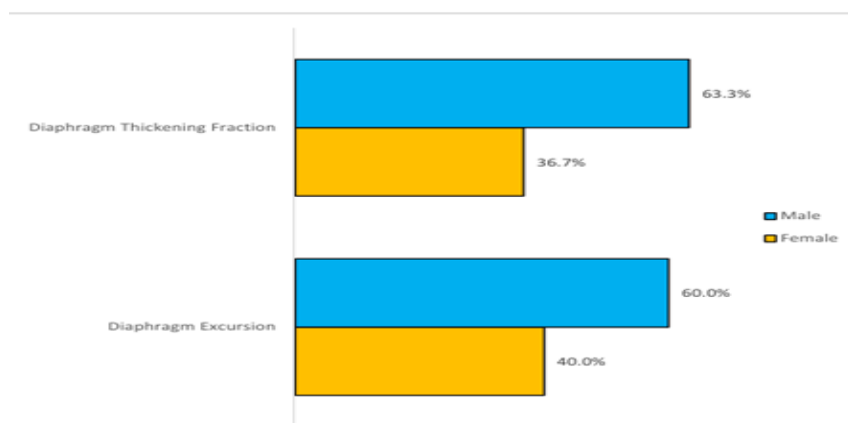


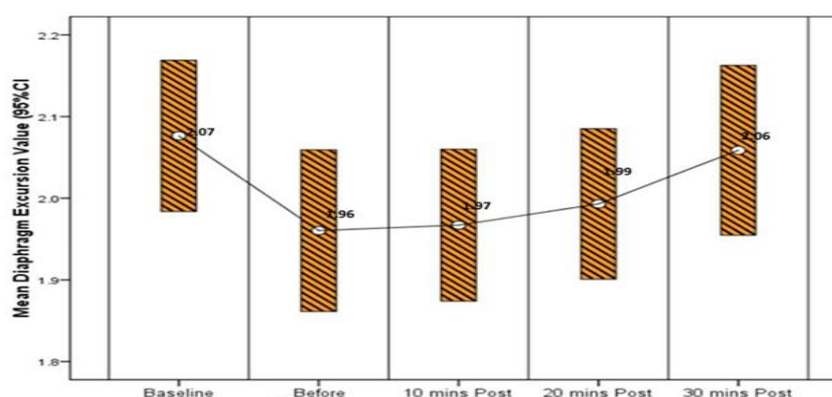
Figure 2. Gender Distribution by Extubating Method



By extubating methods (DE - 41.3 ± 10.5 vs DTF - 41.1 ± 8.2) the mean age was not statistically significant ($p=0.935$). The age distribution, as expected, was also comparable (Figure 1). There males (61.7%) in this study was more. But the gender distribution was the same in both groups (Figure 2.) and was not statistically significantly different ($p=1.000$). Hemodynamic parameters like heart rate, BP and saturation showed no statistical significance over time.

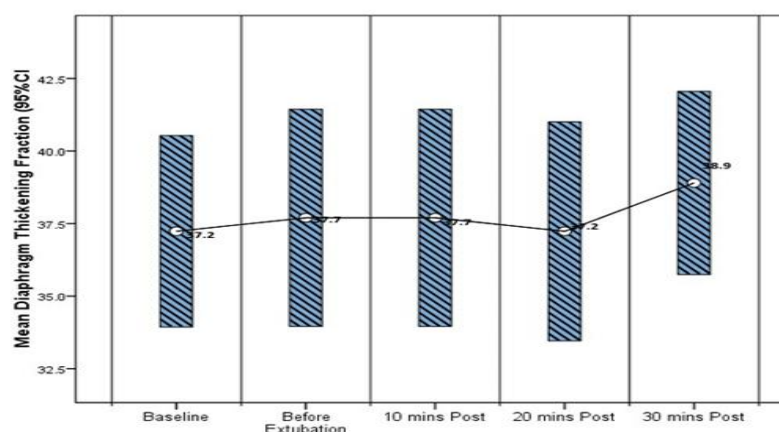
Diaphragm Excursion: In the diaphragm excursion group, the mean diaphragm excursion value at the baseline was 2.1 ± 0.25 cms with a minimum of 1.53 cms and a maximum of 2.51 cm. One female patient (value 1.53 cms) and one male patient (value 1.7 cms) were below the normal diaphragm excursion range. Before extubation 5(16.7%) had values out of normal range and the same was 4(13.3%), 4 (13.3%) and 2 (6.7%) during T10, T20 and T30, respectively. During the repeated measurements, the diaphragm excursion varied statistically significantly over time ($p<0.0001$)fig 3.

Figure 3. Diaphragm Excursion Value Measured over Time



Diaphragm Thickening Fraction: In the group where diaphragm thickening fraction was calculated and monitored, the mean DTF at the baseline was 37.2 ± 8.8 . At baseline abnormal ($<30\%$) DTF was observed in 5 [16.7%] patients, before extubation 23.3%, 10 min 23.3%, 20 mins 20.0% and at 30 mins 5.0% (n=3).

Figure 4. Diaphragm Thickening Fraction Measured over Time



DISCUSSION

The present study shows that diaphragmatic excursion showed clinically significant values when compared to diaphragmatic thickening fraction values. These findings suggest that Diaphragm ultrasound may be used as a tool to predict extubation success. The excursion degree seems to be significantly increased over a period of extubation, when comparing it with the individual patients baseline value. But the thickening fraction values are not significant over a period. Massimo Zamboni⁴ et al. studied Assessment of diaphragmatic dysfunction in the critically ill patient with ultrasound and found DU was performed with different techniques to measure diaphragmatic inspiratory excursion, thickness of diaphragm (Tdi), and thickening fraction (TF). DU is feasible, highly reproducible, and allows one to detect diaphragmatic dysfunction in critically ill patients. During weaning from mechanical ventilation and spontaneous breathing trials, both diaphragmatic excursion and diaphragmatic thickening measurements have been used to predict extubation success or failure.

Houston et al⁵ have measured diaphragmatic motion including the maximal renal bipolar length, and the posterior muscular crus of each hemidiaphragm. The Diaphragm excursion is the distance between the diaphragm and the kidney, at the end of expiration and inspiration was measured. And it was measured in different occasions. The probe should be placed longitudinally to measure the distance between the highest and lowest points of the lung silhouette during inspiration. The advantage of this method is, it can be done on both hemidiaphragms which was not possible in previous methods.

Skaarup et al⁶ have proposed another method for measuring the displacement of the two leaves. On a BD image, the authors have traced the area between the diaphragm and the borders of the ultrasound image. From the study of 19 healthy volunteers, the authors reported that this measurement could be acquired from a lateral mid-axillary view on both hemidiaphragms. If the ultrasound transducer is kept in a fixed position during the respiratory maneuvers, the changes in area are secondary to the sole diaphragm displacement providing a simple, feasible means of assessing diaphragmatic function.

Toledo et al⁷. have measured the craniocaudal displacement of the left branches of the portal vein. It indirectly assessed the right hemidiaphragmatic mobility, because the mean difference between ultrasound measure and radiography measure was only 0.4 mm. For the left hemidiaphragmatic motion, the craniocaudal displacement of the splenic hilum or the 69 inferior pole of the spleen was measured. Indeed, they found a positive correlation between these two methods and the left hemidiaphragmatic excursion measured by radiography or ultrasonography.

Pirompanich P et al⁸, in their study 34 patients were enrolled, of which 25 patients with weaning success, 9 patients in the weaning failure group. The most accurate cutoff value for prediction of successful weaning was right DTF $\geq 26\%$ (sensitivity of 96%, specificity of 68%, positive predictive value of 89%, negative predictive value of 86%). The combination of right DTF $\geq 26\%$ and RSBI ≤ 105 increased specificity to 78% but slightly decreased sensitivity to 92%. Intra-observer correlation increased sharply to almost 0.9 in the first ten patients and slightly increased after that.

Diaphragm measurements, mainly DE and DTF, are significant predictors of successful extubation than traditional parameters like RSBI. In our study, we are comparing the individuals Diaphragm parameters during extubation are in line with their baseline values. Because each individual has one baseline value. Many factors will affect the diaphragm parameter during measurement. In our study, it is found that age, sex doesn't have much significant difference with the Diaphragm parameter values. And in our study, patients were extubated only after meeting the clinical extubation criteria and we were observing the Diaphragm parameters once the clinical criteria is met. This study acts only as a base for future studies, it still needs to add more parameters and factors to be included. In a dilemma of whether to extubate the patient or not occurs in cases of long duration surgeries, neurosurgery patients, cardiothoracic surgeries, patient with lung pathologies preoperatively, in all these conditions Diaphragm parameter will serve as a boon in decision making whether to extubate or elective ventilation. Only thing we need is the skill and training in ultrasonography.

CONCLUSION

In our study, Diaphragm Excursion Vs Diaphragm thickening fraction are studied in 60 patients and the values are compared with the baseline values. It was found that Diaphragm Excursion was better parameter in achieving extubation success than Diaphragm thickening fraction.

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