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Comparison of rapid shallow breathing index versus ultrasonographic guided diaphragmatic thickness fraction as weaning indices on mechanically ventilated patients

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Abstract

Background: The discontinuation or weaning from mechanical ventilation is an important clinical issue which is associated with lot of complications and patient discomfort. So we need a reliable and feasible method for early, safe and effective liberation of patients from mechanical ventilation. The objectives of our study are to determine sensitivity and specificity of rapid sequence breathing index (RSBI) and ultrasonography (USG) guided diaphragmatic thickness fraction (DFT) as weaning indices and to compare their effectiveness.

Methods: The study was carried out on mechanical ventilated patients, when they were considered ready for weaning and the underlying disease is stable or resolving. The measurements of RSBI and DFT using USG were carried out. Weaning was taken as successful if the patients could maintain spontaneous breathing at least 48hrs after extubating, otherwise weaning was classified as failed.

Results: RSBI and DTF group showed no statistically significant difference in extubation of mechanically ventilated patients in the intensive care unit (ICU). RSBI showed sensitivity of 96%, specificity of 74.4%, positive predictive value of 88.2%, negative predictive value of 80.5%, and accuracy of 87.2%, and DTF showed sensitivity of 96%, specificity of 69.7%, positive predictive value of 82.4%, negative predictive value of 78.9% and accuracy of 81.9%.

Conclusion: In our study since there was only one reintubation in each of the groups, that is failure of weaning of one case each in RSBI and DTF groups, both RSBI and DTF has the same sensitivity of 96%, RSBI has better specificity of 74.4% than DTF of 69.7%, RSBI having a better accuracy of 87.2% than DRF which has an accuracy of 81.9%. We conclude that both the methods are equally effective when used as weaning indices for extubation of mechanically ventilated patients.

Keywords: mechanical ventilation; rapid shallow breathing index; diaphragmatic thickness fraction; weaning

Introduction

The science component exists in identifying clinical indicators of improving or recovering physiology. The clinical judgment still plays a crucial role in selecting those who can breathe without support. Some patients wean quickly and uneventfully and, in this respect, their management may be simple. For other patients, this process may be long and protracted [1].

As the conditions that warranted placing the patient on the ventilator stabilize and begin to resolve, attention should be placed on removing the ventilator as quickly as possible. This process often is termed "ventilator weaning" which has two aspects i.e., First liberation from the mechanical ventilation (MV) and its support, and second removal of the artificial airway [2].

Unnecessary delays in this discontinuation process increase the complication rate from MV as well as the cost. Aggressiveness in removing the ventilator,

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however, must be balanced against the possibility that premature discontinuation may occur. Premature discontinuation can cause difficulty in reestablishing artificial airways and compromised gas exchange due to delirium, diaphragm atrophy, thromboembolism or associated pneumonia. It is estimated that around 42% of the time a patient spends on a mechanical ventilator is during the discontinuation process. This percent can be much higher in patients with more slowly resolving lung disease processes. During weaning an understanding of all the reasons that a given patient required a mechanical ventilator is needed for appropriate medical management be optimized along with assessment techniques to identify patients who are capable of ventilator discontinuation [3].

Various weaning indices have been investigated to identify the optimal weaning window. Clinical examination and objective measurements like minute ventilation, maximum inspiratory pressure, breathing frequency, tracheal airway occlusion pressure 0.1, and combined index named CORP (compliance, rate, oxygen pressure index). However none of these parameters have shown a clear independent ability to regain spontaneous breathing during weaning [1].

Tobin and Yang described RSBI as the ratio of respiratory rate (RR) to tidal volume (TV) in litres, with a threshold value of >105 breaths/min/L being highly predictive of weaning failure, while RSBI <105 breaths/min/L is associated with weaning success [4, 5].

The diaphragm is the major muscle of inspiration. Presence of its contraction and shortening should be a prerequisite for successful extubation. Diaphragmatic thickening fraction (DTF) reflects the magnitude of diaphragmatic effort and may predict successful weaning [6]. Recently some studies have shown measurement of diaphragm function would be a useful guide for weaning of patients during MV which is done rapidly via ultrasonography (USG) [7].

But there are very limited studies to compare between RSBI and DFT as a tool for prediction of extubation and proper timing of weaning from mechanical ventilation.

The primary objective of the study was to determine sensitivity and specificity of RSBI and DFT as weaning indices after MV. We also compared the effectiveness of both as weaning indices. Secondary objective was to determine the haemodynamic stability of patients after weaning from MV.

Methodology

The study was conducted at a tertiary centre, after receiving institutional ethical committee clearance (ECR/134/Inst/KA/2013/RR-16), from November 2018 to June 2020. Written informed consent was taken from the patient's relatives. The study was conducted under the guidance of intensivist and a radiologist.

60 patients between 18 - 60 years of age of either sex were divided into 2 groups of 30 patients each. Group R – to determine extubation readiness based on RSBI (n=30) and Group D – to determine extubation readiness based on USG guided DFT (n=30).

These study population consisted of patients on MV for more than 24 hours, who were clinically stable and have met the criteria for weaning from MV as the underlying disease for MV was stable or resolving. This stability or resolving condition was detected clinically by no vasopressor support; oxygen saturation (SPO_2) maintaining more than 94% with fractional inspired oxygen concentration (FiO_2) of less than 0.5; continuous positive airway pressure (CPAP) of 5cm H_2O; RR of less than 30 breaths per minute and thirty minutes of T-tube trial. Also conscious, co-operative and patients with minimal secretions and effective cough were included in the study. RSBI and DFT measurements were carried out and then patients were monitored with SPO_2, RR and haemodynamics like electrocardiogram (ECG), heart rate (HR), systolic blood pressure (SBP) and diastolic blood pressure (DBP). Evaluation of serial arterial blood gas (ABG) and chest X-ray was also done. Patients with neuromuscular diseases, diaphragmatic paralysis, diaphragmatic injury, rib fracture, tracheostomised patients and pregnant woman were excluded from the study.

All the patients were placed in supine position with the trunk flexed at 45 degree. RSBI was calculation RR and TV was directly recorded from the ventilator settings. Patients who will have RSBI >105 were reventilated and RSBI was calculated on the next day. Patients with RSBI< 105 were extubated by taking into account all the medical conditions of the patients.

DTF was measured using USG Mindray M7/M7T at right hemidiaphragm, visualising diaphragm muscle in the zone of apposition, in the midaxillary line, between 8th and 10th intercostal space, 0.5 to 2cm below the costophrenic sinus, in M mode USG using 7-10mHz, linear probe. DTF was measured at the end of inspiration and at the end of expiration during spontaneous breath trials (SBT) to predict extubation outcomes. Diaphragm is visualized as a structure with 3 distinct layers including 2 parallel echoic lines (diaphragmatic pleura and peritoneal membrane) and a hypoechoic structure between them, the muscle itself. The diaphragm should increase in thickness during inspiration, in healthy spontaneously breathing patients, it may increase from 0.2mm at rest to 1.4mm. The right hemi-diaphragm was visualised in the zone of apposition due to better acoustic window on the right side at both end inspiration and end expiration and DTF is calculated as percentage from the following formula: [(thickness at end of inspiration - thickness at end of expiration)/thickness at end of expiration]*100, a change in diaphragm thickness of >30% predicts successful outcome.

Weaning was taken as successful if the patients could maintain SBT at least 48hrs after extubation, otherwise weaning was considered as failed.

The calculation of sample size was done after detailed discussion with the statistician, on the basis of pilot study observations. The observation conducted showed approximately each group should have 23 patients for ensuring a power of study 0.80 for detecting clinically meaningful difference by 15% in heart rate and blood pressure. With assumption of 5% patients would drop out, the final study sample size was fixed at 30 patients in each group, allowing a type 1 alpha error =0.05 and a type 2 error of beta=0.2 and power of 0.8. All the statistical methods were carried out through Microsoft excel SPSS for Windows (version 2.0). The results of the present study between the two groups were compared statistically using 'p' value and statistical tests were repeated measures and independent analysis of variance (ANOVA) /Kruskal-Wallis H test and required graphical techniques are used. A 'p' value of < 0.05 was considered statistically significant and less <0.01 was considered as highly significant. All data were tabulated and presented depicting the mean ± standard deviation.

Results

There is no statistical difference between the two groups in demographic characteristics like age, sex and weight. There was also no statistical significant difference in baseline parameters like HR, SBP and DBP between both the groups (Table 1).

Table 1: Demographic profile and baseline parameters in both the groups.

S. No.	*Parameters*		*Group R (n=30)*	*Group D (n=30)*	*p value*
1	Age (mean ± SD)		47.2±14.8	51.23± 8.36	0.098
2	Sex	Male	14 (46.7%)	15 (50%)	0.79
		Female	16 (53.3%)	15 (50%)	
3	Weight		54.16±8.31	51.23±8.36	0.086
4	Baseline heart rate (beats per minute)		94.1±17.83	90±18.78	0.194
5	Baseline systolic blood pressure (mmHg)		122.2±17.34	122.93±20.49	0.444
6	Baseline diastolic blood pressure (mmHg)		76.13±12.84	73.33±10.61	0.178
7	Baseline oxygen saturation (%)		96.8±1.2	96.86±1.77	0.440
8	Baseline respiratory rate (breaths per minute)		20.96±5.18	21.1±5.71	0.464

Sensitivity was similar in both the groups but specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy was higher in Group R with RSBI than Group D with DTF measured with USG. Both the groups show equal number of patients being weaned from MV with one patient being reintubated (Table 2).

Table 2: Comparison of sensitivity, specificity and successful weaning among two groups.

Parameters	*Group R*	*Group D*
Sensitivity (%)	96	96
Specificity (%)	74.4	69.7
Positive predictive value (%)	88.2	82.4
Negative predictive value (%)	80.5	78.9
Accuracy (%)	87.2	81.9
Successful weaning (%)	29 (96.7)	29 (96.7)

Discussion

Respiratory function declines gradually over a lifetime, the accuracy of RSBI might concurrently decrease with increased patient age; hence in this subset of elderly patients, measuring diaphragmatic function by DTF predicted the successfulness of SBT, with the right DTF being more accurate than the left DTF [4].

In our study, RSBI showed sensitivity of 96%, specificity of 74.4%, positive predictive value (PPV) of 88.2%, negative predictive value (NPV) of 80.5%, and accuracy of 87.2%. DTF showed sensitivity of 96%, specificity of 69.7%, PPV of 82.4%, NPV of 78.9% and accuracy of 81.9%. RSBI has similar sensitivity as DTF but higher specificity, PPV, NPV and accuracy than DTF.

Table 3: Comparison of oxygen saturation in two groups at various time intervals.

Time relation to extubation	*Group R*	*Group D*	*p value*
	Mean (%) ± SD	*Mean (%) ± SD*	
Before 30 min	96.8 ±1.24	96.86 ±1.77	0.440
Before 5min	97.7 ±.14	97.23±1.45	0.082
After 5 min	96.4 ±.3	96.6 ±2.01	0.326
After 1 h	96.56 ±.30	96.23 ±2.01	0.226
After 24 hrs	96.26 ±.31	96.16. ±3.91	0.389
After 48 hrs	96.36 ±.24	96.53 ±1.16	0.294

There was no significant difference between Group R and Group D in SPO_2 and RR at various time intervals during SBT before and after extubation (Tables 3 & 4).

Table 4: Comparison of respiratory rate among two groups at various time intervals.

Time relation to extubation	*Group R*	*Group D*	*p value*
	Mean (breaths per minute)±SD	*Mean(breaths per minute) ±SD*	
Before 30 min	20.96±5.18	21.1±5.71	0.464
Before 5 min	21.2±4.48	20.5±4.89	0.284
After 5 min	21.76±4.54	22.1±4.78	0.389
After 1 h	20.3±4.54	19.6±3.78	0.261
After 24 hrs	19.2±3.73	18.4±3.85	0.209
After 48 hrs	18.4±3.98	17.93±3.46	0.315

Patel et al. conducted where RSBI as weaning indices was compared with 5 cm H_2O CPAP versus T-piece given before weaning [8]. RSBI was also calculated in two different ways and compared- using the machine digital values versus wright spirometry obtained values. Also RSBI as weaning predictor was compared during morning and evening. They concluded that RSBI is significantly affected by the level of ventilator support a patient receives. RSBI seems to be relatively insensitive to the method used for calculation or by the time of day at which it is measured.

We considered SPO_2 maintaining more than 94% with FiO_2 of less than 0.5; CPAP of 5cmH_2O; RR of less than 30 breaths per minute and thirty minutes of T-tube trial using machine value for weaning. RSBI was calculated using machine to obtain RR and TV. Extubation was done during morning, as monitoring the patient would be more feasible during morning than in the evening [8].

In Ferrari et al. study, a cutoff value of a DTF more than 36% was associated with a successful SBT with sensitivity of 0.82, specificity of 0.88, PPV of 0.92 and NPV of 0.75 whereas RSBI less than 105 had sensitivity of 0.93, specificity of 0.88, PPV of 0.93 and NPV of 0.88. The sensitivity, PPV and NPV was higher with RSBI compared to DTF but specificity was similar in both the groups perhaps because they instructed the patient to breathe in up to total lung capacity (TLC) and breathe out up to residual volume (RV). DTF was calculated at TLC and RV unlike our study, which would have increased the specificity of DTF almost equal to DTF to detect SBT adequacy. In our study RSBI and DTF was calculated at normal spontaneous inspiration and expiration and not at TLC and RV [9].

In Banerjee et al. study, RSBI sensitivity, specificity, PPV and NPV all was 100% [10]. Thus similar to our study, all these parameters were higher with RSBI compared to DTF to assess SBT. DTF sensitivity was 0.94, specificity was 0.55, PPV was 0.8 and NPV was 0.76. They concluded that, RSBI is the best clinical tool for weaning of patients if done after 20 min of SBT [9]. They also compared other USG based weaning parameters with each other and inferred that speed of diaphragmatic contraction (DC) can be more reliably used as an additional indices of weaning parameter, and can even be a substitute of RSBI in present days [10].

Soleman et al. study included post complicated cancer surgery patients on MV to assess weaning using RSBI and its correlation with ABG. Also in other group of weaning patients DTF was calculated and correlated with ABG. Kappa value (agreement) between RSBI and ABG was 0.974. Kappa between both DTF and the ABG criteria was 0.891 which signifies RSBI better than DTF as weaning indices. Similarly in our study, RSBI had got higher accuracy than DTF [7]. But after 72 hours of SBT the sensitivity and specificity of DTF was higher. They concluded that diaphragm thickness and its change between end-expiration and end- inspiration showed agreement with ABG for predicting weaning readiness and recommended to add it for liberation from especially longer duration of MV [7].

Alyzeid et al. studied SBT in weaning chronic obstructive pulmonary disease (COPD) patients on MV [11]. They evaluated the RSBI and right hemi-diaphragmatic displacement (DD). Further D-RSBI (RR/DD) was calculated. The sensitivity and specificity of DD were 72.2% and 93.0% respectively. The sensitivity and specificity of RSBI were 77.8% and 70.9%. While the sensitivity and specificity of D-RSBI was 83.3% and 90.7% respectively [10]. They concluded that D-RSBI is superior to the traditional RSBI in predicting weaning outcome patients with COPD patients. Spadaro et al. enrolled 51 patients requiring mechanical ventilation for more than 48hrs who were ready to perform a SBT. They also concluded similarly that DD, when combined with RR in an index that we named D-RSBI (RR/DD), is more accurate than the traditional RSBI (RR/VT) in predicting the weaning outcome. A cut-off of 1.3 is associated with the best sensitivity and specificity [11, 12].

Pirompanich et al. study showed that the combination of right DTF ≥26% and RSBI ≤105 increased specificity to 78% to assess SBT success [13].

Ordanza et al. compared diaghragmatic thickness or RSBI to assess weaning. ROC curve analysis determined >3.2 mm as the best cut-off score for diaphragm muscle thickness on inspiratory phase and it can significantly predict successful extubation with a sensitivity of 73.3% and a specificity of 80%. Thus they concluded diaphragm muscle thickness can successfully predict weaning as much as RSBI can. The slight varied result from our study might be because; we focused on DTF rather than diaphragmatic thickness. But even with DTF the number of patients reintubated in both the groups was not statistically significant [14].

Turton et al. conducted a systematic review and a meta-analysis, assessing the evidence on diaphragm ultrasound and its ability to predict successful weaning from MV and its ability to predict successful weaning from MV. They concluded that diaphragmatic ultrasound has been extensively studied as a predictor of successful weaning from mechanical ventilation and continues to be studied and stated that diaphragmatic ultrasound is a promising diagnostic tool greater standardization of protocols, outcome measures and ventilatory settings is required for further research and clinical application [15].

Limitations

The ultrasound technique recommended by the study needs training for the ICU practitioners to be familiar with. But we assessed DFT with USG under the guidance of an intensivist and radiologist. We were not able to perform a third group combining RSBI and DTF to extubate the patients on MV, which could give better outcome of weaning.

Conclusion

Either RSBI or DTF can be used successfully to wean the patients from MV. In our study, with RSBI and DTF as weaning indices, there was no statistically significant difference in number of patients reintubated among two groups. But RSBI showed higher specificity, PPV, NPV and accuracy than DFT though the sensitivity was same with both. We conclude that both the methods are equally effective when used as weaning indices for patients on MV in intensive care unit and DTF can be safely used as weaning indices similar to RSBI for extubation. Combination could have been more effective.

Conflicts of interest

Authors declare no conflicts of interest.

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