Zagazig University Medical Journal
www.zumj.journals.ekb.eg
https://doi.org/10.21608/zumj.2024.234154.2873 Volume 30, Issue 7, Oct. 2024
Manuscript ID *ZUMJ-2403-3275* DOI . 10.21608/ZUMJ.2024.279107.3275

ORIGINAL ARTICLE

Assessment of Diaphragmatic Excursion-Time Index versus Diaphragmatic Rapid Shallow Breathing Index to predict Successful Weaning from Mechanical Ventilation

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Submit date: 24-03-2024
Revise Date : 16-07-2024
Accept date: 22-07-2024

ABSTRACT

Background: When the diaphragm moves from its level throughout complete expiration to its level during full inhalation, this movement is referred to as diaphragmatic excursion for short.
An evaluation of the value of the diaphragmatic excursion time index & the diaphragmatic rapid shallow breathing index, both of which were evaluated using ultrasonography, in order to forecast the likelihood of successful weaning from mechanical ventilation & extubation.
Methods: For the purpose of predicting the probability of effective weaning from mechanical ventilation & extubation, an assessment of the value of the diaphragmatic excursion time index and the diaphragmatic fast shallow breathing index was performed. Both of these indices were analysed using ultrasonography.
Results: 99 cases were enrolled in this study, there was not a statistically significant distinction amongst the three categories that were investigatedas regards Ventilator hours till SBT p= 0.577. DETI and DRSBI at 30 minutes were more significant predictors of successful weaning than at the beginning of the SBT. Regarding DETI at 30 min, AUC was 0.965, Cutoff value was 1.3, Sensitivity was 99%and Specificity was 88.2%, while DRSBI at 30 min, AUC was 0.895, Cutoff value was 1.07, Sensitivity was 97.2% & Specificity was 86.5%.
Conclusion: When it comes to predicting the result of weaning, comparatively, the diagnostic accuracy of the DETI and DRSBI were better than that of the standard RSBI in supporting clinical decision-making regarding the release of patients from mechanical ventilation.
Key words: DETI; DRSBI; Successful Weaning; Mechanical Ventilation

INTRODUCTION

There is still a problem involved in detecting the best timing to extubate an individual who is in severe condition. The risk of ventilator-associated lung damage and ventilator-associated pneumonias increases when a critically sick individual is weaned off mechanical ventilation (MV) too soon. On the other hand, premature weaning from MV carries a high risk of weaning failure, which leads to re-intubation, which forces the individual to undergo unnecessary stress on their respiratory & hemodynamic systems [1]. Before Yang and Tobin published the fast shallow breathing index (RSBI) in 1991, the majority of weaning predictors were used by doctors. These predictors included spontaneous tidal volume (VT), minute ventilation, vital capacity , & maximum inspiratory pressure (MIP). A threshold value of more than 105 breaths per minute per litre is significantly predictive of weaning failure, whereas RSBI values below 105 breaths per minute per litre are linked with successful weaning [2]. Yang and Tobin defined RSBI as the ratio of respiratory rate to tidal volume (RSBI=RR/VT).However, these measures only evaluate the total respiratory volumes that are generated by the muscles that are responsible for breathing. They do not take into consideration the independent contribution of the diaphragm, which is a muscle that is of vital significance for good spontaneous ventilation [3].

When the diaphragm moves from its level during complete expiration to its level during full inhalation, this movement is referred to as diaphragmatic excursion or DE for short. It is possible to quantify it using the United States as the perpendicular distance among the top borders of the liver (which serves as an acoustic window for the right hemi-diaphragm) at the conclusion of inspiratory & expiratory phases [4].

This research aimed to determine the value of the diaphragmatic excursion time index & the diaphragmatic fast shallow breathing index, both of which were evaluated using ultrasonography, in order to determine whether or not they were able to accurately predict effective weaning from mechanical ventilation & extubation.

METHODS

The purpose of this prospective comparative randomised controlled research was to assess the value of the diaphragmatic excursion time index & DRSBI, both of which were evaluated by ultrasonography, in order to determine whether or not they are able to accurately predict successful weaning from mechanical ventilation and extubation. The research was performed at the surgical intensive care unit of Zagazig University.

Ethical consideration

The investigation that was conducted was authorised by the investigate ethics committee of the Faculty of Medicine at Zagazig University (Institutional review board ZU-IRB #9096/8-12-2021). Written informed permission was acquired from all of the contributors otherwise their legal guardians.

The research has been carried out in a manner that is consistent with the Declaration of Helsinki, which is the Code of Ethics of the World Medical Association for research that involves human subjects.

Inclusion criteria: Adults amongst the ages of 18 & 64 who have a BMI of less than 35 kg/m2 who have been receiving mechanical breathing for more than 48 hours and who meet the requirements for weaning: The underlying cause of mechanical ventilation that has been clinically addressed with treatment includes a FiO_2 level of at least 40%, a PEEP level of at least 5 cmH_2O, a spontaneous respiratory rate of at least 30 cycles per minute, a maximal inspiratory pressure (MIP) of at least 25 cmH_2O, a PaO_2/FiO_2 ratio of at least 200 mmHg, hemodynamic stability (with a heart rate (HR) of at least 100 beats per minute & a mean arterial pressure of at least 65 mmHg), normal levels of electrolytes, blood glucose, & a haemoglobin level of at least 10 gm/dl, & a normal body temperature of less than 38 degrees Celsius, & alertness with minimal or no sedation [5].

Exclusion criteria: Unilateral or bilateral diaphragmatic paralysis (revealed by US as absent diaphragmatic mobility), Patients with known neuromuscular disease such as myasthenia gravis, cervical spine fracture or spinal cord injury, Chest trauma, including but not limited to pneumothorax, rib fracture, and flail chest or post thoracotomy and Pregnant patients or increased intra-abdominal pressure e.g. ascites.

Randomization

To continue the weaning study, individuals were randomly assigned to one of three equal categories by a computer-generated randomization table. These categories were determined by the parameter that was utilised to continue the trial: Group (C) (control group): Included 33 patients who were allowed to continue SBT according to the traditional rapid shallow breathing index (Rapid shallow breathing index<105 predicts successful weaning), Group (DE): Included 33 patients who were allowed to continue SBT based on the result of DETI (DETI greater than 0.92 cm/sec. predicts successful weaning). Group (DR): Included 33 patients who were allowed to continue SBT based on the result of DRSBI (DRSBI less than 1.3 predicts successful weaning).

From each patient the following data were collected: Individual characteristics (sex, age, BMI), Cause of ICU admission, cause of tracheal intubation and mechanical ventilation (e.g. ARDS or septic shock), period of mechanical ventilation & ICU stay, SBT on pressure support mode of mechanical ventilation with inspiratory pressure support 8 cmH_2O and PEEP 5 cmH_2O, Calculation of traditional RSBI, Ultrasonographic measurement of the diaphragmatic excursion and displacement at 1 min, at 30 min and after 120 minutes from the start of SBT, On the horizontal axis, the time interval (in seconds) for each tidal breath was monitored, & the average of the three data was computed,The DETI was calculated = DE in centimeters × TI in seconds, The DRSBI was calculated = RR/DD.

Technique of Diaphragm Ultrasonography & Measurements: Research was conducted on individuals when they were in a semi-recumbent posture. Two-dimensional & M-mode ultrasonography was used to assess the right hemi-diaphragm in order to capture the diaphragm's displacement & excursion. A convex phase array probe operating at 3.5 MHz was used in order to measure the diaphragm excursion [4]. As an acoustic window, the liver was used to position the probe in the longitudinal scanning plane. The probe was positioned precisely below the right costal border at the mid-clavicular line. Following the identification of the diaphragm by the use of two-dimensional imaging, In order to ensure that the M-mode interrogation line was perpendicular to the movement of the posterior one-third of the right hemi-diaphragm, several modifications were made to the line. During the M-mode tracing, the diaphragm excursion was measured along the vertical axis, commencing at the onset of inspiration and continuing until the conclusion thereof. Following the recording of the maximum displacements in five breathing cycles, the mean DE was computed in centimetres in units of measurement. Concurrently, It was determined that the TI for each tidal breath should be recorded on the horizontal axis, and a mean of three measurements should be calculated. This was done in real time. The ultrasonographic measurements of the diaphragm were carried out by the investigator at a pattern of regular tidal breathing in order to exclude any fluctuation that may be attributed to tidal volume. With the diaphragm excursion measured in centimetres and the inspiratory duration measured in seconds, the DETI was determined by multiplying the two values. The diaphragmatic displacement was measured along the vertical axis that followed the course from the beginning to the end of inspiration while the machine was operating in M-mode, & the DRSBI was computed by dividing the RR by the DD [6].

Outcomes

The primary objective was to assess the accuracy of DETI & DRSBI in predicting the result of weaning, & the secondary objective was to assess the utility of DETI & DRSBI in comparison to the standard RSBI in terms of predicting weaning outcome & reducing the length of time spent in the intensive care unit & for mechanical breathing.

RESULTS

There was no observed statistically substantial variance among study groups as regards Age p=0.32, Sex p=0.08 and BMI p=0.1. (Table 1).

Table 1: Demographic data among the three studied collections

	Group C (n = 33)	Group DE (n = 33)	Group DR (n = 33)	Test of Sig.	p
Sex				X2 = 11.993	0.08
- Male	13 (39.39%)	22 (66.7%)	17 (51.52%)		
- Female	20 (60.61%)	11 (33.3%)	16 (48.48%)		
	P1 = <0.001 , P2 = 0.004 , P3 = 0.323				
Age (years)				F = 1.162	0.32
Mean ± SD.	39.94 ± 5	41.67 ± 4.16	41.45 ± 5.77		
	P1 = 0.132 , P2 = 0.865 , P3 = 0.259				
BMI				F = 2.371	0.09
Mean ± SD.	26.29 ± 2.69	27.42 ± 1.83	26.48 ± 2.13		
	P1 = 0.052 , P2 = 0.059 , P3 = 0.762				

$\chi 2$: Chi- Square test SD: standard deviation IQR: interquartile range F: ANOVA test p: p value for comparing amongst the examined collections P-value > 0.05: Non substantial; P-value < 0.05: Substantial; P-value < 0.001: Highly substantial P1: Collection C vs Collection DE P2: Collection DE vs Collection DR P3: Collection C vs Collection DR

Was noted no statistical substantial variance amongst the three studied collections as regards weaning success (p= 0.543), as well as Ventilator hours till SBT p= 0.577. (Table 2)

Table 2: Weaning success and ventilator hours till SBT among the three examined collections

	Group C (n = 33)	Group DE (n = 33)	Group DR (n = 33)	Test of Sig.	p
Weaning success				X2 = 0.37	0.543
- Success	22 (66.67%)	21 (63.64%)	25 (75.76%)		
- Failure	11 (33.33%)	12 (36.36%)	8 (24.24%)		
	P1 = 0.796 , P2 = 0.284 , P3 = 0.415				
Ventilator hours till SBT				F = 0.554	0.577
Mean ± SD.	70.23 ± 7.51	71.1 ± 8.16	68.92 ± 5.55		
	P1 = 0.719 , P2 = 0.307 , P3 = 0.506				

Was observed a statistical significance increase in RSBI (1, 30 & 120 min) among failed compared to weaned cases in group C at 1, 30, and 120 minutes p < 0.01. (Table 3)

Table 3: The association of RSBI with weaning success and failure in Group C:

Variable		Failed (*n*=11)	Succeed (*n*=22)	P
RSBI:1min (breath/min/L)	*Mean ± SD*	67.82±10.4	45.36±4.34	<0.01
RSBI:30min (breath/min/L)	*Mean ± SD*	88.73±9.47	55.36±5.59	<0.01
RSBI:120min (breath/min/L)	*Mean ± SD*	108.73±5.61	61.36±6.17	<0.01

P-value> 0.05: Non significant; < 0.05: Significant; < 0.001: Highly significant

SD: standard deviation

RSBI<105 breath/min/L predicts successful weaning

Was noted there was a statistical significant decrease in DETI (1, 30 & 120 min) among failed compared to weaned cases in group DE p <0.01 (Table 4)

Table 4: The association of DETI with weaning success and failure in Group DE:

Variable		Failed (*n*=12)	Succeed (*n*=21)	P
DETI: 1min(cm*sec)	*Mean ± SD*	1.7±0.12	1.58±0.75	<0.01
DETI: 30 min(cm*sec)	*Mean ± SD*	1.69±1.19	2.85±0.71	<0.01
DETI: 120 min(cm*sec)	*Mean ± SD*	1.39±0.92	2.35±1.23	<0.01

SD: standard deviation

P-value> 0.05: Non significant; < 0.05: Significant; < 0.001: Highly significant

DETI> 0.92 cm*sec. predicts successful weaning

Was observed there was a statistical significant increase in DRSBI (1, 30 & 120 min) among failed compared to weaned cases in group DR p<0.01. (Table 5)

Table 5: The association of DRSBI with weaning success and failure in Group DR:

Variable		Failed (*n*=8)	Succeed (*n*=25)	P
DRSBI:1min (breath/min/mm)	*Mean ± SD*	1.33±0.14	1.06±0.17	<0.01
DRSBI:30min (breath/min/mm)	*Mean ± SD*	2.58±0.75	1.12±0.15	<0.01
DRSBI:120min (breath/min/mm)	*Mean ± SD*	2.59±0.92	1.19±0.13	<0.01

SD: standard deviation

DRSBI< 1.3 breath/min/mm predicts successful weaning

P-value> 0.05: Non significant; < 0.05: Significant; < 0.001: Highly significant

Table (6) showed Receiver operating characteristic curve analysis with cut-off value, sensitivity and specificity of RSBI, DETI and DRSBI at 1 minute to predict weaning success. At cutoff value of 1.05, DETI had higher sensitivity (91.6%) and specificity (84%) than RSBI (88.5%, 69.1%) and DRSBI (90.9%, 81.8%).

Table 6: Receiver operating characteristic curve analysis with cut-off value, sensitivity & specificity of RSBI, DETI and DRSBI at 1 minute to predict weaning success

	Diagnostic parameters			
	AUC	Cutoff value	Sensitivity	Specificity
	0.799	51.5	88.5%	69.1%
	0.880	1.05	91.6%	84%
	0.849	1.09	90.9%	81.8%

Regarding ROC curve analysis with cut-off value, sensitivity and specificity of RSBI, DETI and DRSBI at 30 minutes to predict weaning success. At cutoff value of 1.3, DETI had higher sensitivity (99%) and specificity (88.2%) than DRSBI (97.2%, 86.4%) and RSBI (91.7%, 52.4%). DETI at 30 min, AUC was 0.706, Cutoff value was 1.3, Sensitivity was 91.7%& Specificity was 52.4%.(Table 7)

Table 7: Receiver operating characteristic curve analysis with cut-off value, sensitivity & specificity of RSBI, DETI and DRSBI at 30 minutes to predict weaning success

	Diagnostic parameters			
	AUC	Cutoff value	Sensitivity	Specificity
	0.706	62.5	91.7%	52.4%
	0.965	1.3	99%	88.2%
	0.895	1.07	97.2%	86.4%

Regarding ROC curve analysis with cut-off value, sensitivity and specificity of RSBI, DETI and DRSBI at 120 minutes to predict weaning success. At cutoff value of 1.9, DETI had higher sensitivity (97.2%) and specificity (86.5%) than DRSBI (96%, 84.4%) and RSBI (82.6%, 76.3%). DRSBI at 30 min, AUC was 0.965, Cutoff value was 1.07, Sensitivity was 100%& Specificity was 84% (Table 8).

Table 8: Receiver operating characteristic curve analysis with cut-off value, sensitivity & specificity of RSBI, DETI and DRSBI at 120 minutes to predict weaning success

	Diagnostic parameters			
	AUC	Cutoff value	Sensitivity	Specificity
	0.701	56	82.6%	76.3%
	0.970	1.9	97.2%	86.5%
	0.879	1.17	96%	84.4%

DISCUSSION

Individuals who are receiving mechanical ventilation in the intensive care unit continue to face one of the most significant hurdles, which is the process of weaning off of the ventilator [7].

The main results of our study were as following:

Statistically speaking, there was not a statistically momentous distinction amongst the three categories in terms of age,sexor body mass index, as shown by the p-values of 0.317, 0.081& 0.099, respectively, in the present thesis. Among the groups, the average age was 39.94 years with a standard deviation of 5 years in group C, 41.67 years with a standard deviation of 4.16 in collection DE, and 41.45 years with a standard deviation of 5.77 years in collection DR. In accordance with the findings of a research conducted by Mowafy et al., [8], a randomized clinical trial was conducted on 106 individuals who had been mechanically ventilated for more than 48 hours & were prepared to wean off the ventilator during their first spontaneous breathing experiment. Following the completion of one minute of SBT, the RSBI and DRSBI were computed. Regarding the choice to proceed with SBT, individuals were classified into the following groups: Group I (consisting of 53 individuals) the decision is contingent upon the RSBI. There were 53 individuals in Group II, and the choice was based on DRSBI. After thirty minutes had passed, individuals were reassessed to determine their tolerance to SBT, & then Rapid shallow breathing index & diaphragmatic Rapid Shallow Breathing Index were computed. In terms of age, there were no differences that could be considered statistically significant amongst the three groups (p>0.05).

According to the findings of Hayat et al., [9], the median age of the population under investigation was 40.50 years, with an interquartile range of 25.75 years. A total of sixty-eight individuals were males (68%) & thirty-two individuals were females (32%).

The current research found that the mean traditional RSBI was lower in successfully weaned cases compared to failed cases in the control group. However, in both cases the mean values for RSBI were less than 105, that indicates limitations of this parameter as it reflects the involvement of all inspiratory muscles, not only the diaphragm. So, diaphragmatic dysfunction may be underdiagnosed due to other inspiratory muscles compensation.In agreement was the results of Mashal et al., [10] who found that, Rapid shallow breathing index demonstrated a substantial reduction in successful weaning collection compared with failed weaning collection at baseline, at 30, 90, and 120 min (P=0.011, 0.031, 0.041, and 0.009, respectively).Mowafy & Abdelgalel, 2019 [8] noted that, failed weaning patients had a lower RSBI at 1 min and 30 min. This may be attributed to that patients may show a normal breathing pattern at the beginning of a SBT, but later on deterioration can occur.

In a study conducted by Chatila et al., 2016, [11] they found that RSBI measured at 30 min after initiation of SBT was superior to that measured at the start of the SBT as a weaning predictor.Another study by Krieger et al., 1997 [12] they concluded that serial measurement of RSBI was more consistent to predict weaning outcomes.Kuo et al., 2016 [13] also found that RSBI measured at the end of SBT had better diagnostic accuracy.

In contrast to our study, Banerjee and Mehrotra, 2018 [14] found that RSBI alone compared to diaphragmatic measurements by ultrasound was most accurate to predict successful weaning with sensitivity and specificity 100% and DE can be used as adjunct parameter for weaning success with traditional RSBI.

We found that, the DE is higher, the TI is longer, and DETI is greater in the patients who were successfully weaned from MV as compared with those who failed weaning from MV with DETI cut off value >1.3 at 30 min. with sensitivity 99% and specificity 88.2%. In agreement was a recent study by Song et al., 2022 [15] reported that, a significant differences in DE and DETI at 30 minutes were observed between the weaning success and failure groups (P < 0.001).Palkar et al., 2018 [16] on their study on 73 patients used the ultrasonography to measure DE on right hemi-diaphragm, TI and DETI during SBT and found that DE cut off value was 1.65 and 2.1 cm, while DETI was 1.64 and 2.42 cm*sec in failed and successful weaning cases respectively. They found that DETI measured during SBT may help to predict the outcome of weaning and increases the likelihood of successful extubation.Farghaly & Hasan, 2017 [17] demonstrated that 54 patients who successfully passed SBT were enrolled. They were assessed by ultrasound during SBT evaluating DE. Simultaneously traditional weaning parameters were recorded. Patients were followed up for 48 h after extubation: 14 (25.9%) failed extubation. DE was significantly higher in the successful group compared with the failed one (P<0.05). Sensitivity was 87.5% and specificity was 71.5%.Kim et al., 2011 [18] found that diaphragm excursion less than 1 cm during SBT identified a higher rate of weaning failure than an excursion greater than 1 cm. Osman and Hashim, 2017 [19] found that a cutoff value lower than 1 cm. for diaphragm excursion during SBT had 83.3% sensitivity, 100% specificity, a 94.3% negative predictive value, a 100% positive predictive value, and an AUC of 0.83 for predicting extubation failure. Saeed et al., 2016 [20] in their small study of 50 patients with COPD and receiving MV, found that a cutoff value for diaphragm excursion of 1.1 cm during SBT had a sensitivity of 86.4%, specificity of 87.5%, and accuracy of 89.5% to predict weaning outcome.

In the study of Hayat et al., 2017 [9] used ultrasound in patients who fulfilled the criteria of removal from ventilatory support. The patients were followed up for 48 h and classified according to the outcome as successful weaning and weaning failure. Out of 100 cases, 67 cases were at or above the diaphragmatic excursion of 1.2 cm while 33 cases were below this value. Out of these 67 cases, 60 had a successful weaning (89.55%) while only 7 cases (10.45%) had a weaning failure. Best results were seen at a DE of 1.4 and 1.5 cm. Out of the 33 cases with a diaphragmatic excursion below 1.2 cm, only 17 (51.5%) had successful weaning while 16 (48.48%) had weaning failure.

In other study, Mashal et al., 2021 [10] showed that DETI and DE were stronger than RSBI as a predictor of successful weaning at the end of SBT, sensitivity was 96, 94, and 82%, specificity 82, 80, and 76%, and cut-off values were 1.9, 1.30, and 43, respectively.

In a study by Qian et al., 2018 [21] a total of 436 patients were included. Overall, the DE sensitivity of 95% specificity of 0.74 (95) for predicting weaning success. This result showed that DE reflected good prognostic value to predict weaning outcomes.

In a similar study by Jung, et al., 2014 [22] the sensitivity and specificity of DE to predict successful extubation was 84.4% and

82.6%, respectively, using a mean cut off value of 1.1 cm of spleen and liver displacement.In a study by Abdelhafeez et al., 2019 [23] on 240 cases aged more than 18 years old, DE was measured at the end of SBT with 117 cases were successfully weaned while 123 cases failed weaning with cutoff value 2.19 cm and 1.3 cm in successful and failed cases respectively.

Elshazly et al., 2020 [24] studied 62 mechanically ventilated patients in chest ICU who passed successfully SBT and diaphragmatic ultrasound was done during SBT to assess diaphragmatic excursion and thickness. There was a statistically significant increase in the successful extubation group in the diaphragmatic excursion (p<0.001), with DE cutoff value predictive of weaning was 1.25 cm, with a specificity of 82.1% and a sensitivity of 97.1%.

Moreover, Jiang et al., 2004 [25] concluded that the displacement of the liver/spleen, measured by ultrasonography, is a good predictor for extubation outcome. Using a cutoff value of 1.1 cm, the sensitivity and specificity to predict successful extubation were 84.4% and 82.6%, respectively, better than traditional RSBI.

In contrast to our study, Llamas-Álvarez et al., 2017 [26] concluded that lung and diaphragm ultrasound can help predict weaning outcome, but its accuracy may vary depending on the patient subpopulation.

Our present data showed that, DRSBI is better than traditional RSBI to predict weaning outcome with a cutoff of DRSBI < 1.07 measured at 30 min. There was statistical significant difference as regard DRSBI at 1, 30, and 120 minutes among successful and failed weaning cases.

In a previous study was done by Mowafy & Abdelgalel, 2019 [8] revealed that the sample size was 106 patients, 53 patients in each group, the mean of DRSBI in weaning success patients was 1.2 ± 0.93, while in weaning failure patients was 1.7 ± 0.9 with statistical significant difference (p=0.017). They supported the evidence that the new index DRSBI is superior to traditional RSBI in predicting weaning outcome with a cutoff of DRSBI < 1.6 monitored at 30 min. with the best diagnostic accuracy for predicting weaning success.

Spadaro et al., 2016 [27] in their study enrolled 51 patients requiring mechanical ventilation for more than 48 h who were ready to perform a SBT. During the SBT they simultaneously evaluated right hemi-diaphragm displacement as well as the traditional RSBI. The areas under the ROC curves for DRSBI and RSBI were 0.89 and 0.72, respectively (P = 0.006). They concluded that DRSBI with a cutoff value 1.3 is a more accurate index than the traditional RSBI for prediction of weaning outcome from mechanical ventilation.Also, Abbas et al., 2018 [28] found DRSBI is superior to the traditional RSBI in predicting weaning outcome in COPD patients. A cutoff of DRSBI >1.9 breaths/min/mm yielded 84.6% sensitivity, 100% specificity, 100% positive predictive value (PPV), 94.9% negative predictive value (NPV) and 96% accuracy. The areas under the ROC curves for DRSBI and traditional RSBI were 0.97 (p<0.001) and 0.67 (p<0.06) respectively.

CONCLUSION

When it comes to predicting the result of weaning, the use of DETI &DRSBI to support clinical decision-making about individual liberation from mechanical ventilation has a higher diagnostic accuracy than the traditional RSBI. This is especially true when monitoring occurs thirty minutes after the beginning of SBT.

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Citation:
Kamel Desouky, M., Sawan, Z., Eldorgham, L., Abd Allah Zakzouk, M. Assessment of Diaphragmatic Excursion-Time Index versus Diaphragmatic Rapid Shallow Breathing Index to predict Successful Weaning from Mechanical Ventilation. Zagazig University Medical Journal, 2024; (3254-3264): -. doi: 10.21608/zumj.2024.279107.3275