International Journal of Chemical and Biochemical Sciences
(ISSN 2226-9614)

Journal Home page: www.iscientific.org/Journal.html

Mitral Annular Plane Systolic Excursion (MAPSE) as a Predictor of Weaning Failure in Mechanically Ventilated Patients

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Abstract

Weaning failure is multifactorial in nature; it can result from diaphragmatic dysfunction, excess mechanical load, weaning-induced cardiovascular dysfunction, or a reduced ability to clear secretions. To investigate mitral annular plane systolic excursion (MAPSE) by using M-mode echocardiography as a predictor of weaning failure and its relation to length of intensive care unit stay, and to hospital mortality, and correlation of MAPSE with APACHE II and SOFA scores as predictors of outcome. This was a prospective observational cohort study conducted on 50 patients admitted to Critical Care Medicine Department, Cairo University Hospitals (Kasr Al-Aini Hospitals), with a diagnosis of acute respiratory failure who required mechanical ventilation, from January 2019 to December 2020. There was significant relation between weaning from mechanical ventilation and APACHE II score, we found highly significant difference with SOFA score. ROC curve for detection of weaning using MAPSE showed Area Under the Curve of 0.918 with highly statistically significant relation with cut off value is 13.9 with Sensitivity 83.3% and Specificity 92.3%; and thus, MAPSE could be a good indicator for successful weaning. We concluded that; Low Mitral annular plane systolic excursion (MAPSE) could be a good predictor of weaning failure and mortality, The higher MAPSE values are correlated with lower ICU stay duration. We found that RSBI and SOFA score are predictors for successful weaning, also SOFA and APACHE II scores are indicators of mortality.

Keywords: MAPSE, Weaning failure, rapid shallow breathing index, APACHE II

Full length article *Corresponding Author, e-mail: ptrservices2022@gmail.com Doi # https://doi.org/10.62877/9-IJCBS-24-25-19-9

1. Introduction

Mechanical ventilation (MV) can be discontinued in most patients as soon as the disease that caused the acute respiratory failure improves. However, a cohort of patients (20–30%) remains ventilator-dependent for prolonged periods. Moreover, extubation failure is associated with an increased risk of mortality, ranging between 40 and 50 % [1]. Weaning failure is multifactorial in nature; it can result from diaphragmatic dysfunction, excess mechanical load, weaning-induced cardiovascular dysfunction, or a reduced ability to clear secretions. Most physicians simply look at the patient's ability to tolerate a spontaneous breathing trial (SBT) without distress to determine weaning failure [2]. A more quantitative approach takes into account the respiratory rate (RR) and VT during the SBT. The RR/VT ratio, i.e., the rapid shallow breathing index (RSBI), one of the most used clinical indices to predict weaning outcome, reflects the balance between mechanical load posed on the inspiratory muscles and the inspiratory muscles ability to face it during the weaning attempt. However, RSBI has variable sensitivity and specificity for predicting weaning outcome [3]. Cardiovascular dysfunction is one of the main causes of weaning failure, and during weaning it may involve systolic and/or diastolic alterations [4]. The weaning process comprises two stages: the progressive withdrawal from invasive ventilatory support and removal of the endotracheal tube. Time spent in the first stage represents 40% to 50% of the total period of mechanical ventilation. Several patients after a successful spontaneous breathing trial (SBT) fail in the second stage of the weaning process, requiring reintubation in 24 to 72 hours. Previous studies have reported the significance of predicting weaning success using many variables of weaning predictors, from simple subjective evaluations to complex measurements [5-6]. Mitral annular plane systolic excursion (MAPSE) also known as left atrioventricular plane displacement (AVPD), mitral annulus excursion (MAE) or mitral ring displacement is an M-mode derived echocardiographic marker of LV longitudinal function. MAPSE correlates well with other markers of LV function, is easily obtainable even for the untrained observer and in patients with poor acoustic

windows [7]. Our study was conducted to investigate mitral annular plane systolic excursion (MAPSE) by using M-mode echocardiography as a predictor of weaning failure and its relation to length of intensive care unit stay, and to hospital mortality, and correlation of MAPSE with APACHE II and SOFA scores as predictors of outcome.

2. Materials and Methods

This was a prospective observational cohort study conducted on 50 patients admitted to Critical Care Medicine Department, Cairo University Hospitals (Kasr Al-Aini Hospitals), with a diagnosis of acute respiratory failure who required mechanical ventilation, from January 2019 to December 2020. Patients admitted to the ICU with diagnosis or development of acute respiratory failure who require respiratory support via intubation and mechanically ventilation for more than 48 hours were considered eligible for the study. Informed consent was obtained from the patient. Patients with respiratory failure requiring mechanical respiratory support. Patients with clinical improvement of the underlying acute cause of respiratory failure, had stable cardiovascular status (i.e., heart rate <120 beats/min; systolic blood pressure, 90–160mmHg; and no or minimal vasopressor use, i.e., dobutamine <5μg/kg/min or noradrenaline <0.05μg/kg/min), stable metabolic status (i.e., electrolytes and glycemia within normal range, body temperature <38 °C, hemoglobinemia ≥8–10g/dL) and adequate oxygenation (i.e., arterial oxygen saturation (SaO^2) >92% with inspiratory oxygen fraction (FiO^2) ≤0.5 or arterial oxygen partial pressure to inspiratory oxygen fraction (PaO^2/FiO^2) ≥150mmHg, both with positive end expiratory pressure (PEEP) ≤8 cmH^2O) were included in the study. Patients with age <18 years. Pregnancy, presence of thoracostomy, pneumothorax, or pneumomediastinum, presence of flail chest or rib fractures, use of muscle-paralyzing agents within 48 h before the study, history or new detection of paralysis or paradoxical movement of the diaphragm, presence of large pericardial effusion, presence of severe right heart dysfunction (paradox septal motion), after cardiac surgery and presence of calcified mitral ring (severe mitral disease) were excluded from the study. All included patients were subjected to the following: Full history taking, clinical examination including (general examination, head and neck, upper limb and lower limb, abdominal, cardiac and chest examination), Routine laboratory investigation, Chest radiographs and The Acute Physiology and Chronic Health Evaluation II (APACHE II) score was introduced as a simplified modification of the original on admission.

2.1. Mechanical ventilation

All patients were intubated and mechanically ventilated under volume-controlled ventilation, and they were observed till improvement of their conditions and became eligible to enter the spontaneous breathing trial (SBT) for weaning [8].

Criteria for weaning from mechanical ventilation

Indices of oxygenation (PaO_2/FIO_2 ratio ("PF" ratio) > 200, PaO_2 (on FIO2 0.5 and PEEP 5cm H_2O) >60mmHg), Indices of respiratory muscle strength and endurance ($PaCO_2$ <50mmHg, respiratory frequency <34 breaths/min or >7 breaths/min, tidal volumes >6mL/kg and f/Vt ratio <104 breams/min/L).

2.2. Weaning Trials

Enrolled patients had a spontaneous breathing trial (SBT) that comprised spontaneous ventilation through a T-tube circuit with the FiO_2 set at the same level used during mechanical ventilation. During weaning trials, we simultaneously evaluated MAPSE, Tricuspid annular plane systolic excursion (TAPSE) by using M-mode echocardiography using GE LOGIQ V_2 Ultrasound System, with a probe 3.5 MHZ, after 30min from the beginning of the SBT, or immediately before reconnecting the patient to the ventilator in the case of SBT failure.

2.3. Measuring MAPSE & TAPSE by M-mode echocardiography during SBT

(MAPSE) is measured by the use of M-mode echocardiography in an apical view at the septal and lateral mitral annuli, in normal hearts [9,10].

2.4. Tricuspid annular planimetric systolic excursion (TAPSE)

Tricuspid annular planimetric systolic excursion (TAPSE) is recorded on M-mode using the 2D four-chamber view. The cursor was placed at the junction of tricuspid valve plan with the free wall of the RV, whereas data were averaged over five beats. A TAPSE measurement of<16 mm is highly specific for RV dysfunction. A successful weaning attempt was registered when patients were extubated and breathe spontaneously for more than 48 hours. The reinstitution of mechanical ventilation during or at the end of the SBT, reintubation within 48 hours, or the use of non-invasive ventilation (NIV) within 48 hours of extubation were registered as a failed weaning attempt [11,12].

2.5. Rapid shallow breathing index

RSBI (f/VT) = Respiratory rate/tidal volume.

A threshold of ≤ 105 is necessary to continue the SBT [13]. Outcome of the weaning attempt, length of mechanical ventilation, length of intensive care unit stays, and hospital mortality were recorded.

2.6. Statistical Methods

Data were coded and entered using the statistical package for the Social Sciences (SPSS) version 26 (IBM Corp., Armonk, NY, USA). Data was summarized using mean, standard deviation, median, minimum and maximum in quantitative data and using frequency (count) and relative frequency (percentage) for categorical data. These tests were used: Mann-Whitney test, Chi square ($\chi 2$) test and Exact test. Correlations between quantitative variables were done using Spearman correlation coefficient. ROC curve was constructed with area under curve analysis performed to

detect best cutoff value of MAPSE and other parameters for detection of weaning and mortality. P-values less than 0.05 were considered as statistically significant [14-16].

3. Results and discussion

In table 1 The age of the studied group ranged from 20 to 92 years with mean±SD of 53.82±17.59 years old and females represent more than half of participants (27; 54.0%). In table 2 There was significant relation between weaning from mechanical ventilation and APACHE II score (P-value of 0.024), with mean ±SD of 17.96 ±6.97 with successful weaning and mean of 22.27 ±5.63 in the failed weaning group, we also found highly significant difference with SOFA score (P value of 0.001). With lower scores (mean ±SD of 6.42 ±2.38) associated with successful weaning, and higher mean ±SD of 9.23 ±2.41 in the failed weaning group. In table 3 showed statistically significant difference between ventilator days and weaning outcome (P = 0.014) with less days (mean±SD of 9.38 ±5.81 days) on mechanical ventilation in successful weaning group than that in the failed weaning group (mean ±SD of 14.38 ±6.38 days), but we found no statistically significant difference regarding ICU stay and the outcome of the weaning trial. In table 4 Using Receiver-Operating Characteristic (ROC) curve analysis for detection of successful weaning trials, it illustrated that RSBI showed Area Under the Curve of 0.804 with highly significant relation as P value <0.001, with cut off value of 34.5 and Sensitivity of 62.5% and Specificity 88.5%. SOFA score also showed Area under the Curve of 0.782 with highly significant relation as P-value <0.001 with cut off value of 8.5 and Sensitivity of 79.2% and Specificity 57.7%. In table 5 Receiver-Operating Characteristic (ROC) curve for detection of weaning using MAPSE showed Area Under the Curve of 0.918 with highly statistically significant relation as P value is < 0.001 and cut off value is 13.9 with Sensitivity 83.3% and Specificity 92.3%; and thus, MAPSE could be a good indicator for successful weaning. In table 6 Receiver-Operating Characteristic (ROC) curve for detection of mortality using SOFA score showed Area Under the Curve of 0.707 with statistically significant relationship, and cut off value of 8.5, Sensitivity 51.6 % and Specificity 78.9%. Regarding APACHE II score, Area Under the Curve was 0.892 with statistically significant relationship, and cut off value of 16.5, Sensitivity and Specificity are 100%, 78.9% respectively. Indicating that SOFA and APACHE II scores are good indicators for mortality. Weaning from mechanical ventilation is an essential step in the care of critically ill intubated patients, accounting for approximately 40% of the total duration of mechanical ventilation. Given that increased time on mechanical ventilation is associated with higher mortality rates, it is crucial to safely wean the patient from the ventilator as soon as possible [2]. In the current study regarding demographic data of enrolled patients, we found 54% of the patients were females (27 patients), and mean ±SD of age was (53.82±17.59) years old. With no statistically significant difference (P value>0.05) between successful weaning and gender, but regarding age, there was a statistically significant difference as lower age had more successful weaning trial (P = 0.035). In line with Papanikolaou et al. study which evaluated LV diastolic function before and during spontaneous breathing trial (SBT), it presented an important difference (P = 0.001) between the age of those patients successfully weaned (mean ±SD 43.2 ±3.4-year-old) and those that failed (mean ±SD, 59.6 ±3.2-year-old) which is justified by physiological changes caused by aging [17]. And in another study, Burns et al., which assessed the relationship between Burns Wean Assessment Program scores and outcomes of 1889 weaning trials in patients required mechanical ventilation, with age split into quartiles (≤42, 43-54, 55-62, and 63+ years), it demonstrated that the percentages of successful attempts decrease with increasing age (91%, 91%, 87%, and 84%, respectively) (P-value = 0.02) [18]. Our study demonstrated significant difference between successful weaning group and APACHE II score (P-value of 0.024), with lower scores (mean ±SD 17.96±6.97) in the successful weaning group and higher scores (mean ±SD 22.27 ±5.63) in the failed weaning group, also we found it as a predictor for mortality (AUROC = 0.892) with highly statistically significant relation with Sensitivity and Specificity of 100%, and 78.9% respectively. In agreement with our study, A study conducted by Islam et al., evaluated APACHE II as an important parameter of weaning outcome for mechanical ventilation and found that out of 40 patients, 25(62.5%) was successfully weaned, and among the successfully weaned group, 17 (68%) had lower APACHE II score than the failed group which were statistically significant (p-value >.005) [19]. Also, Su et al., evaluated the involuntary cough peak flow and other parameters to predict the extubation outcome for 150 patients weaned from mechanical ventilation and found higher APACHE II scores (16.0 vs. 18.5, P = .018) in the extubation failures compared with the extubation successes [20]. In our study, there was highly significant difference between successful weaning and SOFA (P<0.001). With higher scores in failed weaning group (mean ±SD of 9.23 ±2.41) compared to the successful weaning group (mean ±SD of 6.42 ±2.38), also ROC curve illustrated SOFA as a predictor for successful weaning (AUROC = 0.707) with cut off value 8.5, with Sensitivity of 51.6 % and Specificity of 78.9%. Study by Shin et al., evaluated the clinical factors predicting weaning failure in patients undergoing prolonged mechanical ventilation in medical intensive care unit, and found that a high SOFA score on day 21 of mechanical ventilation could be predictive of weaning failure in patients (AUROC 0.77, 95% CI, 0.67–0.87; P=0.000) [21]. We demonstrated a highly significant difference between successful weaning with RSBI (P<0.001), we found its median in successful weaning group was 31 breaths/min/L and in failed weaning group was 57 breaths/min/L, also ROC curve for detection of successful weaning illustrated RSBI is a good predictor for successful weaning (AUROC = 0.804) with highly significant relation and cutoff value was 34.5 breaths/min/L and Sensitivity of 62.5% and Specificity of 88.5%. In a study by Youssef et al., examined the value of RSBI measured at initiation and termination of a spontaneous breathing trial (SBT) in predicting weaning outcome for patients with acute on top of chronic type II respiratory failure. The ROC curve analysis of RSBI-1 (initial RSBI) at the weaning trails and RSBI-2 after 2 hours showed cut-off values of 51 and 57 respectively. RSBI-1 showed a higher diagnostic accuracy of 61.9% compared to RSBI-2 which showed a diagnostic accuracy of 58.4% [22].

Table 1. Demographic data of the studied patients

	Count	**%**	
Sex	**Male**	23	46.0%
	Female	27	54.0%
	Mean	**Standard Deviation**	**Range**
Age	53.82	17.59	(20.00-92.00)

Table 2. Relations between clinical scores and weaning outcome

	Weaning										**P value**
	Successful (24)					**Failed (26)**					
	Mean	**SD**	**Median**	**Minimum**	**Maximum**	**Mean**	**SD**	**Median**	**Minimum**	**Maximum**	
SOFA	6.42	2.38	6.00	2.00	10.00	9.23	2.41	9.00	6.00	13.00	0.001
APACHE II	17.96	6.97	16.00	6.00	30.00	22.27	5.63	22.00	9.00	31.00	0.024

Table 3. Relation between weaning outcome and ICU stay and ventilators days

	Weaning										**P value**
	Successful (24)					**Failed (26)**					
	Mean	**SD**	**Median**	**Minimum**	**Maximum**	**Mean**	**SD**	**Median**	**Minimum**	**Maximum**	
ICU Stay	15.21	7.92	14.50	4.00	28.00	17.31	7.05	15.00	7.00	30.00	0.280
Ventilator Days	9.38	5.81	9.00	2.00	20.00	14.38	6.38	13.00	5.00	28.00	0.014

Table 4. Receiver-Operating Characteristic (ROC) curve's analysis fordetection of weaning using RSBI, SaO2 and Sofa score

	Area Underthe Curve	P value	95% Confidence Interval		Cut off	Sensitivity %	Specificity %
			Lower Bound	Upper Bound			
RSBI	0.804	< 0.001	0.683	0.924	34.5	62.5	88.5
SaO2	0.402	0.236	0.243	0.561	-----	-----	-----
SOFA	0.782	0.001	0.658	0.906	8.5	79.2	57.7

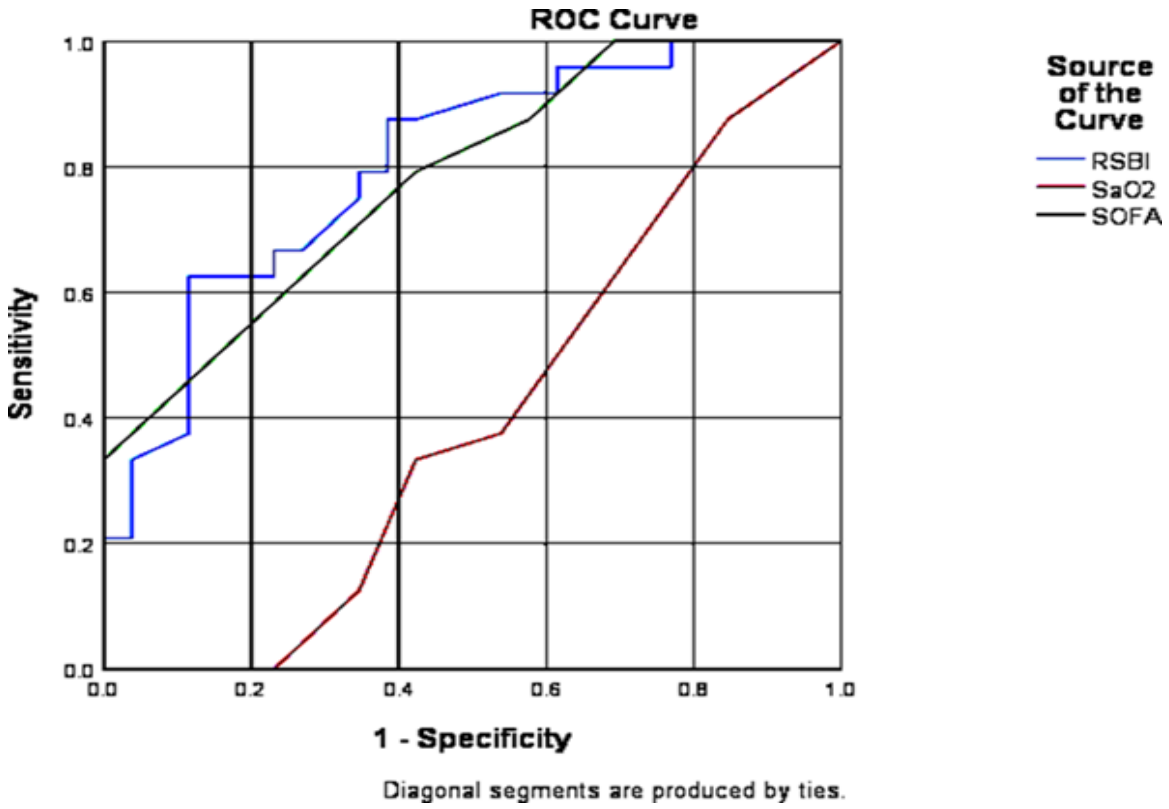

Figure 1. Receiver-Operating Characteristic (ROC) curve for detection of weaning using RSBI, SaO2 and Sofa score

Table 5. Receiver-Operating Characteristic (ROC) curve's analysis for detection of weaning using MAPSE

Area Underthe Curve	P value	95% Confidence Interval				
		Lower Bound	Upper Bound	Cut off	Sensitivity %	Specificity %
0.918	< 0.001	0.840	0.997	13.9	83.3	92.3

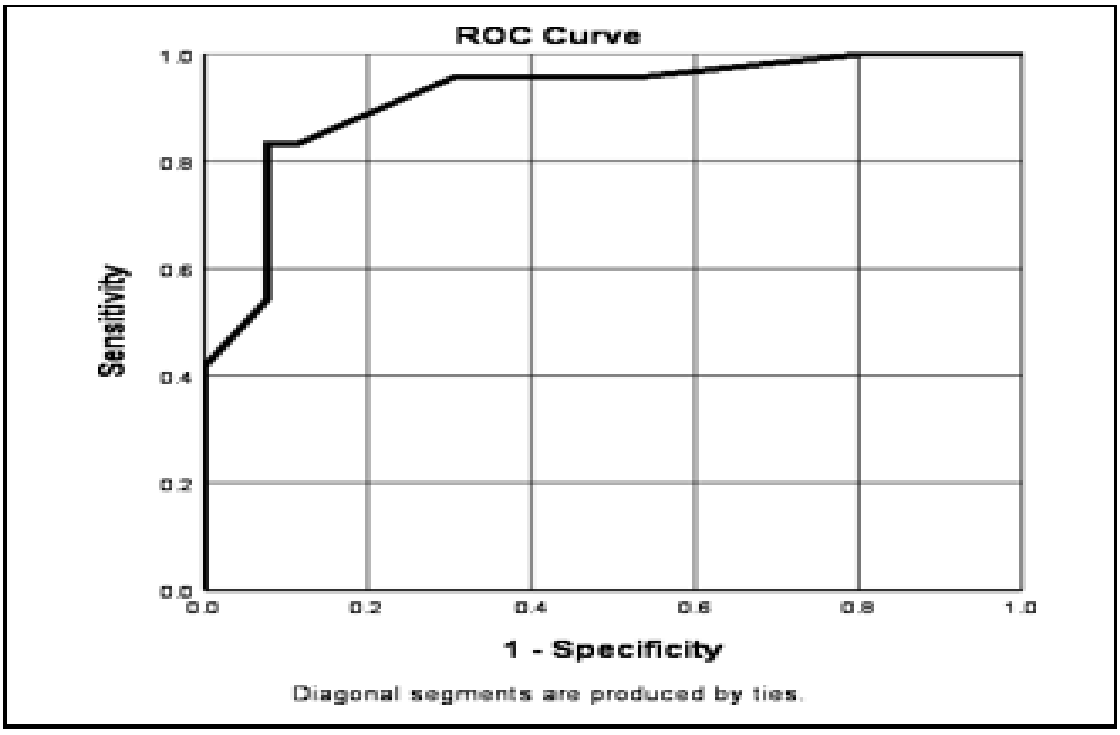

Figure 2. Receiver-Operating Characteristic (ROC) curve for detection of weaning using MAPSE

Table 6. Receiver-Operating Characteristic (ROC) curve's analysis for detection of mortality using SOFA and APACHE II scores

	Area Underthe Curve	P value	95% Confidence Interval		Cut off	Sensitivity %	Specificity %
			Lower Bound	Upper Bound			
SOFA	0.707	0.015	0.562	0.852	8.5	51.6	78.9
APACHE II	0.892	< 0.001	0.787	0.997	16.5	100	78.9

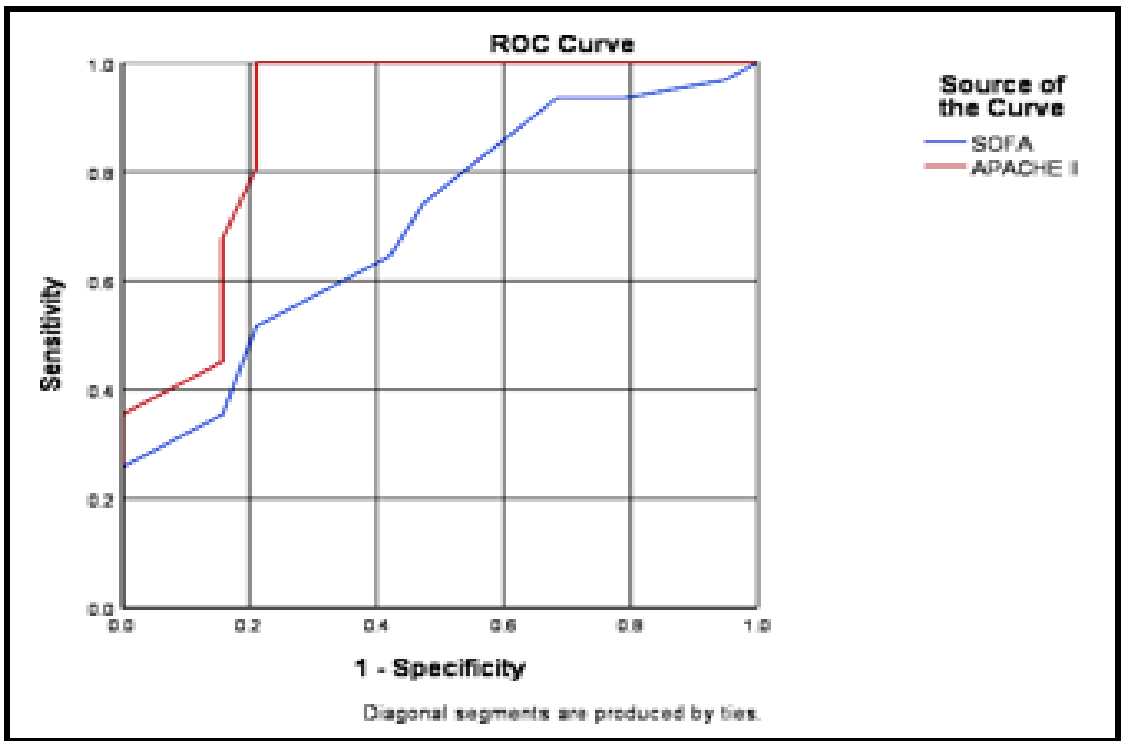

Figure 3. Receiver-Operating Characteristic (ROC) curve for detection of mortality using SOFA and APACHE II scores

On the other hand, a study conducted by Savi et al., with 500 patients demonstrated that both, RSBI at the first minute of an SBT and after 30 minutes of an SBT can predict the extubation outcome [2]. The current study illustrated statistically significant difference between ventilator days and weaning outcome with less days on mechanical ventilation in successful weaning group (P= 0.014), our result agrees with Wu et al., which also aimed to assess predictors of successful weaning from prolonged mechanical ventilation, and both have demonstrated that the longer the duration (in days) of invasive mechanical ventilation, the lower the chance of success in weaning and extubation (p <0.001) [23]. In our study, we found highly significant difference between successful weaning group and MAPSE (P<0.001). ROC curve for detection of weaning using MAPSE, in our study found that area under the curve is 0.918 with highly statistically significant relation and cut off value is 13.9mm with Sensitivity 83.3% and Specificity 92.3%. There a study by Shah et al., concluded that MAPSE as measured in critically ill mechanically ventilated patients correlates well with LVEF (P-value < 0.001), and can be used accurately to differentiate between normal or mildly impaired LVEF and moderate to severely impaired LVEF, The ROC analysis of this study showed that a MAPSE cut-off point of ≥12.5mm diagnosed normal or mildly reduced LVEF (AUROC = 0.91) with 82.14% sensitivity and 91.67% specificity [24].

3.1. Limitations

The small sample size, and possible bias related to the selective use of echocardiography are limitations of our study. Also, there are some limitations to MAPSE measurement as some of the variations of MAPSE are due to cardiac size. Theoretically, this means that the annular displacement should be normalized for heart size. This is definitely necessary in children, where the variation in cardiac size is great

4. Conclusions

We concluded that; Low Mitral annular plane systolic excursion (MAPSE) could be a good predictor of weaning failure and mortality, The higher MAPSE values are correlated with lower ICU stay duration. We found that RSBI and SOFA score are predictors for successful weaning, also SOFA and APACHE II scores are indicators of mortality. Future studies involving a greater number of patients and multiple observers are indicated to validate results of this study.

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