

**An Overview of the Predictor Standard Tools for Patient Weaning from Mechanical Ventilation**Acieh Dehghani¹, Gholamhossein Abdeyazdan², Elham Davaridolatabadi³

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Type of article: Review**Abstract**

Most patients staying in the intensive care unit (ICU) require respiratory support through a ventilator. Since prolonged mechanical ventilation and weaning from the ventilator without criteria or at the inappropriate time can result in many complications, it is required that patients be weaned off the ventilator as soon as possible. This study was conducted to investigate a few standard tools that predict successful and timely weaning of patients from the ventilator. In the literature, SOFA and APACHE II scores, along with various tools, including Burn, Morganroth, and Corgian, have been used in weaning patients from the ventilator. In most of these studies, the increase or decrease in the APACHE II score was correlated with the patient's weaning time, and this score could be used as a criterion for weaning. Several authors have expressed their belief that the SOFA score in the ICU is a good indicator of the prognosis of patient's weaning from the ventilator, length of stay, mortality, and rate of recovery. Several studies have compared SOFA and APACHE II scores and have shown that there is a positive correlation between the SOFA and APACHE II scores and that both mortality and dependence on the ventilator are related to these two scores. Another tool is Burn's weaning program. A higher Burn score indicates successful weaning off of the ventilator, successful extubation, lower length of mechanical ventilation, and shorter stay in the hospital. However, the capabilities of the Morganroth scale and the Gluck and Corgian scoring systems were evaluated only for successful weaning off of the ventilator, and a decrease in the Morganroth and Gluck scores indicated successful weaning.

Keywords: tools, APACHE II, SOFA, Morganroth, Gluck, burn**1. Introduction**

Many patients in the ICU require respiratory support by a mechanical ventilator (1). The ventilator is used to sustain gas exchange in patients who are incapable of maintaining sufficient alveolar ventilation. Typically, this device is used for patients with respiratory failure, chronic obstructive pulmonary disease (COPD), status asthmaticus, and heart failure. In addition, it is used for many patients after surgery, for drug-overdose patients, and patients with neuromuscular diseases (2). The ultimate goal of caring for patients using mechanical ventilation is to obtain spontaneous breathing and successful weaning off of the ventilator. Weaning a patient from the ventilator involves gradual movement from dependence on the ventilator toward spontaneous breathing. Thus, when respiratory support is no longer required, the patient's respiration occur naturally (3). Muscle strength reduction, COPD, heart failure, female gender, and especially reduced CO₂ response are among the reasons for prolonged use of a ventilator (4). Increase in airway resistance in patients with COPD makes it difficult to wean the patients from the ventilator. Among factors that impose a negative effect on patient's weaning from the ventilator are heart surgery in patients with cardiac dysfunction, left ventricular dysfunction, cardiogenic shock, and low ejection fraction (EF) (5). Low

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hemoglobin results in dysfunction and failure of weaning patients from the ventilator, whereas blood transfusions decrease respiratory function and facilitate patients' weaning from the ventilator (6). Prolonged ventilation and taking sedatives such as Nesdonal impose an unfavorable effect on the duration required to wean the patient from the ventilator (7). Since prolonged mechanical ventilation and weaning of the patient from the ventilator without criteria or at an inappropriate time can result in numerous complications, it is essential to wean the patient from the ventilator as soon as possible. Using the ventilator too long can lead to dyspnea or respiratory arrest. In addition, it is required to wean the patient from ventilatory support as soon as the patient is capable of spontaneous breathing. Failure in weaning patients from the ventilator increases morbidity, mortality, the duration of mechanical ventilation, and the length of the stay in the ICU (8). Reducing the amount of time the patient spends on the ventilator leads to improved quality of life, increased motor function, and sense of independence in the patients. Furthermore, quick weaning from the ventilator reduces ventilator-associated pneumonia (VAP) (9). Prolonged use of the ventilator can result in numerous complications, including respiratory tract infections, instability of hemodynamic status, sleep disorders, psychological dependence on the ventilator, higher rate of mortality, lung damage, laryngeal injuries, tracheal stenosis, sinusitis, pneumothorax, decreased cardiac output, physiological problems, reduction in oxidative enzymes in the respiratory muscles, nervous myopathy, increase in taking sedatives, higher gastrointestinal stress, skin fragility, bed sores, muscle atrophy and weakness, and pulmonary barotrauma. These direct complications could result in indirect complications, including prolonged length of stay (LOS), emotional distress, increase in expenditures, and lower satisfaction among personnel or patients and their families. Higher expenditures are mostly related to numerous tests to be conducted, drugs, and multiple imaging and radiographic techniques.

It is noteworthy that short-term mechanical ventilation decreases complications by 50% and prevents reintubation of the trachea (10, 11). Ten to 15% of trachea reintubation is acceptable for most intensive care units with ideal conditions. This means that the goal of zero percent reintubation is unrealistic in the ICU (12). Reintubation of the trachea increases the prevalence of pneumonia. About half of the crude mortality rate among patients with reintubation is associated with the development of pneumonia. In addition, patients with unsuccessful extubation stay in the ICU longer than those with successful extubation. The mortality rate among patients with unsuccessful extubation in the hospital is seven times higher. Patients with unsuccessful extubation who have survived in the hospital require six times more long-term care and rehabilitation facilities (13). Considering the unfavorable effects of reintubation, it is an important issue to predict the results of extubation to prevent its failure (12). Prediction of prolonged mechanical ventilation is a challenging issue. Currently, there is no reliable tool for doing so. Most of the time, decisions are made according to clinical criteria that are discovered with delay, and they are subjective and unreliable (14). Predictive criteria provide us with prognosis, cost-effective analyses, comparing different centers, investigating new medications, and comparing the sample with other studies. Predictive criteria of the time required to wean a patient from the ventilator could be effective in preventing disabilities, reducing the stay in the ICU, and improving the efficiency of the health care system (15). There are numerous tools to measure patients' readiness to be weaned from the ventilator. These tools investigate patients' readiness for weaning, and they result in on-time weaning (16). In general, accurate and reliable tools are required to reduce expenditures, length of stay, and early weaning from the ventilator. In different studies, various indices, scores, and tools have been used to predict the weaning time. This study was conducted to examine a few of the standard tools that are used to predict successful and on-time weaning from the ventilator.

2. Material and Methods

This is a review study, and papers published within the period of 1996-2014 were investigated. To obtain related scientific documents, web surfing was conducted in Persian and English using various keywords, including ventilator, mechanical ventilation, SOFA score, APACHE II score, Burn's wean assessment program, Morganroth and Gluck index, weaning predictor criteria, and effective factors on duration of mechanical ventilation. Conducting this search, papers related to this subject were extracted from PubMed, Magiran, Google Scholar, Elsevier, and SID databases.

3. Findings and discussion

Some studies have used the SOFA and APACHE II scores and various tools, including Burn, Morganroth and Gluck for patient's weaning from the ventilator. In this section, these tools, scores, and their relationships with weaning time are explained.

3.1. APACHE II score

From 1979 to 1982, APACHE II scores were obtained through some studies in the United States (17), and an assessment of the scores was developed by Knaus et al. in 1985 (18). After changes during these years, this score consists of three main criteria, i.e., acute physiologic score (APS), age, and history of chronic diseases. The APS score consists of 12 physiological variables, i.e., temperature, mean arterial pressure (MAP), heart rate, respiratory rate, oxygenation, arterial pH, serum sodium and potassium, serum creatinine, hematocrit, white blood count, Glasgow Coma Scale (GCS), and serumHCO₃⁻. The total score was between zero and 71, and it was evaluated at the time of admission (17). Higher scores indicate more intensive diseases and a higher mortality rate (19). The APACHE II score accurately indicates the degree of physiological disorder, and it is correlated with the clinical course and length of stay in the ICU. This scoring system is used in the ICU to evaluate, study, compare, and manage patients, predict results, and ensure quality treatment for critically ill patients (18, 20). The APACHE II score is indicative of success or failure in weaning the patient from the ventilator (21, 22). In fact, it could be used as a predictor of the results of weaning from the ventilator (8). It even has been stated that the APACHE II scoring system is the best method for predicting early weaning and the mortality of patients (19). Patients with lower APACHE II scores are more successful in treatment and weaning from the ventilator, and those with higher APACHE II scores are less successful in being weaned from the ventilator (23). In 2007, a study conducted by Matic et al. indicated that an APACHE II score of less than 20 indicated greater success in weaning the patient from the ventilator (23). However, in 2012, the study conducted by McConville et al. indicated that an APACHE II score greater than 12 is the failure index of patients' weaning from the ventilator (24). In addition, patients with unsuccessful extubation have higher APACHE II scores at the beginning of the weaning (13). A study conducted by Carpena et al. in 2010 indicated that the APACHE II score at admission time could indicate the success or failure of weaning patients from the ventilator (25). In addition, a study conducted by Zeytoun et al. in 2014 indicated that patients in the ICU who had higher APACHE II scores at admission had more severe conditions, and weaning them from the ventilator was not successful (26). Planí's study in 2010 cited by Meade et al. stated that the most promising tests to predict successful extubation are respiratory rate, rapid shallow breathing index (RSBI), and the APACHE II scores measured at admission (10). In 2013, Sanabria et al. conducted a study on predicting factors of early extubation and tracheostomy as well, and they used various criteria, including the APACHE II score, the simplified acute physiology score (SAPS), and the GSC score (14). Sanabria et al. believed that, although the APACHE score was recognized as a predictor factor, studies on populations were very diverse and heterogeneous; therefore, they concluded that this score could not be generalized to other populations (14). Currently, there is no simple index to predict mechanical ventilation time in patients in the ICU. Lack of generalizability of APACHE II could be explained by the dynamic nature of patients in ICU in that their main clinical changes occur within a few hours (14). In addition, different types of medications, differences between clinical criteria among physicians, and the relationship between known and unknown factors could conceal the real predicting factors. Sarabria et al. stated that it is not possible to predict early extubation in patients by invasive mechanical ventilation through common clinical criteria in the ICU (14). In a study conducted by Irajpour et al. in 2014, it was stated that efficiency of tools, including APACHE II, has not been specified for weaning patients from the ventilator; however, it could be slightly effective (27).

3.2. SOFA Score

In 1994, the European Society of Intensive Care Medicine defined and introduced SOFA. It was reviewed in 1996 and in 1998, and Vincent et al. assessed the SOFA scores of 1,449 patients. This score was developed to quantify the severity of a patient's illness based on the degree of organ dysfunction data on six organ failures, and the scores range from 0-4. (28). The six organ systems depending on the level of dysfunction were respiratory, nervous, cardiovascular, coagulation, hepatic and renal system. Scores range between zero and 24, and they were evaluated at admission time and daily in the ICU. A higher score indicates organ dysfunction (17). The SOFA score first was used for patients with sepsis and evaluating the morbidity in ICU patients with sepsis; however, in later years, it was realized that the SOFA system could be used for non-sepsis patients as well (29). Since SOFA criteria control daily changes of organs' functions, it could assess patients' reaction to medication. Therefore, later changes in SOFA, including any increase or decrease, could be utilized to predict possible outcomes of the ICU stay (17). The SOFA score during the first days in the ICU is a good indicator of the patient's mortality. In addition, it could be a useful tool to classify patients according to total score in clinical tests (30). In their study in 2014, Rapsang et al. cited Bale et al.'s conclusion that the mean and highest SOFA score are good predictors of mortality during a stay in the ICU (28). Using these two variables, the maximum and total organ dysfunction could be indicated for a patient or group of patients during hospitalization (30). In previous studies, it was specified that the SOFA score is correlated with the time required to wean a patient from the ventilator, and dynamic changes in the SOFA score predict patients'

weaning from the ventilator (31). The accuracy of the SOFA score appears to be significantly better than that of IPS for predicting mechanical ventilation need (MVN), and, in fact, it has greater sensitivity for the need for mechanical ventilation (32). Ismaeili et al. in their study in 2013 cited Adel's conclusion that the SOFA scoring system has high predicting value in diagnosing respiratory complications in respiratory patients in the ICU (33). In addition, Ismaeili et al. used the SOFA system in their study and stated that SOFA score predicts patients' readiness for successful extubation or its failure (33). In another study conducted on patients' weaning from the ventilator, initial SOFA score and Delta-SOFA score (difference between SOFA score when admitting and maximum SOFA score during ICU stay) were used, along with other criteria, to obtain data. It was concluded that the initial SOFA score, the duration of ventilation before patients' weaning from the ventilator, and the method of weaning the patients affected the successful weaning from the ventilator (34). In one study, it was stated that the SOFA score could be used to assess patients' response to medication and that successive changes of the SOFA score (increase or decrease) could predict the ultimate results of their stay in the ICU (including mortality) (35, 36). However, in a study conducted by Antonelli et al. in 1999, it was shown that SOFA score is a useful tool to explain the evolution of patients' condition and it is not for prediction; in fact, it gives us information (20). SOFA is a descriptive score for organ failure and dysfunction and it could be useful in diagnosing multiple traumas of patients with weak prognosis along with high possibility of a long stay in ICU (20). In a study by Paulo et al. in 2007, it was stated that the SOFA score is not reliable to predict results in ICU, although it is useful in analyzing frequency and severity of acute organic failure in connection with mortality (37).

3.3. Comparison of SOFA and APACHE II Scores

In previous studies, SOFA and APACHE II scoring systems have been compared; however, this comparison has often been conducted to predict mortality and sepsis in patients, and no comparison has been conducted between these two scores in predicting weaning time from the ventilator. For example, Bale et al., in their study in 2013, believed that to assess sepsis severity and multiple organ failures, SOFA scoring system is more successful compared to other scoring systems and it is a good predictor of mortality results (41). Haddadi et al., in their study conducted in 2014 on patients with nosocomial infections, stated that SOFA score has a higher predictive power of mortality compared to other scoring systems (42). According to the study by Tseng et al. in 2012, mortality and ventilator dependence are both related to SOFA and APACHE II scores. Higher SOFA and APACHE II scores suggest that pulmonary function is endangered and patients' weaning from the ventilator would be performed with difficulty. In addition, they state that in the onset of ventilator-associated pneumonia, SOFA and APACHE II scores are independent factors to predict ventilator dependence. In Tseng et al.'s study, sensitivity, specificity, and area under the ROC curve related to SOFA score were higher than APACHE II (43). Furthermore, it was stated that there is a strong positive correlation between SOFA and APACHE II scores at the time of admission. According to the study by Qiao et al. in 2012, mean SOFA and APACHE II scores in patients who survived were lower than those who died, and there is a positive correlation between these two scores at the time of admission ($r = 0.541$; $p < 0.01$). However, the discriminatory power of the APACHE II score is higher than that of the SOFA score, since sensitivity, specificity, and area under the ROC curve related to the APACHE II score were greater than those of the SOFA score at the time of admission (38). In 2012, Velissaris et al. reported that the SOFA score is related to the APACHE II score and mortality results. This positive correlation possibly shows that combining these two scores could improve the accuracy of individual scores (16, 39, 29). However, Mansour et al., in their study in 2013, used linear regression analysis to investigate the relationship between scoring systems and stated that there is a minor relationship between SOFA and APACHE II scores when the patient is admitted ($r^2 = 0.61$) (29). According to the research results, APACHE II score and total SOFA score were higher in those patients under prolonged mechanical ventilation than for those who received mechanical ventilation for less than seven days (44). In fact, SOFA and APACHE II scores are useful for predicting the length of stay (LOS) in the ICU, especially in the surgery ICU (SICU). However, the APACHE II score at the time of admission has no value in predicting the length of stay in the cardiology ICU (CICU) (45). However, in 2009, Millie cited Siddiqui et al. as stating that the APACHE II score at the time of admission is reliable in predicting LOS in the ICU (45).

3.4. Burns Wean Assessment Program (BWAP)

Checklist of Burns wean assessment program is a tool used to measure patient's readiness for weaning from the ventilator. This tool evaluates parameters of patients' weaning from the ventilator systematically and examines all parameters related to pulmonary function, gas changes, physiological and psychological conditions of patients. It is an easy-to-use checklist, and its parameters could be measured within 10 minutes (16). BWAP is measured daily and evaluates patients' readiness for weaning from the ventilator (46). The BWAP program consists of 26 clinical factors

that are used for patients' improvement and wellbeing (47). In a study conducted by Burn et al. in 2010, the efficiency of this checklist was evaluated for five years in the ICU, and it was shown that, for patients who stay in the ICU more than 72 hours, using this tool has resulted in successful weaning from the ventilator in 80% of cases (47). BWAP determines factors that prevent weaning from the ventilator, and it is used as a tool for systemic assessment of weaning. The BWAP score is helpful in determining patients' readiness for weaning from the ventilator (47). With a higher score, there is a chance of successful weaning; patients with scores over 90 are capable of having successful weaning from the ventilator (96%). In addition, a BWAP score of about 50 is related to successful weaning from the ventilator (47). In a study by Jiang et al. in 2014, 527 patients in need of mechanical ventilation for more than 21 days were selected. The BWAP program was used to wean these patients from the ventilator, and it was concluded that scores equal to or higher than 60% represent a successful rate of 94.3% in extubation (48). In fact, in this study it was stated that BWAP is a good predictor for the results of weaning from the ventilator extubation in those patients who require prolonged mechanical ventilation (longer than 21 days) (48). However, in another study, it was stated that the mean BWAP score was 53% in patients with successful weaning from the ventilator and 50% in patients with unsuccessful weaning. This is not a significant difference and could be the result of the small sample size (40 patients) (46). Systematic follow-up of patients using assessment scores, such as BWAP, could assist physicians in determining patients' readiness for being weaned from the ventilator and could result in more successful extubation of the patients. Furthermore, following BWAP scores and correcting factors available in the BWAP program could increase the process of successful weaning from the ventilator (47). In a study by Yazdannik et al. in 2012, it was stated that evaluating patients by a nurse and a burn tool for weaning from the ventilator decreased the duration of mechanical ventilation in patients undergoing mechanical ventilation for over 48 hours. Therefore, it reduced the length of stay and provided room or bed for others who needed medical care in this unit (49). Using BWAP as a checklist to determine patients' readiness for weaning and extubation could increase the effectiveness of both. The traditional weaning parameters, such as rapid shallow respiratory index and maximal inspiratory mouth pressure (P_Imax), affect the success of weaning patients from the ventilator; however, they have no impact on the success of extubation, i.e., successful weaning does not necessarily mean successful extubation (48). The BWAP score affects both weaning and extubation. Part of this score (respiratory mechanics, gas exchange and X-ray studies) are useful in predicting the time of weaning, and other parts of this scoring system (the ability to cough, alertness, and features of tracheal secretions) are useful in predicting the ability to support the airway and, as a result, undergo secure and successful extubation (48).

3.5. Morganroth Scale

The Morganroth scale consists of 21 variables that are evaluated every three days. Since patients received respiratory support, the ventilator score with six additional variables was added to the 21 variables (50). In fact, in 1984, Morganroth et al. published details of the "ventilator score" and the "adverse factor score," consisting of 27 variables. These scores together were related to the patient's capability of being weaned from the ventilator. However, these scores were examined retrospectively on 11 patients under prolonged mechanical ventilation (51). Factors used in the Morganroth scale include heart rate; psychological and psychomotor status; taking sedatives, antibiotics, vasopressors; body temperature; respiratory secretions; cardiac status; percentage of oxygen in the air; end-expiratory positive pressure; compliance; minute ventilation; and sensitivity of the device (27). The primary score did not predict the failure or success of weaning; however, it indicated that this score decreased significantly for patients who had to be gradually weaned from the ventilator (50).

3.6. Gluck and Corgian Scoring system

In 1996, Cluck and Corgian provided a scoring system (51) that consisted of five subsets, i.e., rapid shallow breathing index, ratio of dead space to tidal volume, static lung compliance, airway resistance, and CO₂ pressure (27) (Table 1). In a study conducted by Bruton et al. in 1999, it was stated that this system did not show any false negative results; however, it included a few false positive results (51). In the study conducted by Gluck and Corgian in 1996, 20 patients entered the study with prolonged connection to the ventilator (50). The five parameters they mentioned were obtained from the study of two Latin texts on intensive care that had chapters related to weaning patients from ventilators. Data were collected on the day the patients were admitted to the hospital. In this study, electrolytic balance and diet were considered when the patients were admitted (50). In Gluck's and Corgian's study, several physiological parameters were identified that prospectively could be used for patients and that were capable of predicting success or failure when weaning patients from the ventilator (50). This scoring system has logical sensitivity and positive and negative predictive values. In addition, its parameters are inexpensive, and they can be measured and calculated easily at the patient's bedside (50). In this study, it was concluded that a score greater than

3 was related to failure in weaning the patient from the ventilator, and a score less than 3 was related to successful weaning. The meaning of a score of exactly 3 was not presented (50).

Table 1. Gluck and Corgian Scoring System

Indices	0	1	2
RSBI (f/vt)	< 120	120-180	> 180
VD/VT	<0.64	0.64-0.74	0.74>
Compl (st)	> 36	32-36	< 32
Resistance	< 9	9-17	> 17
PaCO ₂		> 64	

VD/VT: dead space to tidal volume ratio, Compl (st): static lung compliance, Resistance: airway resistance

3.7. Comparing Burn's, Morganroth's and Gluck & Corgian's Programs

So far, no comparison has been conducted between the three scoring systems of Burn, Morganroth, and Gluck & Corgian. However, it could be stated that the Burn program consists of special, objective criteria related to physiological (respiration, nervous status, diet, and hemodynamic) and psychological conditions, while other tools only investigate parameters related to respiratory and pulmonary functions or some other parameters in patients (16). As stated before, a greater Burn score implies successful weaning from the ventilator, successful extubation, shorter duration of mechanical ventilation, and shorter length of stay in the hospital (47, 49). However, the capabilities of other two systems were evaluated only for successful weaning from the ventilator, and it has been stated that a lower score implies successful weaning (50). In addition, the prediction capability of the Morganroth scale has not been evaluated prospectively (51). However, in some studies, it has been stated that Burn's and Gluck's systems could be used for patients prospectively (47, 50).

4. Conclusions

Weaning of patients from ventilators is a costly and complicated process. To prevent the complications associated with prolonged mechanical ventilation and to predict successful weaning from the ventilator, certain criteria and indices are required. Parameters could be useful for weaning from the ventilator, especially when it is difficult to make decisions concerning weaning (52). Using structured weaning tools relative to commonly performed methods in the ICU shortens the duration of mechanical ventilation, shortens the patient's length of stay in the ICU, and reduces expenditures along with fewer unsuccessful extubations. It is suggested that additional studies be conducted to determine and evaluate simple, yet accurate and reliable, predictive tools.

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Conflict of Interest:

There is no conflict of interest to be declared.

Authors' contributions:

All authors contributed to this project and article equally. All authors read and approved the final manuscript.

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