

AN INTEGRATIVE REVIEW OF EVIDENCE-BASED PARAMETERS UTILITY IN
PREDICTING PATIENT SUCCESS IN MAINTIAINING SPONTANEOUS
VENTILATION POST-EXTUBATION

by

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DEDICATION

I dedicate this professional paper to my wonderful children; Mckenzie, Katherine, Domminick, and Devon along with my parents, Wayne and Louise Billings. Without you, this wouldn't have become a reality.

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GLOSSARY

Endotracheal Intubation-Insertion of a specialized tube through the mouth into the trachea, for the purpose of maintaining a patent airway, managing overwhelming secretions, providing oxygenation or mechanical ventilation.

Mechanical Ventilation-The actual process of providing ventilation with a ventilator in order to maintain respiratory function.

Positive End Expiratory Pressure (PEEP)- A method of ventilation in which airway pressure is maintained above atmospheric pressure at the end of exhalation by means of a mechanical impedance, usually a valve, within the circuit. The purpose of PEEP is to increase the volume of gas remaining in the lungs at the end of expiration in order to decrease the shunting of blood through the lungs and improve gas exchange. (MedicineNet.com)

Rapid Shallow Breathing Index (RSBI)-Ratio of respiratory frequency to tidal volume during the first minute immediately after disconnection from ventilatory support while patients are still intubated and breathing spontaneously on room air. Threshold value 105 breaths per minute/liter (Tobin and Yang, 1991).

Weaning- The entire process of liberating the patient from mechanical support and from the endotracheal tube, including relevant aspects of terminal care (Epstein, S. K., 2009).

ABSTRACT

The purpose of this integrative literature review is to identify the current standard of care in determining mechanically ventilated patients' readiness for extubation and evidence-based parameters utility in predicting the patients' maintenance of unassisted ventilation post-extubation. This topic was explored using an integrative literature review. Literature was gathered by searching databases with key search terms related to endotracheal intubation and mechanical intubation. A review of abstracts using the inclusion and exclusion criteria was conducted to determine which studies would be incorporated. Next, the literature selected was sorted into three categories, a) reviews of the current standard of care in determining a patients' readiness to wean from mechanical ventilation; b) measurement technique, validity, and use of the RSBI; and c) other parameters in predicting successful extubation. Results of this integrative literature review showed the current standard of care in extubation to be 1). Patient's underlying reason for intubation is resolving and patient is medically stable 2). A spontaneous breathing trial is attempted 3). If tolerated, patient continues to second spontaneous breathing trial that is longer in duration (30-120 minutes). 4). If the second spontaneous breathing trial is tolerated, the patient is extubated. The spontaneous breathing trial tolerance predicts approximately 86% of successful extubations. The next purpose was to identify evidence based parameters utility in predicating patients' maintenance of unassisted ventilation post-extubation. The rapid shallow breathing index was review along with the integrated weaning index, swallow study data, addition of dead space and involuntary cough peak flow. These parameters were shown to approximate the spontaneous breathing trial prediction data. In conclusion, determining the value of the rapid shallow breathing index would benefit patients being extubated and a shift in paradigm from indicators of failure to indicators of success may prove helpful in proceeding with determining a patient's ability to maintain spontaneous ventilation post-extubation.

INTRODUCTION

Each year hundreds of thousands of patients endure the physical and psychological stress associated with mechanical ventilation (Blackwood, 2000; Larson, Ahijevych, Gift, Hoffman, Janson, Lanuza, Leidy, Meek, Roberts, Weaver, and Yoos, 2005; McIntyre, 2004). Between 1999 and 2006, the number of patients discharged with a principal procedure of respiratory intubation and mechanical ventilation increased by 164,000 (National Center for Healthcare Statistics, 2010). Thousands of healthcare provider hours and millions of healthcare dollars are spent on the approximately 12% to 25% (Eskandar & Apostolakos, 2007. Solsana et al., 2009) of patients who, once extubated, must be reintubated due to failure to maintain spontaneous ventilation post-extubation.

Pre-extubation, patients who fail extubation do not differ significantly in their clinical presentation from patients who are successful. In order to distinguish these two groups of patients, extubation success and extubation failure, various evidence-based parameters have been employed with varying levels of success. Larson et al. (2005), called for studies to “better understand the factors that facilitate survival and recovery in mechanically ventilated patients, including weaning from prolonged mechanical ventilation” (p 476). It is vital that critical care practitioners identify a reliable evidence based parameter or method of determining a patients ability to maintain spontaneous ventilation post extubation.

The history of mechanical ventilation extends from the 1800’s to contemporary intensive care units (ICU’s). Mechanical ventilation using the tank respirator (negative

pressure) was utilized starting in the mid 1800s to the mid 1950s. It was implemented extensively during the poliomyelitis epidemic of the 1950s. The 1960s and 1970s brought the advent of modern endotracheal intubation and mechanical ventilation (Kotur, 2004). Endotracheal intubation and mechanical ventilation has been the focus of much study throughout the last 40 years. Endotracheal intubation and mechanical ventilation are now the primary intervention used in ICU's. Endotracheal intubation and mechanical ventilation are not without potential life-threatening complications making successful extubation as soon as medically possible an important goal in critical care and a significant predictor of positive patient outcomes. Even with technological advances, increasing survivability and life expectancy following critical illness, devastating injury, and disease, a critical question remains unanswered: Which evidence-based weaning parameter accurately predicts a patient's maintenance of spontaneous ventilation post-extubation? The purpose of this integrative literature review is to identify the current standard of care in determining mechanically ventilated patients' readiness for extubation and evidence-based parameters utility in predicting the patients' maintenance of unassisted ventilation post-extubation.

LITERATURE REVIEW

Endotracheal intubation and mechanical ventilation are two separate, distinct processes that frequently must occur together in order to be useful in critical care. Endotracheal intubation is the insertion of a specialized tube through the mouth into the trachea, for the purpose of maintaining a patent airway, managing overwhelming secretions, and providing oxygenation or mechanical ventilation. Mechanical ventilation is the actual process of providing ventilation with a ventilator in order to maintain respiratory function. Endotracheal intubation and mechanical ventilation are initiated to support respiratory function in patients with a medical issue that led to respiratory failure. Endotracheal intubation and mechanical ventilation are the most frequently performed and most costly interventions utilized in intensive care units (Eskandar & Apostolakos, 2007; Hasani & Grbolar, 2008). As the most frequently performed intervention in intensive care units, increasing positive outcomes in extubation will affect many patients by reducing complications. As endotracheal intubation and mechanical ventilation are the most costly interventions used in critical care, decreasing the need for reintubation and further mechanical ventilation will significantly impact the healthcare dollars spent each year on these interventions.

Two common themes related to the importance of predicting a patient's ability to maintain spontaneous ventilation post extubation are increased healthcare costs and complications of mechanical ventilation (both with delayed extubation and with reintubation, if extubation is unsuccessful). Initial costs of intubation and mechanical ventilation on day one are approximately \$4000 higher than typical intensive care day

charges. Costs stabilize on day three and thereafter add approximately \$1500 per day to intensive care unit costs (Dasta, McLaughlin, Mody & Tak, 2005; National Center for Healthcare Statistics, 2010). Endotracheal intubation and mechanical ventilation contributed most significantly to hospital costs in 2006, estimated at \$15.7 billion dollars. The cost of reintubation, replacement of an endotracheal tube after failed extubation, has been calculated at approximately \$1000 (healthcare provider time and necessary supplies) (Curry, Cobb, Kutash, & Diggs, 2008). Hospital charges, length of stay, and risk of complications increase with each day a patient is intubated. With costs of healthcare and resource utilization continuing to escalate in all areas (Congressional Budget Office, 2008), predicting a patients' ability to maintain unassisted ventilation post-extubation is paramount.

Schweickert, Gehlbach, Pohlman, Hall, and Kress (2004) identified seven significant complications of mechanical ventilation. These were ventilator-associated pneumonia (VAP), upper gastrointestinal (GI) hemorrhage, bacteremia, barotrauma, venous thromboembolic disease, cholestasis, and sinusitis. Each of these complications places a critically ill patient in a more vulnerable medical condition.

Mechanical ventilation places patients at a 6-21 higher risk for healthcare associated pneumonia than non-ventilated patients (Tablan, Besser, Bridges, & Hajieh, 2003). Mortality rates for healthcare associated pneumonia are high, with VAP accounting for as many as 60% of deaths related to healthcare infections. The definition of VAP, according to the Institute for Healthcare Improvement is "pneumonia in a patient intubated and ventilated at the time of or within 48 hours before the onset of the event (diagnosis of ventilator-associated pneumonia)". According to Tablan et al, (2003),

“Hospital associated pneumonia can prolong ICU stay by an average of 4.3-6.1 days and hospitalization by 4-9 days. An estimate of the direct cost of excess hospital stay due to VAP is \$40,000 per patient” (p 7). In a study by Kollef, Nathwani, Merchant, Gast, Quintana, and Ketter (2010) “attributable hospital costs (to VAP) ranged from \$10,000-\$12,000 per episode” (p 14). The difference in estimated cost may be due to regional differences in hospital costs and treatment. Kollef et al. also explored a potential cost differential in treatment of VAP. Results showed the use of doripenem versus comparators in the treatment of VAP found “statistically significant shorter durations of mechanical ventilation (median, 7 versus 10 days) and hospitalization (median, 22 versus 26 days) than with the use of comparator antibiotics (piperacillin/tazobactam or imipenem) in a pooled analysis of two phase III studies (p 6). Either estimate of cost has a significant impact on healthcare costs of the mechanically ventilated patient.

A study by Mutlu, Mutlu, and Factor (2000) identified GI complications as a potential factor significantly contributing to increased length of stay and mortality in the ICU patient. While upper GI hemorrhage was recognized as the most significant GI complication noted in mechanically ventilated patients (Schweickert et al., 2004; Mutlu, Mutlu, & Factor, 2000) Mutlu, Mutlu, and Factor (2000) also recognized stress ulcer, GI hypomotility, erosive esophagitis, diarrhea, ileus, atonic gallbladder, and the possibility of acute pancreatitis as other GI complications associated with mechanical ventilation.

Barotrauma, as defined by Anzueto et al., (2004), is “the development of air outside the tracheobronchial tree resulting from presumptive alveolar rupture and manifested by at least one of the following: interstitial emphysema; pneumothorax; pneumomediastinum; or subcutaneous emphysema” (p 614). Barotrauma can lead to

increased cost and length of stay in ICU for the mechanically ventilated patient particularly if the barotrauma requires treatment i.e., radiographs and chest tube insertion. In addition to barotrauma, diaphragmatic atrophy and contractile dysfunction are being studied as a complication of mechanical ventilation.

Prolonged mechanical ventilation (longer than three days) can lead to diaphragmatic atrophy and contractile dysfunction. This atrophy and dysfunction causes further delay in extubation (Powers, Kavazis, & Levine, 2009) thus extending length of stay and increasing ICU costs. Mechanical ventilation carries a mortality rate of approximately 26% (National Center for Healthcare Statistics, 2010). The costs, both in healthcare dollars and physiologic damage of the patient, are amplified by the length of time the patient remains intubated.

The potential for complications of mechanical ventilation increase with the length of time the patient is intubated (Anzueto et al., 2004; Dasta, McLaughlin, Mody, & Piech, 2005; Mutlu, Mutlu, & Factor, 2001; Powers, Kavazis, & Levine, 2009; Schweickert et al., 2004). It is imperative that healthcare providers be able to determine, with a higher degree of confidence, the outcome of extubation.

METHODS

The purpose of this integrative literature review was to identify the current standard of care in determining a mechanically ventilated patients' readiness to extubate and evidence-based parameters utility in predicating the patients' maintenance of unassisted ventilation post extubation. The starting date of the integrative review was August of 2010 with an end date of January 2011.

The initial review of literature consisted of a review of abstracts gathered during the literature search. Inclusion and exclusion criteria were used as the first screen of abstracts. Inclusion criteria for the integrative review were: adult, general intensive care unit, mechanically ventilated, endotracheal tube. Exclusion criteria included: Special equipment required to perform the recording and/or testing of the respiratory parameter, specialty intensive care unit, long-term respiratory care units, neonates, pediatrics, geriatrics, open-heart surgery, tracheostomy, nasotracheal intubation, other specialties of surgery e.g., cardiothoracic procedures, and respiratory disease e.g. chronic obstructive pulmonary disease, asthma. According to the American Association for Respiratory Care (AARC; 2007) "Guidelines for Removal of Endotracheal Tube", there are some known risk factors for extubation failure. The known risk factors meaningful to this integrative literature review were: age greater than 70 (geriatrics) and less than 24 months (neonates and infants), increased length of mechanical ventilation, and difficult airway. Nasotracheal intubation frequently indicates either a difficult airway or facial and neck surgery, both of which lead to complications in mechanical ventilation and the weaning process. Nasotracheal intubation is associated with complications that are significantly

different than endotracheal intubation and have the potential to affect the decision to extubate and the ability of the patient to maintain spontaneous ventilation post-extubation. The complications of nasotracheal intubation may include epistaxis, hematoma/abscess, trauma to nasal septum, pharyngeal tonsils, infection (otitis, sinusitis, and bacteremia), turbinate fracture, and retropharyngeal dissection (Rector, DeNuccio, & Alden, 1987; Landess, 1994; Piepho, Thierbach, & Werner, 2005). Underlying respiratory disease frequently results in a higher rate of complications and difficult weaning (Sporn & Morganroth, 1988). These diseases, in particular chronic obstructive pulmonary disease and asthma, were excluded due to the change in physiological function and parameters associated with the disease process. During the initial phase (review of abstracts) of the literature review, it was noted that there was a preponderance of research devoted to preventing ventilator acquired pneumonia (VAP) and other complications of mechanical ventilation. While these measures are proving to decrease the morbidity, mortality and healthcare resource utilization of the mechanically ventilated patient, identifying the best practice standard in use of weaning parameters to determine successful maintenance of spontaneous ventilation after extubation will contribute toward positive outcomes for mechanically ventilated patients. After the initial screening of abstracts, articles were reviewed.

Table 1. Levels and Types of Evidence

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Level I: Systematic review or meta-analysis															
Level II: Randomized Controlled Trial															
Level III: Controlled trial without randomization		X		X				X		X	X	X	X	X	X
Level IV: Case-control or cohort study			X												
Level V: Systematic review of qualitative or descriptive studies															
Level VI: Qualitative or descriptive study (includes evidence implementation projects)									X						
Level VII: Expert Opinion or consensus	X				X	X	X								
1-Boles et al (2007), 2-Bein et al (2010), 3-Colonel et al (2008), 4-El-khatib, Zeineldine, and Jamaledine (2008), 5-Epstein (2009),6-Eskandar and Apostolagos, (2007), 7-MacIntyre, (2007), 8-Monaco et al (2010), 9-Mont' Alverne, Lino, and Bizerril, (2008), 10-Nemer et al (2009), 11-Patel et al (2009), 12-Segal et al (2010), 13-Solsona et al (2009), 14-Su et al (2010), 15-Teixeira et al (2008).															

Table 1 delineates the level of evidence for each included study. The majority of studies were either expert opinion or consensus and controlled trials. Each article was reviewed for scientific rigor, sample size, and ability to be generalized to the endotracheal

intubated and mechanically ventilated ICU population. Each article that passed this screening was entered into an annotated bibliography. Each entry in the bibliography was then compared for themes. Emerging themes i.e., rapid shallow breathing index, spontaneous breathing trials, and other parameters for prediction of extubation outcome were then used to organize the literature.

Table 2. Inclusion criteria for Rapid Shallow Breathing Index (RSBI) studies

Study	Bein et al (2010)	El-Khatib et al (2008)	Monaco et al (2010)	Patel et al (2009)	Segal et al (2010)	Teixeria et al (2008)
Length of mechanical ventilation			> 24 hrs of mechanical ventilation	>72 hrs and 8 hrs a day	>48 hrs	>48 hours
Type of intubation					Oral	
Age				> 18 yrs	>18 yrs	
PEEP <5 cm H ₂ O	Yes	Yes	<10 cmH ₂ O	5-8 cm H ₂ O		
Hemoglobin			>7 g/dl		>8 g/dl	
pH					> or = 7.3	
Potassium			3-5			
Sodium			128-150			
Temperature			36-38.5 c		<38c	
PO ₂ and FIO ₂ ratio 200 or greater	Yes	Yes			Yes	
FIO ₂	40%	40%		<50%		
Hemodynamic stability (No vasopressors)	Yes	Yes	Reduced or unchanged dose over previous 24 hrs	Yes	Yes	
No continuous administration of sedation	Yes	Yes				
Glasgow Coma Scale	> 8				>10	
Spontaneous respiratory rate			> 6 bpm			

It was also noted during this phase that there is a difference in definition of terms that varies between disciplines, facilities, and researchers. An example of this difference in definition of terms is seen in the criteria used to establish time of readiness to wean. Several studies began their research timeframe when the patient was determined to be ready to start weaning as assessed by the healthcare team (Nemer, Barbas, Caldeira, Carias, Santos, Almeida, Azeredo, Noe, Buimaraes, & Souza, 2009). The criteria for establishing time of readiness to wean are not clearly delineated. While each study began when the patient was determined ready to wean, the criteria to fit this definition is listed but is not standardized across the studies. Each study used similar criteria based on the AARC guidelines but each was different. Exclusion criteria were also not standardized. Esteban et al (2007) stated, “We, like many clinicians, made a sharp distinction between detecting readiness to liberate from the ventilator and true weaning” (p. 175). Several studies noted this difference in definition of terms directly. The variance in terminology makes it critical to determine the definitions used in each study and then group studies according to compatible terminology. The variance in terminology also makes a linear comparison of the literature difficult.

A frequently used and commonly accepted parameter of predicting extubation success noted in the literature review is the rapid shallow breathing index (RSBI) first researched by Tobin and Yang in their seminal work “A Prospective Study of Indexes Predicting the Outcome of Trials of Weaning from Mechanical Ventilation” (1991). The original RSBI study is one of two significant research works in the documentation of the evolution of mechanical ventilation over the last 20 years. Secondly, the McMaster’s Report (1999) was commissioned and became the basis of the “Evidence-based

ventilator weaning and discontinuation” (MacIntyre, 2004; 2007) guidelines endorsed by the American College of Chest Physicians (ACCP), Society for Critical Care Medicine (SCCM), and AARC. In many of the studies included in this integrative literature review, inclusion criteria for subjects were not uniform. While the AARC (2007) guidelines were almost universally applied to determine readiness to wean, some studies used increased rigor when developing inclusion criteria or loosened criteria in one or two of the recommendations.

The AARC guidelines were updated in 2007. Due to these updated guidelines, reviewed with rigor and accepted by the ACCP, SCCM, and AARC, along with their almost universal use in the literature related to mechanical ventilation and weaning, January 2007 was chosen as the starting date for the literature review. January 2011 was the closing date for literature included within this integrative literature review.

The following electronic databases were searched:

- Cochrane Library
- Ebsco
- CINAHL
- PubMed
- National Institutes of Health
- Agency for Healthcare Research and Quality
- National Guideline Clearinghouse

The following terms were used to search the specified databases (alone, all, and in various combinations):

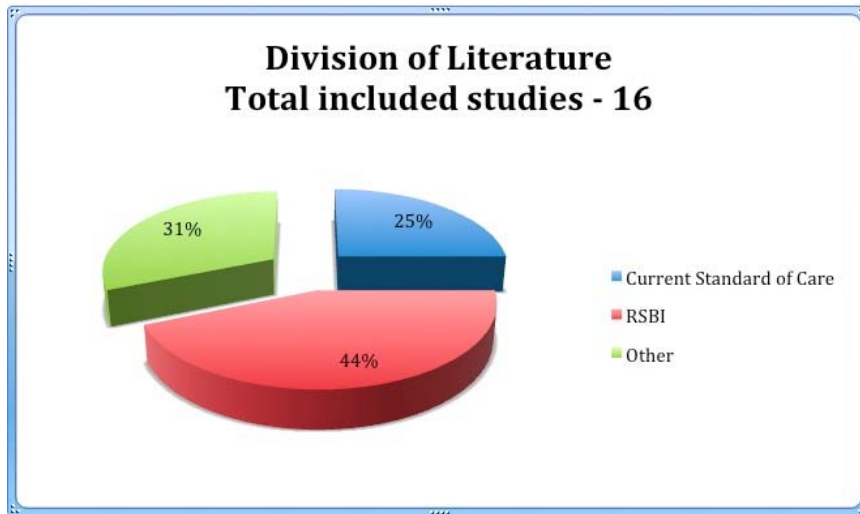
- Weaning parameters
 - Weaning parameters, adults
- Mechanical ventilation
- Extubation
- Extubation, adults
- Prediction, extubation, adults
- Predictor of successful extubation
- Extubation success
- Rapid shallow breathing index
- Endotracheal intubation
- Reintubation
- Respiratory

Using a variety of search terms in multiple databases, a pool of literature was identified related to the purpose of this integrative literature review which is to identify the current standard of care in determining mechanically ventilated patients' readiness for extubation and evidence-based parameters utility in predicting the patients' maintenance of unassisted ventilation post-extubation.

RESULTS

The purpose of this integrative literature review was two fold: 1) Identify the current standard of care in determining mechanically ventilated patients' readiness for extubation and 2) Evidence-based parameters utility in predicting the patients' maintenance of unassisted ventilation post-extubation. Sixteen studies were chosen and sorted into three categories for this integrated review; a) reviews of the current standard of care in determining a patients' readiness to wean from mechanical ventilation, b) measurement technique, validity, and use of the RSBI, and c) other parameters in predicting successful extubation. Figure 1 shows the distribution of the chosen literature into the three categories. Four studies were reviews of current parameters in use to determine extubation success and the current standard of care in ventilator weaning and discontinuation. The reviews of current parameters scrutinized causes of extubation failure, predictive indices, and current clinical standards of determination of readiness to extubate. Seven studies investigated the measurement and validity, and a use of the RSBI. Five studies examined other parameters and their ability to predict successful extubation. These consisted of a variety of techniques applied to the prediction of extubation success. First, the current standard of care in determining mechanically ventilated patients' readiness for extubation will be addressed.

Figure 1. Division of literature into themes



While individual healthcare providers and facilities may have their own specific criteria to determine readiness to extubate, the process of determining readiness to wean is straightforward. The current standard of care in determining a patients' readiness to maintain spontaneous ventilation post extubation begins when the medical team determines that the patient's underlying reason for intubation is resolving and the patient is considered medically stable (cardiovascular and respiratory function are being maintained within normal parameters with minimal or no vasoactive intravenous medications) (Boles, 2007; MacIntyre, 2007; Epstein, 2009; Eskandar & Apostolakos, 2007). The first step in identifying patients that are ready to wean is to screen all patients that are experiencing a resolving underlying condition and are medically stable (Boles, 2007; MacIntyre, 2007; Epstein, 2009; Eskandar & Apostolakos, 2007). After this screen, a spontaneous breathing trial (SBT) is attempted. This initial SBT is short (minutes) and is evaluated using the RSBI. The RSBI is the final measure of readiness to attempt a

longer (30-120 minute) SBT. The RSBI is calculated by dividing the tidal volume by the respiratory rate while the patient breathes spontaneously through a T-piece (original method) or using the continuous positive airway pressure (CPAP) setting on the ventilator (may result in lower RSBI values). Tobin and Yang (1991) determined this value to be less than 105 breaths per minute per liter when measured via a T-piece. The RSBI is the chief determinant in the continuation of the weaning process or in returning the patient to ventilatory support (mechanical ventilation).

The second SBT is a 30-120 minute trial of breathing without ventilatory support. Based on the patients' ability to tolerate the SBT, a decision is made to either attempt extubation or continue with endotracheal intubation and mechanical ventilation (Boles, 2007; MacIntyre, 2007; Epstein, 2009; Eskandar & Apostolakos, 2007). This is the timeframe of interest to this integrative literature review. At this point in the weaning process, a successful SBT predicts approximately 86% of successful extubations. Reducing the rate of reintubation would greatly benefit the patient and the healthcare outcome by reducing trauma and cost. Following the successful SBT, what evidence-based parameters accurately predict a patients' maintenance of spontaneous ventilation post extubation? This is the second question this integrative literature review attempted to answer.

The second purpose of this integrative literature review was to identify evidence-based parameters utility in predicting the patients' maintenance of unassisted ventilation post-extubation.

Measurement and Validity of the RSBI

There is a significant difference in clinical practice in the measurement technique of the RSBI. These differences create enough effect on the outcome of the RSBI to change a patients' status as a potential extubation candidate. Approximately 50% of private hospitals and 49% of public hospital physiotherapist (European equivalent of a respiratory and physical therapist) measure RSBI values using the CPAP setting on the ventilator versus the original method pioneered by Tobin & Yang (1991) in which the RSBI was measured during T-piece ventilation (Mont'Alverne, Lino, & Bizerril, 2008). The results of this variation in technique to measure the RSBI were found to be "in agreement with the original study carried out by Soo Hoo and Park, in the city of Los Angeles and by Rodrigues et al. among respiratory physiotherapists in the city of Sao Paulo" (p. 152), making the results of the study generalizable to a greater population. Patel, Ganatra, Bates, and Young, (2009) found that measurement of the RSBI via the ventilator setting CPAP or with the addition of PEEP lowers the RSBI value significantly enough to include the patients in the extubation pool while Bien et al., (2010) found no difference among the RSBI measured under five different ventilatory strategies in the same patient group.

Monaco, Drummond, Ramsay, Servillo, and Walsh, (2010) also studied measurement and validity of the RSBI to predict early weaning outcomes. The method used by Monaco et al., differed significantly from Patel et al., (2009) and Bein et al., (2010) in that pressure support ventilation (PSV) was employed instead of a SBT and the RSBI was measured on CPAP of 5. Monaco et al., (2010) concluded that "tidal and

minute volume, respiratory rate, and rapid shallow breathing index values at the end of a controlled reduction in mechanical ventilator support were not clinically useful tests to predict subsequent successful weaning from mechanical support in the following 24 h.” (p. 332). El-Khatib et al., (2008) supports the findings of Patel et al., (2009) in that 36% (13 of 36) of patients lower their RSBI value enough when CPAP or PEEP is used in the measurement to meet the criteria to be extubated. After noting the differences in clinical practice and technique in measurement in the application of the RSBI, timing of the RSBI measurement is viewed next.

Single Versus Serial Reading of the RSBI

Measurement of the RSBI over the time of an SBT and noting the percent change is being studied as a potential predictor of extubation success. Segal, Oppenheimer, Goldring, Bustami, Ruggiero, Berger, and Fiel, (2010) studied the RSBI at multiple time points during a 120-minute SBT versus obtaining a single point value to predict extubation success. The authors found that the extubation failure group showed an increase in percentage of RSBI value over the baseline or initial value. This is termed the “evolution of pattern of breathing” (p. 487). Segal et al., (2010) determined that an “increase in RSBI of <5% (at the 30 minute reading) from the initial value predicted extubation success” (p 495) with more accuracy than the single value prediction. In a similar study, Teixeira, Teixeira, Hoher, de Leon, Brodt, and Moreira, (2008) measured RSBI values at 1-minute and then 30-minute intervals over the course of a 120-minute SBT. While they found no significant difference in RSBI values between extubation success and extubation failure groups, there was an increase in RSBI value at 30 minutes

in the extubation failure group. Teixeira et al., (2008) acknowledged the Segal et al., (2010) study noting differences in methodology and potential reasoning behind the differing results. The percent change in RSBI over the time of a SBT shows some promise as a predictor of extubation success.

Other Parameters

Table 3. Percentage of Extubation Failure When Extubation Decision Based on Successful SBT and Studied Parameter

Study	Evidence Based Parameter	Experienced Extubation/Weaning Failure
Colonel et al (2008)	Swallow Study Data	16% (Experienced extubation failure)
Nemer et al (2009)	IWI	15.27 % (Experienced weaning failure)
Solsana et al (2009)	100 ml of dead space	14.5 % (Experienced extubation failure)
Su et al (2010)	Involuntary cough peak flow (CPF _i)	21.3% (Experienced extubation failure)

Solsana, Diaz, Vazquez, Garcia, Zapatero, and Marrugat, (2009) took an interesting approach to determination of readiness to extubate. Using the AARC guidelines to determine patient readiness to complete an SBT, 100 milliliters (mL) of dead space was added to the endotracheal tube at the end of a successful 120-minute SBT then observed the patient for signs of intolerance. Signs of intolerance are the same criteria for signs of intolerance of an SBT. Using these observations after adding 100 mL of dead space, Solsana et al., (2009) achieved an extubation failure rate of 14.5%. It was noted that the one variable that independently correlated with extubation failure was intercostal retractions during the addition of dead space.

Another new variable being studied is the use of swallow studies to determine potential extubation success. Colonel, Houze, Vert, Mateo, Megarbane, Goldgran-Toledano, Bizouard, Hedreul-Vittet, Baud, Payen, Vicaut, and Yelnick, (2008) used tests of swallowing function prior to extubation. The causes of reintubation in this patient group were identified and then correlated to the results of the swallow studies performed. 78% of reintubations were successfully predicted using the bedside swallow studies. This study uses swallow studies that also correlate with cough strength and ability to maintain airway clearance following extubation. Su et al., (2010) also reviewed involuntary cough strength as a predictor of maintenance of successful extubation. The outcome of the Su et al., study correlated with the Colonel et al., (2008) study; 78.7% of extubations were successful.

Notably, one study explored the creation and testing of a new weaning index (Nemer, et al., 2009). The integrative weaning index (IWI) combined the most accurate parameters associated with successful weaning in use today to produce its sum. These parameters included the static compliance of the respiratory system ($C_{st,rs}$) multiplied by the SaO_2 then divided by the (f/V_t) or RSBI. Several statistical methods were used to verify the predictive value of the index. The value of the IWI was most helpful in identifying patients who required reintubation even after tolerating a SBT. Most significant was the following quote, “Interestingly, our new index IWI predicted extubation failure in 9 out of 10 patients that presented with extubation failure” (Nemer et al., 2009, p. 5). These numbers are impressive when compared with the 20% extubation failure rate of most other parameters. The authors pointed out that the IWI combines the most predictive of individual evidence-based parameters with the best predictive index

currently in use, the RSBI. The combination of these parameters and index produced a highly accurate index in predicting extubation failure.

DISCUSSION

The extubation failure rate continued to vary between 12 and 25% in all studies reviewed. Interestingly, Curry, Cobb, Kutash, and Diggs, (2008) study of characteristics associated with unplanned (self) extubations, found a rate of unsuccessful self-extubations to be 20%. This 20% failure of extubation rate mirrors the reintubation rate of approximately 20% for mechanically ventilated patients whose extubation was based on various evidence-based parameters used to predict readiness to extubate. These nearly identical rates of reintubation highlight the need for continuing research to find an evidence-based parameter that can more accurately identify either successful extubation or failure of extubation. Without additional research to find a more accurate evidence-based parameter, the reintubation rate will continue its stability at approximately 20%.

Frequent inconsistencies are noted in the results of the various studies of the application of the RSBI to readiness to extubate. These inconsistencies need to be addressed in order to determine the utility of the RSBI in predicting a patient's ability to maintain spontaneous ventilation post-extubation. Standardized measurement technique must be applied consistently in order to achieve a reliable parameter reading on which to base extubation decisions. If standardized conditions were implemented utilizing the Tobin and Yang (1991) recommendations, a more valid rate of extubation failure could be pinpointed. By decreasing the number of patients extubated based on an altered RSBI score, extubation failure may be more accurately predicted thus decreasing the number of reintubations required. While consistent technique in determining the RSBI value will

positively impact patient outcomes related to extubation, using the RSBI, as part of a list of parameters to determine success of extubation prediction may be a beneficial variation.

Adaption of the RSBI may also be a viable parameter. Further study of the percent change in RSBI over the time of an SBT is required to determine its utility as a reliable parameter on which to base extubation decisions. Within the studies of the RSBI, some interesting views were explored.

Bein et al., (2010) asked a provocative question: Does ventilator brand and/or type itself affect the RSBI or respiratory variables readings? Using a lung test model, they demonstrated that breathing through the open circuit was of less respiratory workload than using CPAP of 5 thus potentially explaining the results of no change in RSBI when measured on CPAP of 5. If ventilator type/brand affects the respiratory variable being measured then the very inconsistencies noted in the literature in the ability of the RSBI to predict extubation success may be partially explained. Beyond weaning protocols and standardizing physiological measurements to determine readiness to extubate, might this need to be adapted to ventilator type?

Further study of the IWI is needed. The initial results are promising. Due to the multiple variables that influence weaning and success in extubation, use of a combination index may provide a more solid basis on which to determine time of extubation.

Interestingly, Bein et al., (2010) included patients intubated via the nasotracheal route among the subjects. All of the patients intubated via the nasotracheal route were unsuccessful in their extubation.

In conclusion, further research is needed to determine the most predictive evidence-based parameter to determine a patient's ability to maintain spontaneous

ventilation post-extubation. This research should be focused on consistent and standardized technique and application of the RSBI to determine its true predictive value. After establishing the RSBI's actual value, noting the difference or lack of difference in the extubation failure rate should determine whether to continue with use of the RSBI as a predictive parameter. As the RSBI is incorporated into the IWI, this will also serve to increase the value of the IWI. Further studies to verify the value of the IWI are required to determine its value as an evidence-based parameter in determining a patient's maintenance of unassisted ventilation post-extubation.

One question that has not been fully answered is based on a paradigm shift. If the focus of research was to identify the characteristics that successfully extubated patients share versus the similarities of the failure to maintain extubation, perhaps there could be a decrease in the reintubation rate. Several factors have been identified as high-risk characteristics for reintubation. These are frequently cited as chronic obstructive pulmonary disease (COPD), high APACHE score, intubation longer than five days, older patient age, and previous failed weaning attempts. A shift in thinking to which characteristics successfully extubated patients share may point the way to a more useful predictor of extubation success. Successful extubation is a multi-faceted process that requires many elements to align appropriately. The ability to decrease the rate of reintubation will serve to decrease the cost, both in healthcare dollars and in physiologic damage experienced by ICU patients and healthcare systems around the globe.

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