A Cross-National Examination of Weaning Parameter Usage: Comparing Respiratory Therapists' Perceptions in Saudi Arabia and the United States

ACCEPTANCE

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A Cross-National Examination of Weaning Parameter Usage: Comparing Respiratory Therapists' Perceptions in Saudi Arabia and the United States

By

Rahaf Atif Katib

Under the direction of

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A CROSS-NATIONAL EXAMINATION OF WEANING PARAMETER USAGE: COMPARING RESPIRATORY THERAPISTS' PERCEPTIONS IN SAUDI ARABIA AND THE UNITED STATES

By

Rahaf Atif Katib

(Under the Direction of Douglas S. Gardenhire)

Abstract

Background: Weaning from mechanical ventilation is a critical goal following patient intubation in intensive care settings. Effective weaning from mechanical ventilation is essential for reducing morbidity and mortality among ICU patients. Weaning parameters play a significant role in determining the success of the weaning process. However, their usage differs across healthcare settings. **Purpose:** This study aims to compare the perceptions of respiratory therapists in Saudi Arabia and the United States regarding the frequency of use and the prioritization of various mechanical ventilation weaning parameters in intensive care units, as well as how patient-specific factors are considered in the weaning process. **Methods:** A cross-sectional study was conducted using an online survey distributed to RTs in both countries. The survey included demographic questions and questions to evaluate the perceived frequency of use of weaning parameters and the influence of patient-specific factors on the success of weaning from mechanical ventilation. Descriptive statistics, independent samples t-tests, and effect size calculations were conducted to analyze the data. **Results:** A total of 99 respiratory therapists participated in the survey (Saudi Arabia: n=63; United States: n=36). The study findings revealed that among patient-specific factors, only age showed a statistically significant difference between countries, with a higher mean rating in Saudi Arabia (M = 3.27, SD = 1.12) compared to the United States (M = 2.53, SD = 1.50), $p = .006$. Furthermore, regarding the perceived frequency of use of 18 various weaning parameters, only the Glasgow Coma Scale (GCS) showed a statistically significant difference between countries, with higher perceived importance among Saudi RTs (M = 13.98, SD = 4.59) compared to U.S. RTs (M = 7.67, SD = 5.47), $p < .001$. Moreover, the most frequently used parameters rated by RTs in Saudi Arabia are Glasgow Coma Scale (GCS), SBT trials, pH, respiratory rate (RR), and partial pressure of carbon dioxide (PCO_2). On the other hand, the five most commonly used parameters in the United States are SBT trials, PCO_2, following commands, pH, and minute ventilation (VE). **Conclusion:** Overall, only a few significant differences were observed, which indicates consistency in the perceived use of weaning parameters between Saudi Arabia and the United States, suggesting a shared foundation in clinical practice. These insights may serve as a reference for other countries aiming to evaluate or systematize their weaning strategies and could also inform educational programs for respiratory therapy students by highlighting the key parameters emphasized in clinical decision-making.

DEDICATION

First and foremost, I thank Allah (God) for granting me the strength, health, protection, and clarity of mind to complete this journey.

This thesis is lovingly dedicated to my parents, whose unwavering support, prayers, and belief in me have been the foundation of everything I've achieved. I am endlessly grateful for your love and guidance.

To my brother and sisters, thank you for always standing by my side and for celebrating every accomplishment, big or small.

To my dearest friends, who hold a special place in my heart, thank you for your encouragement and for sharing this journey with me.

I also dedicate this to myself for staying ambitious, patient, and resilient through every challenge.

Finally, I would like to extend my heartfelt thanks to my country, Saudi Arabia, for providing me with the opportunity and support to pursue this path and grow both academically and personally.

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List of Abbreviations

Abbreviation	Definition
ABG	Arterial Blood Gas
ARDS	Acute Respiratory Distress Syndrome
COPD	Chronic Obstructive Pulmonary Disease
GCS	Glasgow Coma Scale
ICU	Intensive Care Unit
MV	Mechanical Ventilation
NIF	Negative Inspiratory Force
PEEP	Positive End-Expiratory Pressure
RSBI	Rapid Shallow Breathing Index
RT	Respiratory Therapist / Therapy
SA	Saudi Arabia
US	United States

CHAPTER I

INTRODUCTION

Although efforts to resuscitate patients with acute respiratory failure have existed for centuries, mechanical ventilation as it is practiced today is a relatively recent advancement. The introduction of positive-pressure ventilation outside the operating room was notably driven by a poliomyelitis epidemic in Copenhagen in 1951. Bjorn Ibsen's controversial recommendation to use positive-pressure ventilation systematically for patients dying from poliomyelitis resulted in dramatic improvements in survival, leading to the widespread adoption of this technique for managing acute respiratory failure and revolutionizing clinical medicine(Goligher et al., 2016). According to Kavanagh & Meyer (2005), Mechanical ventilation is employed to assist with gas exchange and maintain acid-base homeostasis, thereby preserving life when the respiratory muscles cannot sustain normal pulmonary ventilation due to acute or chronic respiratory dysfunction from pulmonary or systemic causes, typically serving as a bridge to recovery. Since its introduction in the 1950s, significant advancements have been made in refining positive-pressure mechanical ventilation to achieve these objectives.

Invasive mechanical ventilation involves the use of an endotracheal tube (ETT) and a mechanical ventilator. The endotracheal tube (ETT) functions to protect the airway, allows for secretion removal, and facilitates procedures like bronchoscopy while enabling the delivery of mechanical ventilation. This form of ventilation supports patients with hypoxemic and hypercapnic respiratory failure by enabling lung-protective strategies, such as low tidal volume ventilation, for patients with acute respiratory distress syndrome (ARDS) (Walter et al., 2018). Ventilators are devices designed to assist inspiration by coordinating volume, pressure, time, and flow, each functioning as either a dependent or independent variable to deliver tidal breaths under positive pressure (Walter et al., 2018).

According to Jivraj et al. (2023), the provision of invasive mechanical ventilation (IMV) is a cornerstone of contemporary intensive care. However, the initiation and application of IMV can vary across countries, influenced by patient-specific factors such as the burden of comorbidities or end-of-life care goals. Additionally, clinician-related factors play a significant role, particularly when clear physiologic thresholds are lacking to guide decisions on who requires intubation. Leung et al. (2021) argue that Invasive mechanical ventilation (IMV) is linked to significant patient morbidity and discomfort, making prompt discontinuation a priority. Evidence suggests that the effectiveness of protocolized weaning may depend on the availability of resources. Additionally, for weaning protocols to be successful, they must consider the social and cultural context in which they are implemented. A well-crafted questionnaire can help identify factors influencing the use and perceptions of protocolized weaning, determine whether clinical equipoise exists among clinicians regarding specific aspects of weaning, provide data for sample size calculations, and gain insight into clinicians' preferences when designing protocols.

According to Rose (2015), weaning from mechanical ventilation has long been a key focus of research aimed at identifying the most effective methods and implementing evidence-based quality improvement initiatives. Studies emphasize that timely recognition of both readiness to wean and readiness to extubate is crucial to avoid unnecessary prolongation of mechanical ventilation. Poor decision-making during the weaning and extubation process can pose significant risks, including respiratory and cardiac failure due to the increased work of breathing during reduced ventilatory support.

As noted by Burns et al., (2018), Weaning is the process of gradually decreasing mechanical ventilation support as the patient's work of breathing transitions from the ventilator to their own respiratory effort. This phase constitutes approximately 40% of the total duration of invasive MV. Prolonged use of invasive MV is linked to several significant complications, including ventilator-associated pneumonia, sinusitis, gastrointestinal bleeding, and generalized muscle weakness. Among these, ventilator-associated pneumonia is particularly concerning, as it is associated with increased morbidity and a potential rise in mortality rates.

Blackwood et al. (2010) state that Prolonged mechanical ventilation in critically ill patients is associated with adverse clinical outcomes, including physiological and psychological complications. Over the past two decades, significant advancements have been made in optimizing ventilator weaning protocols to reduce ventilation duration and mitigate associated morbidity and mortality. While approximately 77% of patients successfully transition to spontaneous breathing, others experience weaning failure, necessitating prolonged ventilatory support. This subset of patients faces increased risks of ventilator-associated pneumonia (VAP), ventilator-induced lung injury (VILI), and higher mortality rates. Additionally, their care requires extended ICU stays, placing considerable strain on limited resources, including ICU bed capacity, specialized nursing, and equipment availability. As such, timely and safe liberation from mechanical ventilation remains a priority to improve patient outcomes and enhance resource utilization in critical care.

Weaning predictors such as body mass index (BMI) and occlusion pressure at 0.1 s. (P0.1) has been introduced to enhance the weaning process by assessing a patient's likelihood of tolerating a weaning trial before it begins. These predictors can also help identify specific physiological factors contributing to weaning failure. While numerous weaning predictors have been proposed to improve outcomes, their accuracy and reliability remain a topic of debate (Asmaa M Abd El-Moaty et al., 2021). Weaning predictors are parameters designed to assist clinicians in determining the likelihood of success for weaning attempts (Zein et al., 2016).

There is a significant lack of comparative studies on how weaning parameters are perceived and used in mechanical ventilation across different healthcare settings. This study aims to compare the views of Respiratory Therapists in Saudi Arabia and the United States regarding the use of these weaning parameters for ICU patients. I hypothesize that there are differences in how Respiratory Therapists in these two countries perceive and apply weaning parameters.

PURPOSE OF THE STUDY

This study aims to compare the perceptions of Respiratory Therapists in Saudi Arabia and the United States regarding the use of weaning parameters for mechanically ventilated patients. In addition to the use of patient-specific factors in determining the initiation of weaning. It will also investigate how these professionals view the clinical importance and frequency of use of various weaning parameters in practice.

RESEARCH QUESTIONS

1- How do respiratory therapists perceive the influence of patient-specific factors on the success of weaning from mechanical ventilation?

2- What are the perceptions of respiratory therapists in the United States and Saudi Arabia regarding the frequency of use of various mechanical ventilation weaning parameters in ICU patients?

3- Which weaning parameters are most frequently used by respiratory therapists in Saudi Arabia and the United States to initiate the weaning process?

RESEARCH HYPOTHESIS

There are differences in the perception and use of weaning parameters between Respiratory Therapists in Saudi Arabia and the United States.

SIGNIFICANCE OF THE STUDY

The goal of this study is to compare the perceptions of Respiratory Therapists in Saudi Arabia and the United States regarding the frequent use of various weaning parameters in mechanical ventilation for ICU patients, as well as the consideration of patient-specific factors in initiating the weaning process. By examining how Respiratory Therapists perceive the clinical importance and relevance of different weaning indicators, the study aims to identify differences and similarities in approaches to weaning initiation. The findings from this research could illuminate the varying perceptions of weaning parameters across different clinical settings and different countries, contributing to the development of more standardized, evidence-based protocols that enhance patient outcomes. Additionally, the insights gained may refine training programs for respiratory therapists, fostering greater consistency and reliability in weaning decisions across diverse healthcare systems. Ultimately, this research could inform policy changes and guide best practices in managing mechanically ventilated patients. By improving the understanding and application of weaning parameters, this study has the potential to enhance care quality and patient outcomes, not only in Saudi Arabia and the United States but also on a global scale.

CHAPTER II

LITERATURE REVIEW

Introduction to Mechanical Ventilation and Weaning

Mechanical ventilation (MV) is a crucial therapeutic intervention for critically ill patients in intensive care units (ICUs). It serves as the primary treatment for respiratory failure by reducing the workload on respiratory muscles, preventing or reversing muscle fatigue, and allowing for respiratory muscle rest (Asmaa M Abd El-Moaty et al., 2021). Mechanical ventilation is necessary for more than 90% of critically ill adult patients in ICUs. While it saves the lives of thousands of patients experiencing oxygenation issues, it also leads to numerous complications and is associated with a high mortality rate (Taran et al., 2019). Mechanical ventilation is utilized for patients with various medical conditions that do not necessarily involve impaired pulmonary function, including cardiac arrest, altered mental status, and postoperative care (Na et al., 2022).

Since its initial clinical use in the 1920s, mechanical ventilation has undergone continuous advancements. It is now one of the most widely utilized therapeutic interventions for critically ill patients in the intensive care unit (ICU). It has significantly improved survival rates and reduced ICU length of stay for patients requiring respiratory support by ensuring adequate oxygenation and ventilation until their respiratory condition stabilizes. To optimize its benefits and minimize complications, it is crucial to prevent both premature extubation and unnecessary prolongation of mechanical ventilation (Vaibhav et al., n.d.). The ultimate goal of managing mechanically ventilated patients is to achieve spontaneous breathing and facilitate successful weaning (Abd El-Moaty et al., 2021).

Weaning is when the breathing effort is progressively returned from the machine to the patient. It begins with the institution of mechanical ventilation, where patients are assessed daily to determine their readiness for weaning (Vetrugno et al., 2020). It is estimated that nearly 40% of the total duration of mechanical ventilation is devoted to the weaning process (Zein et al., 2016). Early weaning from mechanical ventilation (MV) can compromise gas exchange, resulting in hypoxemia and hypercapnia, which may necessitate reintubation. This increases the risk of nosocomial pneumonia and mortality. Conversely, delayed weaning is associated with a higher risk of complications related to MV, longer stays in the ICU, and increased costs. Multiple clinical and objective criteria for assessing weaning readiness (WR) and predictors of weaning success have been suggested to enhance the rates of weaning and extubation success (ES). (Eriş et al., 2025).

According to the 2006 consensus conference, simple weaning refers to successful extubation after a single attempt. Difficult weaning is characterized by the need for up to three spontaneous breathing trial (SBT) attempts within seven days of the initial trial. Prolonged weaning is defined as the failure of at least three SBT attempts or the requirement of more than seven days of weaning following the first SBT (Bureau & Demoule, 2022). Delayed weaning from mechanical ventilation (MV) can result in complications; however, premature weaning can also lead to unplanned intubation and reintubation. Research indicates that re-intubation raises the risk of hospital-acquired pneumonia by eight times and increases the likelihood of death by six to twelve times compared to the initial intubation (Taran et al., 2019).

Respiratory Therapy and Weaning in Saudi Arabia and the United States.

History of Respiratory Therapy/Care

Respiratory care (RC) is an allied health profession dedicated to treating patients with cardiopulmonary disorders. Under medical supervision, RC professionals evaluate, monitor, and manage individuals with pulmonary and respiratory conditions (Alotaibi, 2015). The respiratory care profession emerged as a distinct specialty in the United States during the 1940s. Initially, hospital personnel trained on the job were responsible for managing oxygen supply and therapy (Mathews et al., 2006). Over the years, the American Association for Respiratory Care (AARC) established the “2015 and Beyond” task force in 2007. The task force was charged with determining the necessary changes in the respiratory care profession to address the evolving needs of the medical community and ensure that RTs continue to be recognized as vital members of healthcare teams in the future (Barnes et al., 2011). The role of respiratory therapists (RTs) has evolved to encompass advanced critical and sub-acute care modalities, including mechanical ventilation, emergency care, pulmonary diagnostics, pulmonary rehabilitation, and home care. Advancements in medical knowledge and emerging medical technologies have created a growing need for highly skilled RTs (Alotaibi, 2015).

Controversially, respiratory care was not officially recognized as a healthcare profession in Saudi Arabia until recently. Initially, the Ministry of Health (MoH) did not acknowledge the value of RC services, which led to its delayed recognition. Later, the profession of respiratory therapy has evolved significantly since the mid-1970s, driven by population growth and the expansion of healthcare services in Saudi Arabia (Al-Otaibi & AlAhmari, 2016). In the mid-1970s, the Military Hospital in Riyadh introduced RC services and sponsored scholarships for Saudi nationals to train in the United States. Since then, various training programs and scholarships have been established to graduate qualified respiratory therapists (RTs) and meet the growing demand for RC services. Additionally, the Ministry of Health (MOH) and the private healthcare sector have incorporated RC services into their hospitals by recruiting both Saudi and expatriate RTs. Furthermore, hospitals seeking recognition from national and international accreditation bodies have increasingly implemented RC services provided by qualified RTs to meet accreditation standards (Alotaibi, 2015).

Weaning Practices

Effective management of mechanical ventilation involves a multidisciplinary team, including respiratory therapists (RTs), physicians, nurses, and allied health professionals. The roles and responsibilities of RTs and physicians in weaning patients from mechanical ventilation can vary depending on factors such as the ICU's staffing, organizational structure, and leadership models. Differences in practices may also be observed between countries due to socio-political factors, as well as between individual ICUs within the same region (Rose et al., 2008a). Three key tools are essential for ensuring seamless interdisciplinary team collaboration without compromising healthcare service delivery. Implementing a standardized care protocol is crucial, as the absence of controlled clinical practice makes standardized guidelines necessary for achieving successful weaning outcomes. Additionally, multidisciplinary meetings play a vital role in keeping all healthcare team members informed about the patient care plan and the progress of the weaning process. Lastly, having a designated team leader provides clear direction, offering support and encouragement to foster collaboration and active participation in the multidisciplinary approach (Al Tabee et al., 2020).

Respiratory care protocols are widely implemented and taught, and with substantial supporting evidence, they have arguably become a standard in respiratory care (Stoller, 2001). However, there are variations in several weaning practices, including screening methods, modes used for weaning, and the techniques employed for conducting SBTs (Burns et al., 2018). Research found that there are no universally defined guidelines for weaning, as variations in weaning protocols across hospitals lead to significant differences in mechanical ventilation duration.

Therefore, establishing a reliable extubation protocol is essential to reducing weaning delays, and a multidisciplinary approach should be utilized to optimize patient outcomes. Furthermore, it is crucial to consider the weaning predictor parameters, as they provide valuable insights into whether a patient is likely to succeed in extubation (Al Tabee et al., 2020).

Prolonged Mechanical Ventilation and Weaning Failure

Weaning failure

Weaning failure is defined as either the inability to successfully complete a spontaneous breathing trial (SBT) or the need for reintubation within 48 hours after extubation (Akella et al., 2022), whereas extubation failure is defined as intolerance to extubation (Nemer & Barbas, 2011). Initial weaning failure often results from either the incomplete resolution of the underlying illness that necessitated mechanical ventilation or the emergence of new complications (Hemant et al., 2006). Moreover, in the study Ghoneim et al. (2017), weaning failure was more commonly observed in patients who had previously been mechanically ventilated, with this group undergoing more attempts at mechanical ventilation. On the other hand, according to Hemant et al., (2006), successful weaning relies on the interplay between respiratory muscle strength, the load imposed on these muscles, and central respiratory drive. A critical factor in weaning success is maintaining a balance between muscle strength and respiratory load. When the load exceeds the capacity of the respiratory muscles, weaning failure is more likely to occur.

Deutschman and Neligan (2019) states that the definition of weaning success is generally straightforward, typically characterized by successful spontaneous ventilation for at least 24 hours after extubation. However, defining weaning failure is more complex. While several researchers suggest using arterial blood gas criteria to determine weaning failure, most agree that changes in arterial blood gases or clinical deterioration characterize it. The study by Ghoneim et al. (2017) identified several key factors influencing weaning outcomes in mechanically ventilated patients, including myocardial ischemia, delirium, hypomagnesemia, hypophosphatemia, and ventilator-associated pneumonia (VAP), all of which were significant risk factors for weaning failure. Moreover, as noted by Vetrugno et al., (2020) Cardiac failure, diaphragmatic dysfunction, acute respiratory conditions (such as lung parenchyma diseases or airway obstructions), neurological impairments, and intra-abdominal complications are among the primary factors leading to weaning failure from mechanical ventilation as well. Ghoneim et al., (2017) Highlights that, in general, numerous factors contribute to weaning failure from mechanical ventilation, and key considerations for all patients include improper ventilator settings, infections, airway patency, respiratory muscle performance, as well as the metabolic and physiological conditions highlighted in the study.

Prolonged mechanical ventilation

Prolonged mechanical ventilation (PMV) and weaning failure contribute to extended hospital stays and higher morbidity and mortality rates. Beyond the impact on patients and their families, these factors also place a significant financial burden on the public health system (Trudzinski et al., 2022). According to Goligher et al. (2016), while most patients requiring mechanical ventilation can be easily weaned once their initial condition resolves, 20–40% experience challenges breathing without ventilatory support. Understanding the mechanisms behind these difficulties is both important and complex. Prolonged mechanical ventilation, combined with extended bed rest, increases mortality and contributes to long-term morbidity, both during the intensive care unit stay and post-discharge, sometimes persisting for years. In some patients, the weaning phase constitutes the majority of their time on the ventilator, prompting the establishment of specialized centers for managing prolonged weaning cases.

The definition of prolonged mechanical ventilation varies across studies, but most have classified it based on the total duration of MV, which can range from 1 day to 4 weeks. The European Respiratory Society Task Force defines prolonged weaning as a weaning process lasting more than 7 days following the first spontaneous breathing trial (SBT). However, this definition has limitations, particularly in classifying patients under varying clinical conditions commonly seen in practice, such as those with tracheostomies (Ghiani et al., 2020).

Asmaa M Abd El-Moaty et al., (2021) States that approximately 20% of patients experience prolonged and complicated weaning due to various factors, including age, comorbidities, nutritional status, muscle strength, and lung mechanics. Additionally, excessive tracheobronchial secretions, an ineffective cough, disease severity, and ventilator-associated pneumonia further contribute to weaning challenges. According to Trudzinski et al., (2022) the Risk factors associated with prolonged mechanical ventilation (PMV) or extended weaning include age, comorbid conditions such as prior stroke, renal impairment, compromised cardiac function, and chronic obstructive pulmonary disease (COPD). Additionally, various laboratory parameters play a role in the weaning process, including blood gas analysis values (lower bicarbonate [HCO_3^-], reduced pH, or elevated $PaCO_2$), ventilator settings ($FiO_2 \geq 0.39$, PEEP levels), and gas exchange efficiency ($PaO_2/FiO_2 < 200$ mmHg).

Research has shown that prolonged weaning is often associated with poorer outcomes and a worse prognosis for patients and is linked to significantly higher rates of morbidity and mortality, and imposes a considerable financial burden on the healthcare system (Windisch et al., 2020). It also increases the risk of complications associated with prolonged mechanical ventilation. On the other hand, if extubation is performed too early, reintubation is linked to an increased risk of mortality and long-term disability. (Jaber et al., 2018). Determining the ideal time for extubation remains a challenge (Vetrugno et al., 2020). Up to 25% of critically ill patients encounter challenges when weaning from invasive mechanical ventilation (IMV), placing additional strain on the intensive care unit (ICU) (Ghiani et al., 2020). The benefit-risk balance for extubation must be evaluated daily (Jaber et al., 2018).

Prolonged mechanical ventilation is linked to several complications, including tracheal injuries, ventilator-associated pneumonia, ventilator-induced lung injury, and diaphragm damage caused by the ventilator. However, Premature extubation places the patient at risk of cardiovascular stress due to spontaneous breathing, often leading to the need for reintroducing ventilatory support (Vetrugno et al., 2020). Successful and timely weaning from mechanical ventilation can reduce the duration of ventilation, thereby lowering the risk of infection, medical costs, and mortality. Evidence suggests that delayed weaning can lead to unnecessary discomfort, higher complication rates, and increased healthcare expenses (Jhou et al., 2021).

Patient-Specific Factors Influencing Weaning Success

While lung function develops and improves throughout life, it gradually declines with aging. According to Suraseranivong et al., (2018) approximately 20% to 35% of patients require reintubation within 48 hours of extubation. Age-related physiological changes, including thoracic cage stiffening, weakened respiratory and diaphragmatic muscles, increased residual volume, reduced cough reflex sensitivity, and declining cardiac function, can make the weaning process from mechanical ventilation more challenging. Another factor is the severity of illness, which is recognized as a predictor of weaning outcomes, with greater disease severity being linked to weaning failure. Patients with lower disease severity tend to have better weaning success, shorter mechanical ventilation duration, and reduced ICU length of stay (Abd El-Moaty et al., 2021).

The presence of multiple comorbidities in mechanically ventilated patients is strongly linked to extended weaning periods, prolonged mechanical ventilation, longer ICU stays, and increased mortality rates. Cardiac and respiratory comorbidities are major risk factors for weaning failure in patients requiring prolonged mechanical ventilation (Abd El-Moaty et al., 2021). Respiratory muscle function plays a crucial role in achieving successful liberation from mechanical ventilation and is a significant factor in recovery from critical illness. Respiratory muscle weakness is common among mechanically ventilated patients, driven by a variety of factors associated with critical illness. The mechanical ventilator supports or replaces respiratory muscles during acute respiratory failure when their capacity is impaired or overwhelmed by an acute pulmonary insult (Goligher et al., 2016).

In a recent review, Abd El-Moaty et al., (2021) Malnutrition is common among mechanically ventilated patients, often due to preexisting chronic illnesses. Studies indicate that 81% of patients requiring mechanical ventilation for at least six days receive insufficient protein and calories. Additionally, increased caloric demands further heighten the risk of malnutrition in these patients. As a result, the role of nutrition in the weaning process is gaining increased attention. Malnutrition negatively impacts lung function by reducing respiratory muscle strength, impairing ventilatory drive, and compromising pulmonary defense mechanisms. The study by Lo et al. (2022) found that achieving a caloric intake close to the target and ensuring protein delivery of more than 1.2 g/kg/day can enhance nutrition, thereby facilitating successful weaning from ventilator support. Therefore, underfeeding and overfeeding can increase the risk of infection in ventilated patients and prolong the duration of ventilator weaning. Thus, nutritional intervention is crucial in critical care settings. A study by Abd El-Moaty et al. (2021) states that proper nutrition plays a crucial role in reducing mortality and morbidity while supporting the weaning process in mechanically ventilated patients. Inadequate nutrition hinders respiratory epithelial regeneration, leading to respiratory muscle exhaustion and delaying the weaning process. Conversely, overfeeding increases physiological stress and carbon dioxide production, raising ventilatory demands and prolonging mechanical ventilation.

Neuromuscular conditions, such as myasthenia gravis, Guillain-Barré syndrome, poliomyelitis, acute intermittent porphyria, and muscular dystrophy, present significant challenges in the weaning process from mechanical ventilation. These patients often require prolonged ventilatory support, leading to physiological adaptations that can hinder successful weaning (Sahn et al., 1976). Moreover, for Brain injury patients, implementing protective MV strategies, such as low tidal volume ventilation and early extubation, helps reduce the risk of pulmonary complications. Prolonged intubation should be avoided when an impaired neurological state is the primary concern. Notably, patients with brain injuries may experience a dissociation between consciousness and respiratory function, meaning that persistent altered alertness is not necessarily a contraindication for initiating the weaning process (Bureau & Demoule, 2022).

Patient-ventilator desynchrony is a frequent occurrence in mechanically ventilated patients. Desynchronies, such as insufficiency, increased work of breathing, and double triggering, negatively impact the respiratory system, often delaying weaning from mechanical ventilation. Mismatched timing between the patient’s inspiration and expiration and the ventilator trigger can lead to respiratory muscle fatigue, further hindering successful weaning.(Ou-Yang et al., 2020a).

Obesity is independently linked to an increased risk of extubation failure in intubated patients. To mitigate this, the prophylactic use of noninvasive ventilation (NIV) has been shown to effectively reduce patients' work of breathing (WOB) and help prevent the need for reintubation. Like obese patients, individuals with COPD exhibit specific alterations in respiratory mechanics, primarily characterized by bronchial obstruction and lung hyperinflation (Ghiani et al., 2020).

Early mobilization in ICU patients has been shown to have numerous benefits, including reducing the incidence of ICU-acquired weakness (ICUAW), improving functional capacity, and increasing the number of ventilator-free days. It also helps minimize delirium, ICU readmissions, and the length of ICU stay. For mechanically ventilated patients who have been intubated for over 24 hours, protocolized rehabilitation focused on early mobilization is highly recommended (Akella et al., 2022). Furthermore, the combined approach of the ABCDE bundle (Awakening and Breathing trial Coordination, Delirium management, and Early mobilization) offers significant benefits, so successful implementation of this bundle ultimately leads to a reduction in delirium and muscle weakness (Khan et al., 2017).

Neuromuscular blocking agents are used in critical care settings, beyond their use for intubation; these agents are also utilized to manage patient-ventilator desynchrony in mechanically ventilated patients. Careful selection of patients and duration of neuromuscular blocking agent use are critical, as prolonged administration carries significant risks. These include ICU-acquired weakness (ICU-AW) and prolonged mechanical ventilation (Tezcan et al., 2019).

Patients with anxiety, depression, or hallucinations before mechanical ventilation are more likely to experience unsuccessful weaning. In contrast, effective communication with patients on mechanical ventilation may lead to successful weaning. Additionally, patients who experience fear, neglect, or insecurity during weaning trials had adverse outcomes. On the other hand, patients receiving family support during mechanical ventilation showed more positive weaning outcomes (Elsehrawy & Saleh, 2024).

Weaning Process

According to Magalhães et al. (2018), the decision to discontinue mechanical ventilation is typically guided by the clinician's assessment. Key factors influencing this decision include the patient's hemodynamic stability, mental and cognitive state, ability to cough, resolution of the primary condition, nutritional status, and specific lung mechanics parameters. Furthermore, the weaning process follows a two-step approach, including readiness assessments and spontaneous breathing trials (SBT). Therapists must evaluate clinical and objective criteria to determine weaning readiness, starting as early as 48 to 72 hours after ICU admission. A "sedation vacation," where sedation is paused or reduced, plays a crucial role in these assessments, helping determine the patient's capability to breathe independently. Some criteria must be met to assess readiness for weaning. Those criteria are $PaO_2/FiO_2 \geq 150$ or $SpO_2 \geq 90\%$ on $FiO_2 \leq 40\%$ and PEEP ≤ 5 cmH_2O, pH >7.25, Hemodynamic stability, initiate inspiratory effort, Hemoglobin ≥ 7 mg/dL, Core temperature ≤ 38 °C, and easily arousable.

Starting in the 1960s, weaning patients from mechanical ventilation gradually increased their time off the ventilator, with oxygen supplied via a T-piece attached to the endotracheal tube. Intermittent mandatory ventilation (IMV) and later synchronized intermittent mandatory ventilation (SIMV) became part of weaning strategies, although these approaches lacked strong evidence. SIMV allowed for gradual reductions in mandatory breaths, increasing the patient's need for spontaneous breathing. When pressure support ventilation (PSV) was introduced, it helped support spontaneous breaths during SIMV, improving the weaning process (Roberts et al., 2024). Identifying reliable predictors for determining the optimal timing to initiate the weaning process remains a significant challenge in clinical practice (Sang et al., 2021; Windisch et al., 2020).

There has been ongoing debate regarding the best approach to weaning. Two large multi-center randomized controlled trials (RCTs) compared gradual rate reductions with IMV or SIMV to gradual decreases in inspiratory pressure using PSV. One RCT found that PSV outperformed SIMV and T-piece trials in weaning success. Another RCT compared IMV and PSV with spontaneous breathing trials (SBTs) using longer T-piece trials, again showing better outcomes. Both studies concluded that SIMV resulted in poorer outcomes, delaying liberation from mechanical ventilation (Akella et al., 2022).

In a study comparing the use of pressure support ventilation (PSV) and T-piece for weaning high-risk patients, the authors found that PSV can speed up extubation without increasing the risk of reintubation. Fewer weaning failures were observed with pressure support ventilation (PSV) compared to the T-piece and synchronized intermittent mandatory ventilation (SIMV). The failure rates were 8% for PSV, 43% for the T-piece, and 42% for SIMV ($p = 0.05$). For patients at high risk of extubation failure, especially those ventilated for more than 24 hours, and who pass their initial spontaneous breathing trial (SBT), the recommendation is to extubate to preventive non-invasive ventilation (NIV) to reduce the likelihood of extubation failure (Akella et al., 2022).

Ou-Yang et al., (2020) Compared the effectiveness of Proportional Assist Ventilation (PAV) and Pressure Support Ventilation (PSV) as methods for weaning mechanically ventilated patients. Patients weaned with PAV showed a higher likelihood of successful weaning compared to those using PSV. These findings were confirmed as robust and conclusive through Trial Sequential Analysis (TSA). Additionally, our results indicated that patients in the PAV group experienced lower reintubation rates and shorter ICU stays compared to those in the PSV group.

Spontaneous Breathing Trial

Weaning initiation is marked by the start of the first spontaneous breathing trial, which can be conducted using various techniques such as the T-tube or T-piece, pressure support ventilation (PSV), and automatic tube compensation (ATC), with or without continuous positive airway pressure (CPAP). A spontaneous breathing trial is considered unsuccessful if the patient exhibits respiratory, cardiovascular, or neurological instability, as determined through clinical evaluation and objective assessments during the trial (Deutschman & Neligan, 2010).

While international guidelines recommend using spontaneous breathing trials (SBTs) to assess readiness for weaning from mechanical ventilation, relying solely on SBTs has proven ineffective in accurately predicting weaning failure and the likelihood of reintubation (Vetrugno et al., 2020). Patients can be weaned from MV if they meet the following minimal criteria: resolution or stabilization of the underlying disease; adequate gas exchange; hemodynamic stability; and capacity to breathe spontaneously. If these criteria are met, the SBT should be performed (Nemer & Barbas, 2011).

The criteria for successful spontaneous breathing trials include several key parameters. These include a respiratory rate of less than 35 breaths per minute, along with good tolerance to the spontaneous breathing trial. Heart rate should be below 140 beats per minute, with a heart rate variability of greater than 20%. Arterial oxygen saturation should be greater than 90%, or PaO2 should exceed 60 mmHg while FiO2 is less than 0.4. Systolic blood pressure should range between 80 and 180 mmHg, with no more than a 20% change from baseline. Additionally, there should be no signs of increased work of breathing or distress during the trial (Zein et al., 2016).

If a patient tolerates a 30- to 120-minute spontaneous breathing trial (SBT), permanent ventilator liberation should be considered (Akella et al., 2022). However, successfully passing a spontaneous breathing trial (SBT) does not always guarantee ventilator liberation or extubation, particularly if the patient has issues like excessive secretions or a weak cough. Moreover, Research found that only 55% of patients who passed an SBT were liberated from the ventilator before requiring another SBT (Robertson et al., 2008).

If the patient fails the SBT based on specific criteria, the underlying cause must be identified and addressed. Once the reversible causes are corrected, another SBT should be attempted every 24 hours, paired with spontaneous awakening trials. After an unsuccessful SBT, the patient should receive comfortable, non-fatiguing ventilatory support until the next attempt (Akella et al., 2022). Clinical practice guidelines (CPGs) continue to guide best practices, emphasizing the regular assessment of a patient's readiness for spontaneous breathing trials and performing them promptly. SBTs serve as the key factor in determining ventilator liberation potential. However, it's also crucial for clinicians to evaluate and address the reasons for any failed SBTs and to implement extubation protocols for patients who complete an SBT, ensuring a systematic approach to weaning from mechanical ventilation. (Roberts et al., 2024).

One method for performing a spontaneous breathing trial (SBT) on a ventilator involves setting pressure support ventilation (PSV) to 0 cmH2O and positive end-expiratory pressure (PEEP) to 0 cmH2O. Many clinicians view this as a suitable alternative to a T-piece trial. This approach takes advantage of the ventilator's monitoring and alarm systems while allowing for a rapid return to full ventilatory support if the SBT fails (Roberts et al., 2024).

Another method is automatic tube compensation (ATC), a ventilator feature designed to offset the resistance imposed by the endotracheal tube, commonly found in modern ventilators. It dynamically measures tube resistance and adjusts inspiratory flow, accordingly, considering factors such as tube diameter, length, accumulated secretions, and potential kinks. ATC has been shown to be as effective as pressure support ventilation (PSV) or T-piece weaning. However, there is no published evidence demonstrating that ATC provides additional benefits over PSV (Deutschman & Neligan, 2010). Automated Tube Compensation (ATC) helps compensate for the pressure drop across the tracheal tube during both inspiration and expiration. Studies show that ATC can reduce the work of breathing, enhance respiratory comfort, and predict extubation success; however, it's not a standalone mode, but rather it supports other ventilatory modes (Akella et al., 2022).

Pressure Support

The PSV assesses whether the patient can overcome the resistance of the endotracheal tube by breathing spontaneously, indicating readiness to begin weaning. However, it may cause discomfort and muscle strain (Sánchez Sánchez et al., 2021). PSV enables the patient to control the depth, duration, flow, and rate of their breathing. It can be utilized for spontaneous breathing trials (usually set at ≤ 10 cm H2O) or, although less effectively, as a weaning strategy that involves gradually decreasing pressure support by 2-4 cm H2O once or twice daily as tolerated. This approach leads to a gradual decrease in ventilatory support over a period of hours to days (Deutschman & Neligan, 2019). If there is no backup mode to take over during apnea, a patient who stops breathing will not receive any breaths while on PS. When a breath is triggered, an inspiratory pressure is applied above the set positive end-expiratory pressure (PEEP) and is maintained throughout the inspiration. As such, PS is pressure-targeted. Additionally, PS is flow-cycled, meaning inspiration ends when inspiratory flow drops to a set threshold, typically a percentage of peak inspiratory flow (e.g., when flow falls to 25% of peak). Thus, PS is patient-triggered, pressure-targeted, and flow-cycled (Walter et al., 2018).

Synchronized Intermittent Mandatory Ventilation

SIMV is a commonly used mode of mechanical ventilation. In SIMV, mandatory ventilator breaths are delivered at a set rate. Suppose a patient attempts to initiate a breath within a designated time interval before the next mandatory breath. In that case, the ventilator will provide a supported breath, thereby synchronizing mandatory breaths with the patient's effort. These mandatory breaths can be delivered using various strategies, such as VC (flow-targeted, volume-cycled), PC (pressure-targeted, time-cycled), or PRVC (pressure-targeted, time-cycled), similar to the AC mode. SIMV is believed to reduce respiratory muscle disuse atrophy, enhance ventilator synchrony, and prevent respiratory alkalosis. However, in patients whose spontaneous respiratory rate is much higher than the set IMV rate, SIMV may lead to respiratory muscle fatigue (Walter et al., 2018).

SIMV may lead to respiratory muscle fatigue or hinder recovery from fatigue due to increased work of breathing related to patient-ventilator desynchrony, greater effort needed to activate the SIMV demand valve, inadequate gas flow, or the respiratory center's inability to coordinate with the intermittent nature of the support and the various types of breaths (Deutschman & Neligan, 2019). While there is no strong evidence to support or discourage the use of SIMV as the primary mode in acutely ill patients, several well-conducted studies have found SIMV to be less effective than other methods during ventilator weaning (Walter et al., 2018).

T-Piece

Other methods include a T-piece trial, which involves disconnecting the patient from the ventilator and providing supplemental oxygen through a T-piece (Akella et al., 2022). T-piece trials are the oldest technique for weaning patients from mechanical ventilation, involving a gradual increase in the duration a patient spends on the T-piece. Traditionally, many units would repeatedly place patients on T-tubes for short periods several times a day. However, research has shown that single daily T-tube trials are just as effective, leading to a significant decline in the use of this more labor-intensive method. One limitation of T-piece trials is the lack of apnea and volume alarms in this setting (Deutschman & Neligan, 2019). The T-piece can be adapted with a PEEP valve to preserve functional residual capacity during the weaning trial (Deutschman & Neligan, 2010).

CPAP

Continuous positive airway pressure (CPAP) trial using a CPAP level equal to the previous positive end-expiratory pressure (PEEP) level (Zein et al., 2016). Extubation of CPAP patients without further testing is generally avoided due to the increased effort required when using it alone. The small diameter of the endotracheal tube, along with resistance from the circuit and the buildup of secretions or biofilms, further increases airway resistance (Sánchez Sánchez et al., 2021). In many ICUs, CPAP is integrated with T-pieces, pressure support ventilation (PSV), and automatic tube compensation (ATC) as part of spontaneous breathing trials. Advocates of CPAP suggest that it enhances functional residual capacity, helps maintain small airway patency, may be advantageous for patients with left ventricular dysfunction, and has minimal adverse effects. However, there is limited evidence to either confirm or challenge these claims (Deutschman & Neligan, 2010).

Weaning Parameters

Weaning from mechanical ventilation (MV) should begin as soon as the underlying causes of respiratory failure are resolved. Despite the widespread use of the spontaneous breathing trial (SBT), extubation failure still occurs in more than 10% of cases (Gong et al., 2021). The criteria used by clinicians to determine whether a patient has sufficiently recovered to tolerate the withdrawal of ventilatory support have not been clearly defined or prospectively assessed in randomized controlled trials. Instead, a variety of subjective and objective assessment criteria, which may serve as surrogate markers of recovery, are used, though they lack sufficient reliability (Borges et al., 2017). The prediction of successful weaning from mechanical ventilation is an art. There has been a significant struggle over the last four decades to convert it into science and to express it into formulas that can be applied at the bedside across the board (Huaringa et al., 2013).

Rapid Shallow Breathing Index (RSBI)

Among the numerous indices used for weaning assessment, the rapid shallow breathing index (RSBI), also known as the RR/VT ratio, is the most recognized and widely utilized. It has been evaluated in over 22 studies and is frequently referenced and recommended in comprehensive review articles on mechanical ventilation weaning (Nemer & Barbas, 2011). The Rapid Shallow Breathing Index is calculated by dividing the respiratory rate (f) by the tidal volume (VT). The RSBI is widely used to assess ventilated patients before attempting a spontaneous breathing trial (SBT). Clinicians favor RSBI for its simplicity and perceived specificity in predicting successful extubation (Akella et al., 2022). However, while RSBI helps guide weaning decisions, evidence from recent reviews indicates that its ability to predict extubation success is only moderately accurate. It may not reliably rule out unsuccessful extubation outcomes, highlighting limitations in its predictive power (Savla et al., 2021).

A 2022 systematic review and meta-analysis by Trivedi et al. (2022) assessed the accuracy of the Rapid Shallow Breathing Index (RSBI) in predicting successful extubation. The review, which included 48 studies and 10,946 subjects, found that an RSBI of less than 105 had moderate sensitivity (0.83) but poor specificity (0.58) for predicting extubation success. RSBI less than 80 showed slightly better specificity (0.62) but with low certainty. Subgroup analyses regarding measurement techniques and timing relative to the spontaneous breathing trial (SBT) showed no significant differences. The study concluded that RSBI is moderately useful but limited as a stand-alone predictor.

The Negative Inspiratory Force (NIF)

The Negative Inspiratory Force (NIF) depends on the patient's ability to initiate spontaneous breathing, which is maximized when they follow commands (Savla et al., 2021). The test for inspiratory muscle strength is commonly used to detect and quantify respiratory muscle weakness. It measures the pressure generated by all inspiratory muscles, along with the elastic recoil pressure of the lungs and chest wall. This assessment can be performed without patient cooperation, and monitoring of oxygen saturation, ECG, blood pressure, dyspnea, and anxiety is essential during the procedure. A PImax value greater than -30 cmH_2O is highly sensitive but has low specificity in predicting successful weaning from mechanical ventilation (Magalhães et al., 2018).

Partial pressure of the fraction of inspired oxygen (P/F) ratio

The ratio of arterial oxygen partial pressure (PaO_2) to the fraction of inspired oxygen (FiO_2), known as the PaO_2/FiO_2 (PF) ratio, is commonly used in ICUs as a quick and straightforward indicator of a patient's oxygenation status. A low PF ratio upon ICU admission has been linked to worse outcomes, including increased ICU mortality and prolonged hospital stays (Kwack, 2022). The P/F ratio has also been identified as a predictive parameter for weaning and extubation. Studies have shown that a P/F ratio greater than 200 reduces the risk of extubation failure to 0.69, while a ratio greater than 300 further decreases the risk to 0.14 (Guzatti et al., 2022). Moreover, the PaO_2/FiO_2 ratio is a standard measure for assessing oxygenation in patients with acute lung injury and acute respiratory distress syndrome (ARDS) (Nemer & Barbas, 2011).

Minute Ventilation

Minute ventilation measures the volume of gas inhaled or exhaled over a minute to assess the feasibility of extubation. However, its limitation lies in the variability of results in the same patient, which depends on the technique employed. It can be performed with or without oxygen, using a ventilator or various devices, making standardization challenging (Sánchez Sánchez et al., 2021). The relationship between minute ventilation (VE) and PaCO2 offers a reliable measure of the respiratory system's workload. Normal VE is approximately 6 L/min, and a value below 10 L/min is preferred for patients undergoing a weaning trial (Deutschman & Neligan, 2019).

Patients receiving ventilatory support frequently undergo considerable changes in respiratory rate. The study by Gutierrez et al. (2013) found that a decreased respiratory rate variability (RRV) during ventilatory support is linked to higher mortality rates. However, the underlying mechanisms for this association are yet to be identified. Additionally, spontaneously breathing patients with higher RRV tend to have better weaning outcomes.

Vital Capacity

Vital capacity (VC) represents the maximum volume of air an individual can exhale following a deep inspiration (Deutschman & Neligan, 2019). A normal vital capacity ranges from 65 to 75 mL/kg, and values greater than 10 mL/kg are indicative of a successful weaning process (Sánchez Sánchez et al., 2021). The study Chevrolet and DeléAmont (2012) demonstrated that vital capacity (VC) measurements were highly effective in predicting respiratory failure several days before intubation. In addition, in patients who eventually required intubation, VC decreased during the 48 hours before respiratory failure. The study also highlighted that VC measurements were crucial for determining the onset of the weaning process, as no weaning trial could be successfully performed when VC was below 7 ml/kg BW. Additionally, extubation was successfully considered when VC was above 15 ml/kg BW.

Driving Pressure

Excessive pressure causing macroscopic rupture of the lung parenchyma, known as barotrauma, was the first identified cause of ventilator-induced lung injury (VILI). Currently, driving pressure is considered the most reliable predictor of VILI in patients with ARDS. Additionally, in patients undergoing general anesthesia, higher driving pressure levels have been linked to an increased risk of pulmonary complications (Tonetti et al., 2017). It is a mechanical parameter that reflects the amount of pressure transmitted through the respiratory system during tidal ventilation (Barbas & Palazzo, 2018). Driving pressure is calculated as the difference between plateau pressure (Pplat) and positive end-expiratory pressure (PEEP). It is a fundamental aspect of mechanical ventilation, with its levels adjusted based on the underlying pathology and severity of lung injury. Higher ΔP levels are associated with reduced lung compliance, thereby increasing the risk of volutrauma. (Williams et al., 2019). Maintaining a lower driving pressure, ideally below 15 cmH_2O, is recommended as part of a lung-protective ventilation strategy for ARDS patients to help reduce hospital mortality in critically ill individuals (Barbas & Palazzo, 2018). A direct relationship exists between reduced compliance and a decrease in functional residual capacity. Elevated DP can impair diaphragmatic function and is linked to increased mortality (Gong et al., 2021).

Work of Breathing (WOB)

The main goal of mechanical ventilation is to help restore gas exchange and reduce the work of breathing (WOB) by assisting respiratory muscle activity. Knowing the determinants of WOB is essential for the effective use of mechanical ventilation and for assessing patient readiness for weaning (Cabello & Mancebo, 2006). Several studies have examined the relationship between work of breathing and weaning outcomes. These evaluations have utilized both work per minute, which is calculated by multiplying work per breath by the respiratory rate, and work per liter, which is derived by dividing the work rate per minute by the tidal volume (Deutschman & Neligan, 2019).

In healthy children, adolescents, and young adults, normal WOB has been reported to range from 0.3 to 0.5 J/L. Recent advancements in technology now provide the capability to objectively measure both the patient's WOB and the ventilator's WOB at the bedside during the weaning process, enhancing the accuracy of assessments made during this critical phase of patient care (Levy et al., 1995). The study by Kirton et al. (1995) found that some patients experienced tachypnea during weaning due to unrecognized imposed work of breathing (WOB). Their findings indicated that unexpected tachypnea in patients with acceptable pulmonary mechanics was primarily linked to the work imposed by the endotracheal tube (ETT) and breathing apparatus. Although 'work of breathing' is stated in the literature as an essential clinical observation, it was excluded from the present study as it is not typically used as a quantifiable weaning parameter in survey-based assessments.

Airway occlusion pressure (P0.1)

Recent technological advancements have made it possible to measure respiratory center function at the bedside, although this is rarely done in routine critical care (Jubran & Tobin, n.d.). Airway occlusion pressure (P0.1), which measures the pressure in the occluded airway 100 ms after the onset of inspiration, was first described 40 years ago and is now available on nearly all modern ventilators (Telias et al., 2018). P0.1 is an essential parameter for weaning from mechanical ventilation, which reflects central respiratory drive (Nemer & Barbas, 2011). It has been extensively studied as a predictor of weaning success or failure, with high P0.1 levels during spontaneous breathing trials indicating a potential for weaning failure due to an elevated respiratory drive (Telias et al., 2018). Among the various methods used to evaluate central respiratory activity, tracheal P0.1 measurement is likely the most accessible in ICU settings (Nemer & Barbas, 2011).

Measuring P0.1 typically requires the use of an esophageal balloon or a ventilator-equipped monitor (Nemer & Barbas, 2011). Several studies have explored the predictive value of Pn1 measurements in assessing a patient's ability to return to spontaneous ventilation after mechanical ventilation. While three groups of researchers have found that elevated Pn1 levels are indicative of weaning failure, the specific thresholds for distinguishing between successful and unsuccessful weaning vary across studies. Although these measurements can provide valuable insights in research contexts, their practical utility in the daily management of critically ill patients remains uncertain (Jubran & Tobin, n.d.).

Oxygen Index (OI)

The Oxygenation Index (OI) is commonly used to assess the severity of hypoxemic respiratory failure (HRF) in neonates. It is categorized as follows: 15 or less indicates mild HRF, 16 to 25 represents moderate HRF, 26 to 40 signifies severe HRF, and values exceeding 40 indicate very severe HRF. OI is calculated using the formula: $OI = (MAP \times FIO_2 \times 100) / PaO_2$ (Muniraman et al., 2019). The study conducted by Mamun et al. (2024) established that the oxygenation index (OI) is an effective tool for predicting mortality and weaning outcomes in patients with ARDS receiving mechanical ventilation. Specifically, the research found that the OI measured on the first day of mechanical ventilation serves as an independent predictor of these outcomes in ARDS patients. The results indicated that the OI was significantly higher in individuals who experienced weaning failure and in those who did not survive. Furthermore, the OI exhibited high sensitivity, specificity, and accuracy in predicting both mortality and weaning outcomes.

Arterial Blood Gas (ABG)

No universally accepted oxygenation index definitively determines when weaning should be withheld. Instead, various criteria based on arterial blood gas (ABG) measurements have been proposed to guide the weaning process (Deutschman & Neligan, 2019). Measurements of arterial blood gas (ABG) constitute an integral part in the assessment of pulmonary gas exchange in ventilator-supported patients (Jubran & Tobin, n.d.). The arterial blood gas is considered the gold standard for monitoring oxygenation, as it directly measures the partial pressure of oxygen (PaO2) in the blood. The ABG provides essential values, including temperature, pH, and partial pressures of carbon dioxide (PaCO2) and oxygen (PaO2), which are used to calculate the percentage of oxyhemoglobin saturation. Only arterial blood samples are suitable for accurate estimations of PaO2. Additionally, the PaCO2 derived from the ABG is the most effective measure of ventilation, similar to how PaO2 indicates oxygenation (Khemani et al., 2007).

Lung Compliance

Pulmonary compliance, which reflects the lung's ability to expand, is essential for effective respiratory function. In mechanically ventilated patients, it can be directly measured (Edwards & Annamaraju, 2025). The static compliance of the total respiratory system (Cstat) in a relaxed patient is determined by dividing the ventilator-delivered volume by the distending transthoracic pressure. This measurement is taken under zero gas flow conditions, achieved either through the ventilator's "inspiratory hold" function or by occluding the expiratory port. The resulting plateau pressure indicates the static end-inspiratory elastic recoil pressure, with adjustments needed for external or auto-PEEP. (Jubran & Tobin, n.d.). In mechanically ventilated patients, normal compliance ranges from 60 to 80 mL/cm H_2O. A reduction in compliance can result from various conditions, including pulmonary edema, interstitial lung disease, auto-PEEP, pleural disease, chest wall deformities, obesity, and ascites. In individuals with decreased static compliance (Cstrs), plateau pressure (Pplt) tends to be elevated for a given tidal volume (VT) (Walter et al., 2018).

Airway Resistance

Airway resistance plays a crucial role in determining ventilator settings, the weaning process, patient comfort, and synchrony with the ventilator. Several factors influence the resistance of endotracheal tubes (ETTs), primarily due to their mechanical properties. Once an ETT is placed, secretions begin to accumulate along the inner wall, potentially increasing resistance to airflow. Given this, ETT size is a key determinant of airway resistance. However, the degree to which resistance increases in an individual patient remains unpredictable (Wilson et al., 2009). Tracheal intubation is one of the factors that increase airway resistance in patients with bronchial hyperreactivity (Brenner et al., 2009). Other reasons for an increase in airway resistance may be the presence of a kinked or obstructed endotracheal tube, intraluminal mucus accumulation, or bronchospasm. In mechanically ventilated patients, normal airway resistance is less than 15 cm H_2O/L/second (Walter et al., 2018).

Level of Consciousness

A successful spontaneous breathing trial (SBT) does not necessarily indicate that the endotracheal tube can be safely removed, as successful extubation also requires an adequate level of consciousness, along with intact swallowing and cough reflexes. Weaning from ventilatory support is defined by the completion of an SBT, either a 30-minute T-tube trial or a total pressure support level of less than 10 cmH_2O (Bureau & Demoule, 2022). The likelihood of a successful extubation is considerably higher when the Glasgow Coma Scale (GCS) score is eight or above compared to a score below 8 (Deutschman & Neligan, 2010). The Glasgow Coma Scale (GCS) is a widely used ordinal score created to assess changes in consciousness, the depth and duration of coma, as well as to detect complications and estimate the potential extent of eventual recovery (Middleton, 2012).

Richmond Agitation Sedation Scale (RASS)

To enhance patient comfort, sedation is commonly administered as part of routine care. The use of sedatives and narcotics helps facilitate mechanical ventilation and medical treatment while also reducing physical and psychological discomfort and managing anxiety (Peck & Down, 2010). Research indicates that excessive use of sedatives can cause respiratory depression, potentially leading to prolonged dependence on mechanical ventilation (Hawks et al., 2013).

Implementing a protocol for pain and sedation management may decrease the duration of mechanical ventilation and shorten both ICU and overall hospital stays. This approach could ultimately lead to reduced mortality rates and lower healthcare costs for patients on mechanical ventilation. The Richmond Agitation-Sedation Scale is a recommended tool for assessing sedation levels in the ICU. Its validity and reliability have been established, and it was also validated for use in the Iranian population in 2009 (Taran et al., 2019). The findings by Yousefi et al. (2015) indicated that implementing the RASS reduced the duration of mechanical ventilation but did not impact the use of certain sedatives. The study by Taran et al. (2019) demonstrated that patients in the intervention group maintained sedation levels closer to the ideal RASS score (-1 to +1). Additionally, the duration of mechanical ventilation and ICU stay was significantly reduced in this group. However, no differences were observed in overall patient outcomes. Notably, ICU costs in the control group were twice as high as those in the intervention group.

Suctioning frequency

Artificial airway suctioning is a vital component of airway management and a critical skill for clinicians responsible for maintaining airway patency. However, despite being generally safe, suctioning through an endotracheal or tracheostomy tube carries potential risks. Transient adverse effects such as oxygen desaturation, bleeding, hemodynamic instability, and heart rate alterations have been reported. Additionally, improper suctioning techniques may lead to long-term complications, including airway mucosal damage and an increased risk of hospital-acquired infections (Blakeman et al., 2022). The study by Kirton et al. (1995) demonstrated that Successful extubation was associated with manageable physiological WOB, adequate consciousness levels, and minimal secretions. Quantifying secretions is crucial, as a higher volume of secretions and the need for frequent suctioning reduce the likelihood of successful weaning (Deutschman & Neligan, 2010).

Gaps in the Literature

Several international studies have documented substantial variation in mechanical ventilation weaning practices across ICUs. For example, Burns et al. (2021) found significant international differences in screening methods and weaning protocols across six countries. Esteban et al., 2000 Conducted a global review of mechanical ventilation use and noted that practices varied widely, with limited focus on standardized extubation strategies. More recently, the WEAN SAFE study by Pham et al., 2023 reported considerable variability in weaning approaches across 50 countries, highlighting the ongoing lack of uniform criteria. Rose et al., 2008b It is further emphasized that decision-making responsibility for weaning differs among professionals and settings internationally. However, these studies primarily focus on institutional or physician-level practices, and few have directly explored how respiratory therapists perceive and apply specific weaning parameters. This gap is particularly relevant in comparing countries like Saudi Arabia and the United States, where protocols, training, and healthcare systems differ. This study addresses that gap by examining and comparing RTs' perceptions of weaning criteria across both countries.

Summary

In conclusion, the primary objective of this study is to compare the perceptions and practices of respiratory therapists regarding weaning parameters and patient-specific factors considerations in the United States and Saudi Arabia. The review of literature underscores the complexity of the weaning process, with multiple studies identifying key factors that influence weaning success and ICU length of stay as well as weaning parameters that Respiratory therapists commonly use in different settings and finally revealed the history of Respiratory Therapy in the two countries, which could have contributed to the differences hypothesized in this study. The literature highlights that variations in weaning practices exist not only across different countries but also among ICUs within the same region. Addressing these differences contributes to the standardization of protocols, improves patient outcomes, and ensures evidence-based approaches to the management of mechanical ventilation. Understanding the factors influencing these variations is essential for optimizing weaning strategies and reducing the risks associated with prolonged mechanical ventilation and increased length of stay. Acknowledging these variations provides valuable insights for students and healthcare practitioners, enhancing their ability to adapt to uncommonly used parameters in their facilities and to evolve their practices. Furthermore, this knowledge contributes to future research, guiding the development of improved weaning practices and advancing the field of respiratory therapy.

Chapter III

Methodology

This descriptive cross-sectional study examines the perceptions of mechanical ventilation weaning parameters in ICU patients in Saudi Arabia and the United States. In this descriptive study, the researcher used a self-administered questionnaire to investigate healthcare providers' perceptions of various weaning parameters and patient-specific factors in both regions. This chapter outlines the methodology and procedures employed in the current study.

RESEARCH QUESTIONS

1- How do respiratory therapists perceive the influence of patient-specific factors on the success of weaning from mechanical ventilation in Saudi Arabia and the United States?

2- What are the perceptions of respiratory therapists in the United States and Saudi Arabia regarding the frequency of use of various mechanical ventilation weaning parameters in ICU patients?

3- Which weaning parameters are most frequently used by respiratory therapists in Saudi Arabia and the United States to initiate the weaning process?

Instrumentations

For this study, the instrument employed is a survey consisting of 10 questions. The questionnaire was carefully crafted to accurately assess healthcare professionals' perceptions regarding the use of mechanical ventilation weaning parameters in ICU patients. The survey is divided into two parts: the first part includes seven questions that gather socio-demographic details, such as gender, age, professional background, and years of experience in ICU settings. These questions help contextualize the data and allow for a better understanding of the sample population's profile. The second part focuses on the frequency and factors affecting the use of weaning parameters. It comprises three questions aimed at evaluating the practices and perceptions of respiratory therapists concerning mechanical ventilation weaning parameters. A five-point Likert scale, ranging from "No impact" to "Extremely significant impact," is used to measure participants' attitudes, practices, and beliefs regarding the use of various weaning parameters. This section examines the frequency of weaning parameter usage, its perceived effectiveness, and factors that influence the decision to initiate weaning.

Study Design

This study employs a descriptive cross-sectional design to explore the perceptions and practices related to weaning parameters among healthcare providers in ICU settings in Saudi Arabia and the United States. The primary data for this study will be collected through a self-administered online survey, distributed via email to respiratory therapists in both Saudi Arabia and the U.S. The survey will be designed to gather detailed information on respiratory therapists' perceptions regarding the effectiveness of patient-specific factors on the success of weaning from mechanical ventilation. The survey also aims to assess the frequency with which different weaning parameters are used in clinical practice. This design allows for a comprehensive analysis of how healthcare providers perceive the influence of patient-specific factors on weaning and the relative use of weaning parameters across the two regions.

Study Population and Sampling Technique

The target participants for this study are respiratory therapists working in intensive care units (ICUs) in Saudi Arabia and the United States. Respiratory therapists with a minimum of one year of experience in managing mechanical ventilation in ICU patients will be eligible for inclusion in the study. Those working in non-respiratory therapy roles, or with less than one year of experience, will be excluded. The study will employ a non-probability convenience sampling method, with participants selected based on their accessibility and willingness to participate. Even though this method is not randomized, it will still provide valuable insights into the perceptions and practices of respiratory therapists across both countries. Participants will be recruited from a variety of hospitals, including both public and private institutions, to ensure a broad representation of respiratory therapy weaning practices. Participants will be recruited through internal communication channels within hospitals and associations in both countries, using email. The survey will be anonymous, and no identifying information will be collected to maintain participant privacy.

Data Collection

Upon receiving Institutional Review Board (IRB) approval, the survey will be distributed to participants via email. The email will include an invitation letter explaining the study's purpose, along with clear instructions on how to complete the survey. It will also outline the voluntary nature of participation. Additionally, the confidentiality and anonymity of responses will be highlighted, assuring participants that no personally identifiable information will be collected. The survey will be designed to be convenient and accessible, allowing healthcare professionals to complete it at their own pace. Once participants have finished the survey, they will submit their responses electronically. This online distribution method ensures flexibility while accommodating busy schedules in the healthcare field. All responses will be anonymized prior to analysis. Confidentiality will be maintained throughout the process, with only the principal investigator and the research team having access to the anonymized data. To further assure participants, contact information for the principal investigator will be provided in the survey invitation, enabling them to reach out with any questions or for additional information about the study.

Data Analysis

The data will be analyzed using descriptive statistics to compare the perceptions of participants from both Saudi Arabia and the United States. This study will focus on identifying trends in the frequency of use of weaning parameters. Descriptive statistics will include frequencies, percentages, means, and standard deviations for all survey responses. Demographic information, such as years of clinical experience, professional role, and education, will be considered to explore how these factors might influence the application of weaning parameters in ICU settings. To assess whether demographic factors such as education impact the perceived weaning practices, One-Way Analysis of Variance (ANOVA) will be used. This will help identify significant differences in practices and perceptions across various subgroups. Additionally, a two-tailed independent t-test will be used to compare differences between responses from respiratory therapists in Saudi Arabia and those in the United States, to assess any regional differences in the frequency of use and perceived effectiveness of weaning parameters. A significance level of $p < 0.05$ will be used for all statistical tests.

Chapter IV

Results

This study aimed to evaluate and compare the perception of mechanical ventilation parameter use across multiple countries (Saudi Arabia and the United States), as well as how certain patient-specific factors may affect the success of weaning patients from mechanical ventilation. This chapter presents a statistical analysis of the data collected from the participants. The study targeted Respiratory Therapists from both SA and the US who have graduated and hold a practice license. Participants were recruited using a convenience sampling method. Invitation emails were sent to RTs in different healthcare settings in both countries, which included information about the voluntary nature of participation, along with the survey link. A total of 99 responses were collected, 63 worked in SA, and 36 worked in the US. This chapter also aims to present the findings related to the research questions through both descriptive and inferential statistical analyses:

1- How do respiratory therapists perceive the influence of patient-specific factors on the success of weaning from mechanical ventilation in Saudi Arabia and the United States?

2- What are the perceptions of respiratory therapists in the United States and Saudi Arabia regarding the frequency of use of various mechanical ventilation weaning parameters in ICU patients?

3- Which weaning parameters are most frequently used by respiratory therapists in Saudi Arabia and the United States to initiate the weaning process?

Demographic Findings

Demographic data is presented in Table 1. In terms of country of practice, (n= 63 participants, 63.6%) participants were from Saudi Arabia, while (n= 36, 36.4%) were from the United States. In terms of gender, among participants from Saudi Arabia, 42 (66.7%) were female and 21 (33.3%) were male. Among participants from the United States, 24 (66.7%) were male and 12 (33.3%) were female. In terms of age, participants' ages ranged from 22 to 60 years. The mean age for Saudi participants was 28.03 years (SD = 4.43), while the mean age for U.S. participants was 33.97 years (SD = 10.03). Regarding educational level, the majority of participants in the Saudi group held a bachelor's degree (n = 56, 88.9%), followed by a master's degree (n = 6, 9.5%) and a Ph.D. (n = 1, 1.6%). No participants from Saudi Arabia reported holding an associate's degree. In contrast, the U.S. participants were more evenly represented across different educational levels: 15 (41.7%) held a bachelor's degree, 14 (38.9%) a master's degree, and 7 (19.4%) an associate's degree.

For years of experience, Saudi participants were most frequently in the 3–5 years category (n = 32, 50.8%), followed by 1–2 years (n = 16, 25.4%), 6–10 years (n = 13, 20.6%), and over 10 years (n = 2, 3.2%). In the U.S. group, 12 participants (33.3%) had 1–2 years of experience, 11 (30.6%) had 3–5 years, 4 (11.1%) had 6–10 years, and 9 (25.0%) had over 10 years of experience. Regarding the primary area of work, most Saudi participants worked primarily in adult care (n = 43, 68.3%), followed by multiple care areas (n = 17, 27.0%), pediatric care (n = 2, 3.2%), and neonatal care (n = 1, 1.6%). For the U.S. participants, 24 (66.7%) worked in adult care, 6 (16.7%) in multiple care areas, 3 (8.3%) in pediatric care, and 3 (8.3%) in neonatal care.

Table 1

Characteristics of the study population

Characteristic	Saudi Arabia (n = 63) (%)	United States (n = 36) (%)	Total (N = 99) (%)
Gender			
Male	21 (33.3%)	24 (66.7%)	45 (45.5%)
Female	42 (66.7%)	12 (33.3%)	54 (54.5%)
Mean Age [years] (SD)	28.03 (4.43)	33.97 (10.03)	30.19 (7.52)
Education Level			
Associate Degree	0 (0.0%)	7 (19.4%)	7 (7.1%)
Bachelor's Degree	56 (88.9%)	15 (41.7%)	71 (71.7%)
Master's Degree	6 (9.5%)	14 (38.9%)	20 (20.2%)
Doctorate (PhD)	1 (1.6%)	0 (0.0%)	1 (1.0%)
Years of Critical Care Experience			
1–2 years	16 (25.4%)	12 (33.3%)	28 (28.3%)
3–5 years	32 (50.8%)	11 (30.6%)	43 (43.4%)
6–10 years	13 (20.6%)	4 (11.1%)	17 (17.2%)
>10 years	2 (3.2%)	9 (25.0%)	11 (11.1%)
Primary Area of Work			
Adult Care	43 (68.3%)	24 (66.7%)	67 (67.7%)
Pediatric Care	2 (3.2%)	3 (8.3%)	5 (5.1%)
Neonatal Care	1 (1.6%)	3 (8.3%)	4 (4.0%)
Multiple Areas	17 (27.0%)	6 (16.7%)	23 (23.2%)

Perceptions of the Impact of Patient-Specific Factors on Weaning

Table 2 presents a comparison of patient-specific factors between the two countries, which addresses Research Question 1. An independent samples *t*-test was conducted to compare the perceptions of respiratory therapists in Saudi Arabia and the United States regarding the influence of various patient-specific factors, age, comorbidities, severity of illness or trauma, neurological status, sedation level, early mobilization, and neuromuscular blockade on weaning success. The results indicated that there was no statistically significant difference in overall perception between therapists in Saudi Arabia and the United States (p = .074).

A statistically significant difference was only found for the age factor: therapists in Saudi Arabia perceived age as having a significantly greater impact compared to those in the U.S., p =

.006. Although not statistically significant, a difference was observed for the neuromuscular blockade factor and early mobilization, with Saudi respondents rating them slightly higher than their U.S. counterparts. For the remaining factors, no significant differences were found between the two groups.

A follow-up two-way ANOVA was performed to further investigate the effect of country and educational level on patient-specific factor usage, based on the summed Likert scale score of patient-specific factor perceptions. This test revealed a statistically significant main effect of country, p = .006. Respiratory therapists in Saudi Arabia (M = 31.12, SE = 1.45) reported higher usage of patient-specific factors compared to those in the U.S. (M = 26.07, SE = 1.28). However, no significant main effect of educational level was found (p = .433), and the interaction between country and educational level was not significant (p = .117).

Table 2

Patient-Specific Factors Comparison Table

Factor	Saudi Arabia M (SD)	United States M (SD)	p-value	Effect Size (Cohen's d)	Effect Size Interpretation
Overall Perception	4.06 (0.93)	3.72 (0.85)	.074	0.378	Small to Medium
Neuromuscular Blockade	3.59 (1.49)	3.06 (1.33)	.079	0.371	Small to Medium
Age	3.27 (1.12)	2.53 (1.50)	.006	0.583	Medium
Early Mobilization	3.27 (1.54)	2.75 (1.27)	.089	0.359	Small to Medium
Severity of Illness	3.27 (1.27)	3.06 (1.37)	.366	0.190	Small
Sedation Level	3.44 (1.31)	3.08 (1.24)	.145	0.307	Small to Medium
Neurological Status	3.62 (1.30)	3.39 (1.17)	.424	0.168	Small
Comorbidities	3.44 (1.26)	3.33 (1.34)	.685	0.085	Negligible

Note: M = Mean; SD = Standard Deviation. Scores are based on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).

Perceptions of the frequency of use of MV weaning parameters

Table 3 presents the frequency of use of MV weaning parameters among Respiratory therapists in SA and the US, which addresses Research Question 2. An independent samples t-test was conducted to compare the frequency with which respiratory therapists in Saudi Arabia and the United States use various weaning parameters. Among the Nineteen parameters assessed, the Results indicated that the only statistically significant difference between the two countries was found for the Glasgow Coma Scale (GCS) factor. Saudi Arabia reported significantly more frequent use than those in the United States, $p < .001$. For all other parameters, the differences in reported frequency were not statistically significant ($p > .05$), and effect sizes were small, suggesting similar practices between the two countries. Although not statistically significant, directional trends in the data indicate that some parameters, such as airway resistance and P/F ratio, were reported more frequently by Saudi participants, indicating possible differences in practice patterns that warrant further investigation.

A follow-up exploratory analysis was conducted using two-way ANOVA to evaluate the impact of country and educational level on the frequency of use of weaning parameters. The results indicated that there were no statistically significant main effects of country ($p = .423$) or educational level ($p = .898$). Additionally, the interaction effect between country and educational level was not significant ($p = .901$). These results suggest that neither country nor educational level had a significant impact on the total weaning parameter scores.

Table 3

Frequency of weaning parameters use

Parameter	Saudi Arabia M (SD)	United States M (SD)	p-value	Cohen's d	Effect Size Interpretation
Airway Occlusion Pressure	4.60 ± 5.66	4.75 ± 5.96	.903	-0.025	Negligible
Airway resistance	7.52 ± 4.55	6.03 ± 4.76	.125	0.321	Small
Lung compliance	7.79 ± 4.57	6.75 ± 3.45	.237	0.247	Small
pH	12.29 ± 4.73	11.36 ± 5.46	.379	0.183	Small
PCO_2	11.43 ± 4.56	11.83 ± 4.19	.663	-0.091	Negligible
PaO_2	9.92 ± 4.90	9.11 ± 4.77	.427	0.167	Negligible
Driving pressure cmH_2O	6.05 ± 4.69	5.56 ± 4.36	.608	0.107	Negligible
Frequency of suctioning	9.29 ± 4.29	9.61 ± 5.33	.741	-0.069	Negligible
VC mL	5.90 ± 4.52	6.94 ± 5.58	.315	-0.209	Small
SBT trials	13.84 ± 5.69	14.83 ± 4.65	.376	-0.184	Small
RASS	7.27 ± 5.28	8.03 ± 5.80	.509	-0.137	Negligible
Following commands	10.63 ± 4.31	11.44 ± 5.37	.414	-0.170	Negligible
GCS	13.98 ± 4.59	7.67 ± 5.47	.001	1.283	Large
OI	6.00 ± 4.76	7.17 ± 5.91	.286	-0.223	Small
VE	10.51 ± 4.45	11.14 ± 5.22	.525	-0.133	Negligible
RR	12.27 ± 4.51	11.81 ± 4.29	.617	0.104	Negligible
P/F ratio	10.35 ± 4.71	8.83 ± 4.88	.132	0.315	Small
NIF	10.25 ± 6.07	9.53 ± 5.94	.565	0.120	Negligible

Note.VC = Vital Capacity; SBT = Spontaneous Breathing Trial; RASS = Richmond Agitation-Sedation Scale; GCS = Glasgow Coma Scale; OI = Oxygenation Index; VE = Minute Ventilation; RR = Respiratory Rate; P/F ratio = Partial Pressure of Oxygen/Fraction of inspired oxygen; NIF = Negative Inspiratory Force. M = Mean; SD = Standard Deviation.
Scores represent total ranking frequency, with higher scores indicating more frequent use.

The frequently used weaning parameters by RT's in SA and the US

Table 4 presents the most frequently used parameters in SA and the US, which addresses Research Question 3. To determine the most frequent weaning parameters that are used to initiate the weaning process in both SA and the US, mean scores were analyzed for each parameter across both countries. Results indicated that the top five weaning parameters used in Saudi Arabia are as follows: Glasgow Coma Scale (GCS), SBT trial (e.g., CPAP, PS), pH, respiratory rate (RR), and partial pressure of carbon dioxide (PCO_2). On the other hand, the five most commonly used parameters in the United States are SBT trial (e.g., CPAP, PS), PCO_2, following commands, pH, and minute ventilation (VE). While this study focused on the most frequently used parameters, additional findings regarding the least utilized metrics, such as airway occlusion pressure, are discussed in the implications section.

Table 4

Most Frequently Used Weaning Parameters by Country

Country	Parameter	Mean (SD)
Saudi Arabia	Glasgow Coma Scale (GCS)	13.98 ± 4.59
Saudi Arabia	Spontaneous Breathing Trial (SBT)	13.84 ± 5.69
Saudi Arabia	pH	12.29 ± 4.73
Saudi Arabia	Respiratory Rate (RR)	12.27 ± 4.51
Saudi Arabia	Partial Pressure of Carbon Dioxide (PCO_2)	11.43 ± 4.56
United States	Spontaneous Breathing Trial (SBT)	14.83 ± 4.65
United States	PCO_2	11.83 ± 4.19
United States	Following Commands	11.44 ± 5.37
United States	PH	11.36 ± 5.46
United States	Minute Ventilation (VE)	11.14 ± 5.22

Note. Scores represent total ranking frequency, with higher scores indicating more frequent use.

Chapter V

Discussion

The purpose of this discussion chapter is to interpret and contextualize the key findings of the study, which explored the perceptions of respiratory therapists (RTs) in Saudi Arabia and the United States regarding various weaning parameters and patient-specific factors that influence weaning decisions. While the results provided statistical insights into these perceptions, this chapter seeks to connect the findings to existing literature, professional practice, and possible implications for future clinical and educational strategies. By examining areas of alignment and divergence between the two groups, we aim to gain a deeper understanding of how regional, academic, and experiential factors influence clinical decision-making in respiratory care. This discussion also considers how the results relate to the original research questions and offers recommendations for future research and practice improvements in mechanical ventilation weaning protocols. The following research questions guide this chapter:

1- How do respiratory therapists perceive the influence of patient-specific factors on the success of weaning from mechanical ventilation in Saudi Arabia and the United States?

2- What are the perceptions of respiratory therapists in the United States and Saudi Arabia regarding the frequency of use of various mechanical ventilation weaning parameters in ICU patients?

3- Which weaning parameters are most frequently used by respiratory therapists in Saudi Arabia and the United States to initiate the weaning process?

Demographic Considerations

The demographic findings of participants highlighted some noteworthy differences between respiratory therapists from Saudi Arabia and the United States, which may help explore variations in perception and practice. U.S. participants tended to be older on average and had a more varied educational background, including a higher proportion of participants with associate and master's degrees. In contrast, Saudi respondents were predominantly bachelor's degree holders and younger. These patterns align with the historical development of the respiratory therapy profession in both countries. In the United States, the profession has been formally established since the 1940s (Mathews et al., 2006). In contrast, in Saudi Arabia, respiratory care only gained formal recognition in the mid-1970s (Al-Otaibi & AlAhmari, 2016). Moreover, the availability of respiratory therapy programs in Saudi Arabia remains uneven, contributing to a relatively younger and more uniformly educated workforce.

Years of clinical experience further illustrated this contrast: a larger proportion of U.S. therapists reported more than 10 years of experience, whereas Saudi participants were more concentrated in the early and mid-career ranges. The relatively homogeneous educational background and fewer years of experience among Saudi therapists may reflect the relatively new infrastructure for respiratory therapy education and practice in the Kingdom, which has only recently expanded beyond major urban centers (Alotaibi, 2015; Al-Otaibi & AlAhmari, 2016). These demographic differences may influence respondents' clinical judgment, exposure to diverse protocols, and familiarity with evidence-based weaning practices. Although the statistical analyses did not reveal significant differences in perception between the two groups overall, these demographic insights provide valuable context for understanding how country-specific professional development may influence decision-making at the bedside.

Perceptions of the Impact of Patient-Specific Factors on Weaning

This section addresses Research Question 1 and explores how respiratory therapists (RTs) from Saudi Arabia and the United States perceive patient-specific factors in influencing the weaning process from mechanical ventilation. Although the independent samples t-test revealed no statistically significant difference in the overall perception scores between the two groups ($p = .074$), the detailed analysis highlighted meaningful insights worth contextualizing.

A significant difference was found regarding the age factor, where Saudi RTs perceived age as having a greater influence on weaning outcomes than the U.S. participants ($p = .006$). This finding may reflect a greater awareness of age-related physiological changes that can complicate the weaning process, which aligns with (Suraseranivong et al., 2018) who stated that such modifications including thoracic cage stiffening, weakened respiratory and diaphragmatic muscles, increased residual volume, reduced cough reflex sensitivity, and declining cardiac function can increase the risk of weaning failure.

Although the difference in perception of early mobilization between Saudi and U.S. respiratory therapists was not statistically significant, Saudi respondents rated it slightly higher. This finding may reflect a greater clinical emphasis or awareness of its role in ICU care, which supports the findings of Akella et al. (2022) that early mobilization in mechanically ventilated patients has been shown to reduce ICU-acquired weakness (ICUAW) and increase ventilator-free days. As well as (Khan et al., 2017) findings, which state that the inclusion of early mobilization in multidisciplinary protocols has been associated with reduced rates of delirium and muscle weakness.

The neuromuscular blockade agent was also not statistically significant, but it was rated notably higher by the RTs in Saudi Arabia compared to the US side. This aligns with the fact that

Neuromuscular blocking agents require cautious application due to the associated risks of ICU-acquired weakness and prolonged mechanical ventilation. These potential complications may contribute to the higher ratings observed among Saudi participants. The observed perception differences, although modest, may suggest variability in training emphasis or institutional adherence to such evidence-based protocols.

The Follow-up two-way ANOVA confirmed that the country factor significantly influenced overall usage of patient-specific considerations, with Saudi RTs reporting greater use than the U.S. participants ($p = .006$). This finding may reflect broader differences in institutional protocols, training, and clinical workflows between the two countries. This supports the findings of Al Tabee et al. (2020) and Rose et al. (2008), which suggest that mechanical ventilation and weaning practices are subject to variation due to socio-political contexts, leadership structures, and the presence or absence of standardized protocols. These differences can shape how clinical teams engage with weaning predictor parameters, thereby influencing daily practice patterns among RTs in different healthcare systems.

Educational level, however, did not significantly affect these perceptions ($p = .433$), suggesting that clinical judgment regarding weaning initiations may be determined more by institutional protocols and hospital training than by academic qualification alone. Together, these findings highlight how national context and health system structures shape perceptions of critical care practices, even when formal training appears similar across borders.

Perceptions of the frequency of use of MV weaning parameters

This section addresses Research Question 2 and examines the frequency with which respiratory therapists (RTs) in Saudi Arabia and the United States report the use of various weaning parameters. Among the nineteen parameters analyzed, only the Glasgow Coma Scale (GCS) showed a statistically significant difference, with RTs in Saudi Arabia reporting that it is used significantly more frequently than among participants in the U.S. ($p < .001$). The higher frequency noted of GCS usage among Saudi participants may reflect an emphasis on neurological status as a key indicator for weaning initiation. Literature supports the findings, indicating that the likelihood of a successful extubation is considerably higher when the Glasgow Coma Scale (GCS) score is eight or above compared to a score below eight (Deutschman & Neligan, 2010). Moreover, these findings are consistent with those of Bureau and Demoule (2022), indicating that a successful spontaneous breathing trial (SBT) does not necessarily suggest that the endotracheal tube can be safely removed, as successful extubation also requires an adequate level of consciousness.

Interestingly, despite Saudi participants reporting slightly higher but not significant use of the P/F ratio, oxygenation index, and airway resistance, the general similarity in usage patterns suggests alignment in clinical training and bedside practice. This may reflect growing convergence in respiratory therapy education or increased adoption of international weaning protocols across countries. This interpretation is further supported by the two-way ANOVA, which showed no statistically significant effects of country or educational level on the total frequency of weaning parameter usage. However, our findings differ from those of Burns et al. (2018), who reported significant regional variations in several weaning practices, including screening methods, weaning modes, and spontaneous breathing trial (SBT) techniques. In contrast, the present study observed comparable patterns in the perceived frequency of use for most parameters across both countries.

The frequently used weaning parameters by RTs in SA and the US

This section addresses Research Question 3 and explores the most frequently used weaning parameters by participants in SA and the US. The most rated parameter by RTs in Saudi Arabia is the GCS. This further reinforces the clinical priority placed on neurological assessment in Saudi ICUs. On the other hand, the top-rated weaning parameter by US participants is the SBT trial, which is supported by Akella et al. (2022) findings that indicate that if a patient tolerates a 30- to 120-minute spontaneous breathing trial (SBT), permanent ventilator liberation should be considered. These findings are consistent with those of Rose et al. (2008). Differences in practices may also be observed between countries due to socio-political factors, as well as between individual ICUs within the same region.

Among the five highest-rated parameters in both countries, three were shared by both groups. Those parameters are SBT trials, PH, and PCO2. This emphasizes the importance of these parameters in the global weaning initiation process. In addition, these findings align with those of Deutschman and Neligan (2019), who state that no universally accepted oxygenation index definitively determines when weaning should be withheld. Instead, various criteria based on arterial blood gas (ABG) measurements have been proposed to guide the weaning process. The findings also align with those of Roberts et al. (2024), who suggest that SBTs serve as a key factor in determining ventilator liberation potential. The emphasis on SBT trials, PH, and PCO2 parameter values aligns with international and institutional standards that prioritize objective, evidence-based criteria in weaning decisions. Respiratory care protocols are widely implemented and taught, and with substantial supporting evidence, they have arguably become a standard in respiratory care (Stoller, 2001). This may help explain the consistency observed in some of the top-rated parameters across both groups.

Implications of the study

The findings of this study suggest a high degree of consistency and similarity in the overall reported use of weaning parameters between respiratory therapists in Saudi Arabia and the United States. This similarity may reflect standardized training, share clinical competencies, and increase global alignment in respiratory care protocols. However, an exploratory analysis of the least frequently used parameters revealed that several were underutilized across both countries. Specifically, airway occlusion pressure (P0.1), vital capacity (VC), airway resistance, and driving pressure were among the least reported by participants in both Saudi Arabia and the United States. Additional low-use parameters in Saudi Arabia included the oxygenation index (OI), while U.S. participants also reported low usage of lung compliance. These findings suggest that although core weaning practices are consistently applied, some evidence-based parameters may be underutilized in daily practice. Therefore, including these underused parameters in respiratory therapy education, competency assessments, and clinical training may help improve decision-making and ensure that a broader set of weaning indicators is considered in complex cases.

Delimitations

This study focused exclusively on respiratory therapists working in ICU settings in Saudi Arabia and the United States. The scope was limited to evaluating the perception and frequency of use of specific weaning parameters, rather than examining clinical outcomes. Additionally, the study targeted specific hospitals in both countries based on existing professional connections and access, rather than employing a randomized or nationally representative sample. These boundaries were intentionally set to maintain a focused and feasible research scope aligned with the study's objectives.

Limitations and Strengths

The study has several limitations. First, the use of a self-reported questionnaire introduces the possibility of response bias, as participants may have answered based on their perception or institutional protocol rather than actual clinical practice. Second, the sample sizes were unequal between countries, with a larger number of responses from Saudi Arabia than from the United States, which may affect the balance of the comparison. Additionally, the overall sample size was relatively small and recruited through convenience sampling, which limits the generalizability of the findings to all respiratory therapists in each country. Moreover, since the questionnaire was distributed by email, response rates were initially slow, requiring three follow-up reminders. The first two reminders allowed for a six-week response window, while the final reminder had a shorter five-day window due to time constraints imposed by the academic deadline. The study was also limited by some of the confidence intervals extending into negative values, which may be attributed to a relatively small sample size or the presence of outliers. Although negative values are not clinically meaningful in some parameters, their presence within the statistical interval reflects the variability in the dataset.

Despite these limitations, the study has several strengths. It is one of the first to compare how respiratory therapists in Saudi Arabia and the United States perceive and use weaning parameters, providing valuable cross-country insights. The questionnaire used was carefully designed and based on validated tools, which helps ensure the quality and reliability of the data. Additionally, the survey included participants from various clinical settings, making the results more applicable to diverse practice environments. The study also collected information about the participants' backgrounds, such as their education level and years of experience. This allowed for a more meaningful interpretation of the results, as it provided helpful context for understanding the responses. These strengths offer valuable insights into global weaning practices and highlight areas for further research and educational development.

Recommendations for Future Research

Based on the findings of this study, several recommendations can be proposed to enhance mechanical ventilation weaning practices across clinical and educational settings. Future research and training programs may consider emphasizing the clinical application of underused weaning parameters and incorporating a broad range of validated indicators where appropriate. Additionally, while general alignment in the reported use of weaning parameters was observed between respiratory therapists in Saudi Arabia and the United States, notable differences in perceptions of patient-specific factors were found, with Saudi participants reporting greater use. This suggests that institutional norms and cultural context may have an impact on how weaning initiation is determined. Therefore, healthcare and educational institutions are encouraged to include and emphasize the importance of using patient-specific factors in determining the initiation of weaning. Finally, further international research is recommended to investigate the impact of cultural and institutional factors on the decision-making of respiratory therapists. Such work may benefit students, interns, registered respiratory therapists, or researchers to understand the global differences and the factors that influence the initiation of weaning.

Conclusion

To the best of our knowledge, this is the first study to compare the perception of Respiratory therapists regarding the use of weaning parameters and patient-specific factors between Saudi Arabia and the United States. By utilizing a cross-national sample, the study offers valuable insights into global similarities and differences in clinical practice. This study was guided by the hypothesis that there are differences in the perceptions and use between the two groups. Although the hypothesis anticipated broad differences, the findings partially supported this assumption. Statistically significant differences were observed in specific areas, namely, the perception of age as a patient-specific factor and the reported frequency of using the GCS parameter. In contrast, the majority of parameters showed comparable usage across both countries. Finally, the most frequently used parameter among the Saudi RTs is the GCS, while the most frequently used one among the US RTs is the SBT trial. Additionally, underutilization of specific evidence-based parameters, such as airway occlusion pressure, driving pressure, and Vital Capacity (VC), was noted in both countries. These gaps highlight the need for greater emphasis on these parameters in education and practice. Overall, the study provides a solid foundation for future research and protocol development aimed at standardizing best practices globally.

Appendix A

Survey Instrument

1- What is your gender?
- Male
- Female

2- Where do you currently work?
- Saudi Arabia
- United States

3- What is your age in years at the time of taking this survey?

4- What is your highest educational qualification as of today?
- Associate degree
- Diploma
- Bachelor’s Degree
- Master’s Degree
- Doctoral Degree

5- What is the most frequent area you work in? (e.g., Adult ICU, Pediatric ICU, Neonatal ICU, etc.)

6- How many years of experience do you have in critical care as of today?

7- What is the name of the healthcare facility you work in as of today?

8- What is the average number of mechanically ventilated patients you are assigned for per shift?

9- In your experience, as a respiratory therapist, how much do patient-specific factors, e.g., comorbidities, age, severity of illness) influence weaning success?

Please rate your perception on a scale of 0 to 5:

0. No impact
1. Minimal impact
2. Some impact
3. Moderate impact
4. Significant impact
5. Extremely significant impact

10- In your experience as a Respiratory Therapist, how do the following patient factors affect the success of weaning from mechanical ventilation? Please rate each factor from 0 to 5:

a. Age

0. No impact
1. Minimal impact
2. Some impact
3. Moderate impact
4. Significant impact
5. Extremely significant impact

b. Comorbidities (e.g., COPD, heart disease)

0. No impact
1. Minimal impact
2. Some impact
3. Moderate impact
4. Significant impact
5. Extremely significant impact

c. Severity of illness/trauma

0. No impact
1. Minimal impact
2. Some impact
3. Moderate impact
4. Significant impact
5. Extremely significant impact

d. Patient's neurological status

0. No impact
1. Minimal impact
2. Some impact
3. Moderate impact
4. Significant impact
5. Extremely significant impact

e. Sedation level

0. No impact
1. Minimal impact
2. Some impact
3. Moderate impact
4. Significant impact
5. Extremely significant impact

f. Early mobilization

0.No impact
1. Minimal impact
2. Some impact
3. Moderate impact
4. Significant impact
5. Extremely significant impact

g. Neuromuscular blockade agents

0. No impact
1. Minimal impact
2. Some impact
3. Moderate impact
4. Significant impact
5. Extremely significant impact

11- Please rank the following parameters based on how often you use them to initiate the weaning process. Rate on a scale of 0–18 where 0 (least frequently used) and 18 (most frequently used). YOU CAN ONLY CHOOSE THE NUMBER ONCE.

a. Rapid Shallow Breathing Index (RSBI)

0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18

b. Negative Inspiratory Force (NIF)

0| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18

c. P/F Ratio (PaO2/FiO2)

0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18

d. Respiratory Rate (RR)

0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18

e. Minute Ventilation (VE)

0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18

f. Oxygenation Index (OI)

0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18

g. Glasgow Coma Scale (GCS)

0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18

h. Following commands

0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18

i. Richmond Agitation-Sedation Scale (RASS)

0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18

j. SBT Trial (e.g., CPAP, PS)

0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18

k. Vital Capacity (VC)

0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18

l. Frequency of suctioning

0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18

m. Driving Pressure

0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18

n. PaO2

0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18

o. PCo2

0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18

p. PH

0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18

q. Lung Compliance

0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18

r. Airway resistance

0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18

s. Airway occlusion pressure (P0.1)

0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18

Appendix B

Consent Form

A Cross-National Examination of Weaning Parameter Usage: Comparing Respiratory Therapists' Perceptions in Saudi Arabia and the United States

Principal Investigator: Douglas, Gardenhire.

Student Principal Investigator: Katib, Rahaf

Institution: Georgia State University- Respiratory Therapy Department

Email: dgardenhire@gsu.edu – Rkatib1@student.gsu.edu

You are invited to participate in a research study that aims to explore how respiratory therapists in Saudi Arabia and the United States perceive the use of weaning parameters in mechanical ventilation. Weaning parameters are guidelines used to help patients gradually transition off mechanical ventilation. The goal of this study is to understand the differences in how these parameters are perceived and applied in both countries.

If you decide to participate, you will be asked to complete an anonymous online survey. The survey will take approximately 5 minutes to complete and will include questions regarding your perceptions and experience with weaning parameters in your clinical practice. Your responses will be kept anonymous and confidential.

Participation in this study is completely voluntary. You may choose not to participate or withdraw from the study at any time without any negative consequences. There is no penalty for choosing not to participate or for withdrawing at any time during the study.

Your responses will be kept confidential. No personally identifiable information will be collected. Data will be stored securely on an encrypted cloud storage system. Only the research team will have access to the data, which will be deleted after the study.

There are no foreseeable risks associated with this study. The study involves minimal risk as it only requires the completion of a survey, which does not involve sensitive or harmful topics.

While there is no direct benefit to you for participating, your participation will help improve understanding of weaning parameters and their application, which could contribute to better patient care in the future.

If you have any questions about this study or your participation, please contact the principal investigator, Dr. Gardenhire, at dgardenhire@gsu.edu. If you have concerns about your rights as a research participant, you may contact GSU Human Subjects IRB at irb@gsu.edu.

By selecting "I agree" or signing below, you are indicating that you have read the information provided above and that you agree to participate in this study. Your participation is voluntary, and you may withdraw at any time.

Participant's Signature: _________________________

Date: _________________________

Appendix C

IRB Approval

April 07, 2025

Principal Investigator: Douglas Gardenhire

Key Personnel: Gardenhire, Douglas; Katib, Rahaf A

Study Department: Georgia State University, Respiratory Therapy

Study Title: A Cross-National Examination of Weaning Parameter Usage: Comparing Respiratory Therapists' Perceptions in Saudi Arabia and the United States

Submission Type: Exempt Protocol Category 2 IRB Number: H25536
Reference Number: 384116

Determination Date: 04/07/2025 Status Check Due By: 04/06/2028

The above-referenced study has been determined by the Institutional Review Board (IRB) to be exempt from federal regulations as defined in 45 CFR 46 and has evaluated for the following:

1. Determination that it falls within one or more of the eight exempt categories allowed by the institution; and

2. Determination that the research meets the organization's ethical standards

If there is a change to your study, you should notify the IRB through an Amendment Application before the change is implemented. The IRB will determine whether your research continues to qualify for exemption or if a new submission of an expedited or full board application is required.

A Status Check must be submitted three years from the determination date indicated above. When the study is complete, a Study Closure Form must be submitted to the IRB.

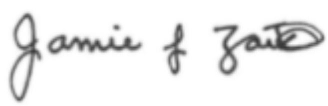
This determination applies only to research activities engaged in by the personnel listed on this document.

It is the Principal Investigator's responsibility to ensure that the IRB's requirements as detailed in the Institutional Review Board Policies and Procedures For Faculty, Staff, and Student Researchers (available at gsu.edu/irb) are observed, and to ensure that relevant laws and regulations of any jurisdiction where the research takes place are observed in its conduct.

Any unanticipated problems resulting from this study must be reported immediately to the University Institutional Review Board. For more information, please visit our website at www.gsu.edu/irb.

Sincerely,

Jamie Zaikov, IRB Member



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