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The effectiveness of ventilator weaning using a weaning protocol compared to non-protocol: a systematic review

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Abstract

Ventilator use can reduce respiratory function, heighten infection risk, extend ventilator dependence, and, in severe cases, necessitate prolonged mechanical ventilation. Systematic weaning protocols can alleviate these issues, enhance breathing, and aid extubation. This review assesses studies on weaning protocols in ICU patients. Using the PRISMA framework, an extensive search was performed in databases such as ClinicalKey Nursing, ScienceDirect, ProQuest, SAGE, EMBASE, MEDLINE, Scopus, SpringerLink, and PubMed. This search aimed to find studies comparing protocolized and non-protocolized weaning in adult ICU patients. Included were peer-reviewed randomized controlled trials (RCTs) and quantitative studies focusing specifically on adult ICU weaning protocols. Studies involving non-adult populations were excluded. The JBI and CASP tools were used to assess the quality of the studies. Out of 475 identified articles, six met the inclusion criteria. Three types of weaning protocols were identified: nurse-led, respiratory therapy-led, and automatic protocols. These protocols demonstrated effectiveness by reducing ventilator time, increasing extubation success, and shortening ICU stays. Evidence supports that weaning protocols positively impact patient outcomes, particularly by shortening intubation periods, and can enhance inter-professional collaboration in the ICU.

Introduction

The Intensive Care Unit (ICU) is designed to monitor patients with high levels of dependency, complex health issues, and the need for advanced technology. Worldwide, approximately 80% of primary care needs in the ICU involve the use of mechanical ventilation (VM) or ventilators. According to data from the United States, nearly 5.7 million

patients are treated in the ICU annually, of which 30% require ventilators.¹ Most instances of acute respiratory failure require mechanical ventilation, which can be discontinued once the underlying cause has been resolved through the process of weaning and extubation. However, 20-30% of ICU patients are considered challenging to wean from mechanical ventilation.²

Patients who receive treatment using a ventilator aim to be weaned from the device. The process of weaning, also known as ventilator weaning, is influenced by the patient's healing and the improvement of lung capacity, which can optimize ventilation and enhance circulatory support. Successful weaning is dependent on several factors, including breathing exercises while using the ventilator.³⁻⁵ Nurses, particularly those in critical care or ICU settings, play a crucial role in the care of patients with critical conditions.⁶⁻⁹ The American Nurses Association recognizes critical nursing as a distinct field involving interdisciplinary collaboration and comprehensive nursing care. Experts also agree that ICU nurses play a central role in developing weaning plans for patients.¹⁰

Critical care is a comprehensive healthcare field that encompasses various specialists and interventions. To enhance the quality of care in the intensive care unit, international organizations have created evidence-based guidelines, protocols, and bundles.¹¹ Ventilator weaning is a significant aspect of ICU management, and nurses have increasingly played a crucial role in this process over the past two decades through the implementation of nurse-led and nurse-driven weaning protocols.¹² Studies have demonstrated that involving nurses and therapists in weaning patients from mechanical ventilation and extubation leads to better outcomes.^{3,13-15} Historically, physicians were primarily responsible for weaning patients and making key decisions during the process. In contemporary practice, some countries continue to handle the weaning process collaboratively within the ICU, lacking a specific patient weaning protocol.

A study by Hirzalah stated that the nurse's weaning ventilator protocol resulted in a significant reduction in the duration of ventilator use and a significant reduction in weaning time.¹⁵ A study conducted in the United States in 2013, which examined the weaning protocol by nurses, resulted in a shorter extubating time of 2 h and 13 min compared to protocols from other groups. The study also identified four independent predictors of weaning duration, one of which was the nurses' weaning protocol.¹⁶ This systematic review aimed to determine the effectiveness of ventilator weaning using a protocol compared to ventilator weaning without

the use of a protocol in patients on ventilators in the ICU. In addition, this study will explain the types of protocols that have been proven safe.

Materials and Methods

The aim of the study was to identify the effectiveness of ventilator weaning protocol compared to the non-protocol. We followed the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA) statement.

Search strategy and selection criteria

To meet the methodological standard of a systematic review, specific keywords were used to conduct a comprehensive literature search and data extraction from Scopus, Medline, SAGE, ProQuest, ClinicalKey Nursing, PubMed, JSTOR, EMBASE, ScienceDirect, and SpringerLink electronic databases, adhering to PRISMA guidelines. The search included quantitative research articles on mechanically ventilated ICU patients, published in English between 2019-2023, using keywords such as "intubated patient", "ventilated patient", "mechanical ventilated patient", "ICU patient", "weaning protocol", "Nursing protocol in weaning", "usual care", "extubation", "extubation readiness", and "improving ICU outcome".

Selection of studies

An investigator (DFA) independently conducted the initial screening of articles by reviewing the titles, abstracts, and full texts from all databases. The results of candidate articles were saved using EndNote X9 software for the initial screening and identification of duplicates. In the subsequent step, DFA performed a comprehensive screening with the aid of Rayyan software to assess eligibility. DFA organized and analyzed the literature by label for decisions on inclusion or exclusion. DFA then invited two investigators (RR & EN) for collaborative screening, who independently reviewed the articles without seeing each other's choices until the process was complete, minimizing potential bias. Disagreements were resolved through a consensus-building meeting.

Inclusion and exclusion criteria

We included full-text articles from 2019-2023 on Randomized Controlled Trials and quantitative methods related to mechanical ventilation weaning protocols in the ICU, excluding studies on pediatric ICUs or those outside the scope. Extraction was primarily carried out by one investigator (DFA). From all databases, 475 articles were obtained: 128 from ClinicalKey Nursing, 21 from ScienceDirect, 22 from ProQuest, 53 from SAGE, 6 from EMBASE, 10 from PubMed, 30 from MEDLINE, 29 from JSTOR, 16 from SCOPUS, and 160 from SpringerLink. DFA grouped each database in EndNote and checked for duplicates. A total of 165 duplicates were identified, leaving 310 articles meeting the criteria. Three investigators (DFA, RR, EN) conducted a second round of checks. DFA ensured all tasks were accurately completed, contributing to the project's successful completion for RR and EN.

Data extraction and synthesis

The following data were extracted from all studies: i) publication details (English full text, title, publication date, author's name and country), ii) study design (RCT, Cross-sectional, Quasi-experiment, Cohort), iii) setting (sample, adult intensive care unit, mechanically ventilated), iv) model selection (weaning method, ventilator weaning protocol type, usual care, non-protocol ventilator weaning, weaning decision maker), v) data specifics (patient characteristics, duration of mechanical ventilation, duration of weaning). DFA conducted the initial screening by reviewing the titles and publication dates of all articles using EndNote and the Rayyan AI Powered Tool for Systematic Review. This process filtered out 200 irrelevant articles and 19 articles that were not fully accessible, resulting in 91 articles meeting eligibility criteria. Three investigators (DFA, RR, EN) independently performed a second review, identifying 6 potential articles. Data from eligible studies were then extracted into a specific spreadsheet by DFA, RR, and EN (Figure 1).

Quality assessment

The methodological quality of selected studies and the correctness of data extraction were reviewed by two independent investigators (DFA, RR). One investigator was asked for the expert judgment (EN). In general, articles or studies are assessed for quality based on: i) clear research questions, ii) concepts or terminology can be explained operationally, iii) clear

inclusion and exclusion criteria, iv) methods which answer research questions, v) precise data analysis, vi) relevant results and discussion, vii) minimal risk of bias, viii) relevant implications, and ix) described research limitations. The author uses measuring instruments according to the characteristics of the study, namely, The Critical Appraisal Skills Program (CASP) for RCT research and the Joanna Briggs Institute (JBI) for cross-sectional, quasi-experiment and cohort research (Table 1 and Table 2).

Results

Study selection

The outcome of the literature search was 475 studies sourced from all electronic databases. Of these, only 91 articles were deemed eligible for further consideration after 200 articles were determined to be irrelevant, and 19 articles were not provided in full text. Following a second stage screening conducted by all investigators (DFA, RR, EN), only six potential articles remained. A total of 41 articles were excluded due to various reasons, such as incorrect outcome, incorrect publication type, incorrect study design, use of a foreign language, and lack of full text.

Study characteristics

All six studies incorporated in the review follow a quantitative research methodology, comprising one cross-sectional study, one quasi-experimental study, two cohort studies, and two Randomized Controlled Trials (RCTs). Each article is in English, accessible in full text, and published between 2019 and 2023. The studies share a common population, which consists of adult ICU patients aged over 18 years and ventilated for at least 24 hours. The systematic review features studies from a range of sources, with a total of 5,380 participants taking part in the studies. To ensure accurate and relevant results, the review includes adult ICU patients from Sweden, Iran, Brazil, Japan, and the United Kingdom. All articles feature structured weaning intervention protocols in contrast to conventional weaning procedures (Table 3).

Primary outcome

Type of weaning protocol

This Systematic Review assesses six articles that examine various aspects of ventilator weaning protocols. Five of the six articles under consideration focus on comparing weaning protocols with conventional care. These include the works of Ghanbari *et al.*,¹⁷ Lago *et al.*,¹⁸ Vahedian-Azimi *et al.*,¹⁹ and Vizcaychipi *et al.*²⁰ In contrast, the study by Caderwall *et al.* examines weaning protocols and accompanying practices in patients who require ventilator support in the ICU.²¹ A study conducted by Ghanbari *et al.* evaluated the effectiveness of the Nurse-Led Weaning Protocol, which differs from physician-based protocols for weaning patients from mechanical ventilation.¹⁷ The Nurse-Led Weaning Protocol utilizes the Burn's Weaning Scale (BWS), containing 40 items, and employs a combination of ventilation methods, including CPAP, PCV, BIPAP, SIMV, and PSIMV. The study revealed that the nursing protocol involved monitoring several laboratory values on a daily basis.

Lago *et al.* compared the International Consensus Conference (ICC) guideline protocols with the WIND classification, which categorizes patients' weaning types as no weaning, short weaning, difficult weaning, and prolonged weaning.¹⁸ However, the specific weaning method employed in this study remains indeterminate. Nitta *et al.* conducted research on the development of weaning and extubation protocols, encompassing an evaluation checklist with four components: Spontaneous Breathing Trial (SBT), extubating eligibility, non-invasive positive pressure (NPPV) prophylaxis, and post-extubation assessment.²² The study revealed that the weaning method utilized was SBT for 30 minutes, with a flow trigger set at 0, PSV 0, Positive End Expiratory Pressure (PEEP) established at 5 cmH₂O, or through the use of a T-tube.

The RCT conducted by Vahedian-Azimi *et al.*, found that weaning from RT was preceded by a checklist of weaning criteria. The method used was continuous positive airway pressure (CPAP) set at 5 cmH₂O, fraction of inspired oxygen (FiO₂) set at 0.4, arterial oxygen saturation value greater than or equal to 92%, and a Rapid Shallow Breathing Index (RSBI) less than 105 times per minute per liter.¹⁹ Spontaneous Breathing Trials (SBT) were performed for 120 minutes. Typical care, which is usually provided, is based on the clinical decisions of the intensivist, considering the patient's clinical status, airway conditions, and RSBI or NIF respiration indicators. Another RCT study compared weaning protocols with a mathematical system (iCareWean) in a special healthcare system called BEACON with standard weaning or routine care. In the intervention protocol, systematic charts compiled by the research team were used.²⁰ Weaning interventions encompassed Blood Gas Analysis (GBA) parameters, automatic lung parameter estimators, ventilator setting adjustments,

consultations, sedation types, and SBT. This study utilized the BEACON Care system monitor to track Pressure Support (PS) and positive end-expiratory pressure (PEEP) values during SBT conditions.

A national survey in Sweden showed that about 55% of Intensive Care Units (ICUs) utilized a weaning protocol comprising individualized and collaborative plans for ICU nurses and doctors.²¹ Additionally, 65% of ICUs used a collaborative approach for weaning, while 27% relied on the decision of the doctor. Common methods for weaning include pressure support reduction, Low Flow Oxygen (LFO₂), High Flow Oxygen (HFO₂), Continuous Positive Airway Pressure (CPAP), and Volume Support (VS). The study identified three main features of the weaning protocol used: i) a nurse's weaning protocol using the Burn's Weaning Scale and controlling daily laboratory results; ii) a therapist weaning protocol using predefined criteria and Spontaneous Breathing Trials (SBT) results; iii) a comprehensive protocol that includes the nurse's decisions in collaboration with intensivists. The review underscores the importance of structured weaning protocols, whether nurse-led, therapist-led, or collaborative, in enhancing patient outcomes during the weaning process. Each protocol type offers distinct advantages, depending on the clinical setting and the specific needs of the patient population.

The effectiveness of weaning protocol

According to A. Ghanbari et al., the weaning protocol employed by nurses, specifically the use of BWS, yielded safer and more effective outcomes compared to the clinical judgment of physicians.¹⁷ The average duration of mechanical ventilation for the intubated patient group using BWS was 111.75 ± 33.46 hours, while the physician group had a duration of 125.12 ± 43.43 hours, with a significant difference observed in the duration of mechanical ventilation between the two groups ($P = 0.000$). Lago *et al.* suggested that the WIND classification is more suitable for use in the intensive care unit, particularly in patients with severe conditions and prolonged weaning.¹⁸ The study found that not all patients could be fully classified as receiving usual care (ICC). In the WIND classification category, all groups exhibited better outcomes with shorter mechanical ventilation time compared to the ICC classification ($P = 0.0001$).

A study from Nitta reported that the weaning protocol demonstrated effectiveness, as 213 patients were successfully extubated following 30 minutes of SBT.²² A comprehensive protocol for weaning and extubation can prevent post-extubation respiratory failure, with a PERF incidence of 9.7% and a reintubation rate of 5.2%.²² Extubation failure is a major risk

in mechanical ventilation, but a standardized protocol can significantly reduce post-extubation respiratory failure rates. Vahedian-Azimi's research also indicates that the weaning process can be effectively managed by Respiratory Therapy.¹⁹ The results are safe, effective, and associated with reduced reintubation rates. The protocol's effectiveness is demonstrated by increases in minute ventilation ($P < 0.001$), C_s and C_{dyn} ($P < 0.05$), $P_{0.1}$ ($P < 0.001$), NIF ($P < 0.001$), and RSBI ($P < 0.001$).

Vizcaychipi et al. describe the protocol for evaluating the BEACON Care system's effectiveness in the general medical ICU population.²⁰ This protocol is pivotal for utilizing advice and applies only to patients intubated for over 24 hours, highlighting the BEACON Care system as an effective ventilation strategy. Caderwall *et al.* argue that the weaning protocol is not suitable for all ventilated patients, particularly in PMV conditions.²¹

Therefore, weaning protocols may not be relevant for ICUs that use individualized treatment approaches. However, individualized treatment plans necessitate collaborative efforts to reduce ICU mortality and length of stay.

Upon evaluating six separate studies, it was determined that all weaning protocols were both safe and effective for patient care. The effectiveness of these protocols was established through the analysis of statistical data, specifically the duration of intubation and the success rate of extubation when compared to instances where no protocol was employed, or only clinical assessment was used.

Secondary outcome

Ventilator duration

One study strongly suggested that the average duration of intubation in the patient group with the nurse's weaning protocol was shorter than in the patient group with the doctor's protocol ($P = 0.0001$).¹⁷ As many as 80% of patients are ready for weaning before a clinical decision or clinical judgment from a doctor. In addition, the study also suggested that there was a significant difference in the duration of MV in female and male patients in the nurse's weaning protocol group ($P = 0.039$). Moreover, another study was found that the duration of intubation in the weaning protocol group was longer than the usual care group ($P < 0.001$).¹⁹

Length of stay

According to Japanese studies in 2019 found that there was no notable difference in the duration of stay between the two groups, with a P-value of 0.16.²² However, one study findings revealed that the weaning protocol resulted in a reduction in the length of stay, with a P-value of <0.001 because of the implementation of RT's weaning protocol.¹⁹ Furthermore, Brazilian studies indicated that individuals in the difficult weaning category experienced an extended period on mechanical ventilation compared to those in other classifications.

Mortality

According to Nitta's research , there was no significant difference in mortality rates between the two groups, which were found to be 1.2% and 6.9%.²² However, these figures were lower than previously reported. Vahedian's research showed that the mortality rate was constant at P = 0.19.²² On the other hand, Lago's study found an increased risk of death, particularly in the difficult weaning classification group.¹⁸

Discussion

Mechanical ventilators assist respiratory function and maintain alveolar gas exchange. The main goal of using a ventilator is to restore spontaneous breathing and enable weaning. Weaning is essential to prevent complications like dyspnea, respiratory arrest, Ventilator Acquired Pneumonia (VAP), and death. Hence, early weaning is recommended once the patient exhibits signs of spontaneous breathing.

The global consensus currently endorses the ICU Liberation ABCDEF bundle for evidence-based ICU care. These guidelines recommend ventilator weaning procedures that include Spontaneous Awakening Trials (SAT) and Spontaneous Breathing Trials (SBT) to improve patient recovery and ICU treatment efficacy.²⁴ In some countries, data on the ABCDEF bundle's use are limited, and there is no evidence of routine, awake, and scheduled breathing trials. Ventilator weaning often involves individualized processes without standardized protocols, relying on medical decisions for weaning and extubation.⁸

Over the past two decades, nurses' involvement in the weaning process has grown due to the implementation of weaning protocols.¹² Studies indicate that the participation of nurses and therapists benefits ventilator weaning. Research by Roh *et al.* in South Korea found that nurse-administered weaning protocols are safe and reduce weaning time from mechanical ventilation in respiratory failure patients.¹³ The weaning protocol represents a shared

objective for all ICU team members caring for mechanically ventilated patients who are successfully weaned with ventilation support.²³

Typical weaning protocols comprise three main components: readiness assessment standards, ventilator support reduction guidelines, and decannulation criteria. However, these elements may vary across protocols, and not all explicitly outline extubation criteria.¹⁹ This systematic review identifies four effective weaning protocols in the ICU: i) nurse weaning protocols, ii) respiratory therapist weaning protocols, iii) collaborative weaning protocols, and iv) systematic automatic weaning protocols. According to Ghanbari *et al.*, the nurse's weaning protocol uses the Burn's Weaning Scale (BWS).¹⁷ This is consistent with previous research suggesting that a high Burn Score predicts successful weaning, extubation, reduced intubation duration, and shorter hospital stays.²⁵

In the past five years, the BWS has been used in five ICUs, with an 88% success rate and a 12% failure rate. The Burn's Protocol, particularly effective in younger patients during weaning, includes 26 questions on general and respiratory assessments and is supported by various tools and guidelines such as assessment checklists, weaning trial protocols, and sedation guidelines. ICU healthcare professionals are authorized to conduct ventilator weaning. A study by

Vahedian, an RCT on weaning protocols managed by therapists, indicated that respiratory therapists, along with doctors and nurses, participated in the process. The study demonstrated that respiratory therapists adhered to predefined criteria and guidelines from Spontaneous Breathing Trials, assessing physiological variables, Blood Gas Analysis (GBA) results, RSBI, and NIF.²⁶

The weaning process begins with recognizing the signs of readiness for spontaneous breathing from each patient. Health workers and inter-collaborative processes are needed in making the right decisions about the patient care process. Research by C-J Cederwall states that the weaning protocol is very effective in patients with PMV, but the rest of the weaning decisions are made based on the collaboration of ICU nurses and doctors.^{19,27} In contrast to the study conducted by Ghanbari *et al.* which focused on comparing the use of weaning protocols by nurses with the clinical judgment of doctors, which proved that nurse protocols were more effective with shorter duration ventilator use results.²²

All reviewed studies employed a uniform weaning method, specifically the use of SBT per ICU Liberation guidelines. Nitta's study utilized SBT for 30 minutes,¹⁸ while Vahedian *et al.* applied the SBT procedure for 120 minutes, following weaning screening and various physical examinations to assess patient readiness.¹⁹ Another study, using a systematic

protocol with instruments, conducted SBT after confirming satisfactory signs and respiratory values.²⁰ Additionally, A.F. Lago's study indicated that weaning is effective when patients are classified by their ventilator weaning level.

The weaning protocol primarily enhances patient outcomes by reducing intubation duration, length of stay, and mortality rate.²⁸⁻²⁹ A systematic review identified three major outcomes. A study by A. Ghanberi found that intubation duration was shorter, reducing the risk of VAP and PMV. Although length of stay can vary, successful weaning generally shortens it, except in high-risk patients where a prolonged stay is expected. Notably, a reduction in mortality rate has not been observed in patients undergoing protocol weaning compared to standard care, likely due to disease severity, comorbidities, and other factors.

Weaning patients from mechanical ventilators is crucial for improving outcomes and reducing complications like VAP, PMV, and mortality. Evidence-based guidelines, including the ICU Liberation ABCDEF bundle with SAT and SBT, are globally endorsed. However, implementation data is limited and often excludes many countries lacking standardized protocols. Research indicates that weaning protocols developed by nurses, respiratory therapists, and automated systems are effective and safe, with nurse-designed protocols notably decreasing ventilation duration compared to standard care. Using the Burn's Weaning Scale, nurses can formulate guidelines that significantly improve weaning success rates.

Despite the benefits of standardized weaning protocols, the lack of uniformity across different settings is problematic. Variability in patient populations, protocol details, and implementation practices can result in inconsistent weaning outcomes. Additionally, while shorter ventilator durations and reduced lengths of stay are commonly noted, the effect on mortality rates remains inconclusive, influenced by disease severity and comorbidities.

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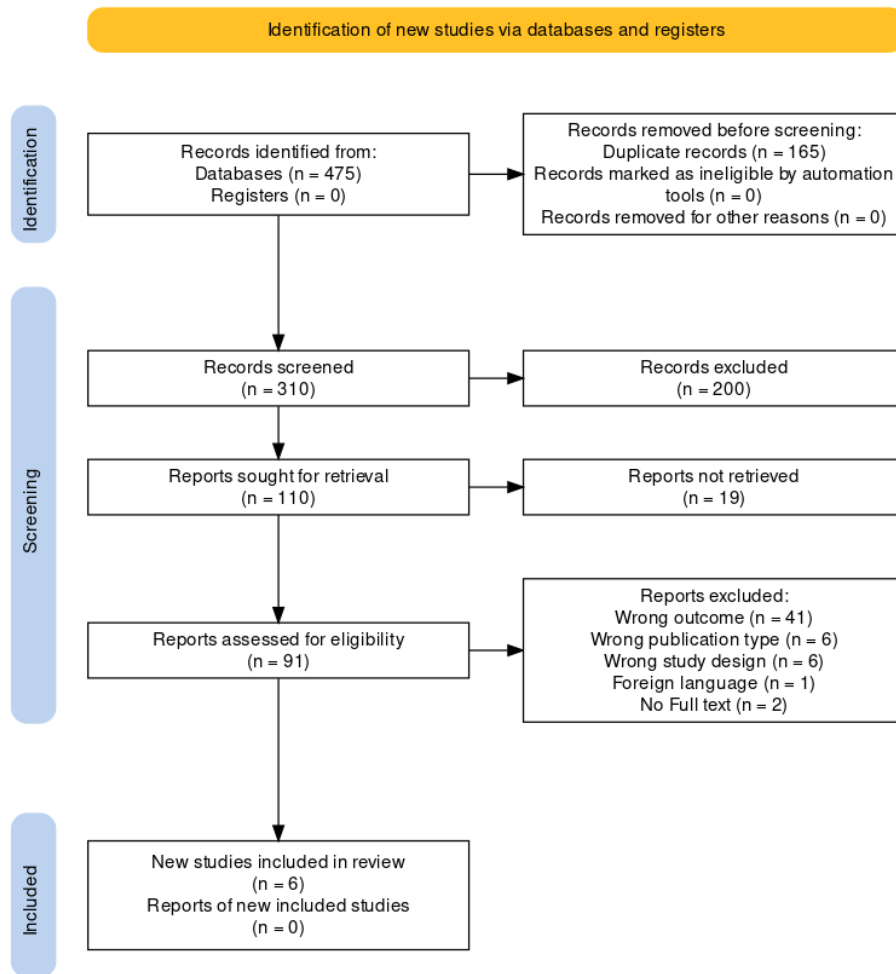


Figure 1. PRISMA Table.

Table 1. JBI critical appraisal for cross-sectional, quasi experiment, and cohort research.

Researcher and Year	Design	Question											Overall Appraisal	
		1	2	3	4	5	6	7	8	9	10	11		
Cederwall, et al. ²¹	Cross Sectional	Y	Y	Y	Y	N	N	Y	Y					INCLU E
Ghanbari, et al. ¹⁷	Quasi Experiment	Y	Y	N	N	Y	Y	Y	Y	Y				INCLU E
Lago et al. ¹⁸	Cohort	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y		INCLU E
Nitta et al. ²²	Cohort	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y		INCLU E

Table 2. CASP critical appraisal for RCT research.

Researcher and Year	Design	Section	Question					DECISION
			1	2	3	4	5	
Vahedian-Azimi et al. ¹⁹	RCT	Section A	Y	Y	Y			INCLUDE
		Section B	Y	Y	Y			
		Section C	Y	Y	Y	Y	Y	
Vizcaychipi et al. ²⁰	RCT	Section A	Y	Y	Y			INCLUDE
		Section B	CNT	Y	Y			
		Section C	Y	CNT	Y	CNT	Y	

Table 3. Study characteristics.

No.	Title	Year	Design	Participant	Intervention
1	Care practices for patients requiring mechanical ventilation more than seven days in Swedish intensive care units: A national survey	2023	Cross Sectional	77 Adult ICUs	Weaning protocol in patients with > 7 days VM installed
2	Comparison between a nurse-led weaning protocol and a weaning protocol based on physician's clinical judgment in ICU patients	2020	Quasi Experiment	65 ICU patients	Nurse Weaning Protocol: Burn's Weaning Scale (BWS)
3	Comparison of International Consensus Conference guidelines and WIND classification for weaning from mechanical ventilation in Brazilian critically ill patients: A retrospective cohort study	2019	Cohort	327 ICU patients	Multicenter multinational prospective observational study, the weaning according to New Definition (WIND Protocol)
4	A comprehensive protocol for ventilator weaning and extubation: a prospective observational study	2019	Cohort	464 ICU patients	Weaning and Extubating Protocol

No.	Title	Year	Design	Participant	Intervention
5	Protocolized ventilator weaning verses usual care: A randomized controlled trial	2020	RCT	4200 ICU Patients	Weaning Protocol: SBT from Respiratory Therapy
6	Intensive Care Weaning (iCareWean) protocol on weaning from mechanical ventilation: a single-blinded multicentre randomised control trial comparing an open-loop decision support system and routine care, in the general intensive care unit	2020	RCT	247 ICU patients	Intervention: iCareWean Protocol - BEACON HealthSystem: Advice Enabled