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AARC Clinical Practice Guideline: Spontaneous Breathing Trials for Liberation From Adult Mechanical Ventilation

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Despite prior publications of clinical practice guidelines related to ventilator liberation, some questions remain unanswered. Many of these questions relate to the details of bedside implementation. We, therefore, formed a guidelines committee of individuals with experience and knowledge of ventilator liberation as well as a medical librarian. Using Grading of Recommendations Assessment, Development, and Evaluation (GRADE) methodology, we make the following recommendations: (1) We suggest that calculation of a rapid shallow breathing index is not needed to determine readiness for a spontaneous breathing trial (SBT) (conditional; moderate certainty); (2) We suggest that SBTs can be conducted with or without pressure support ventilation (conditional recommendation, moderate certainty); (3) We suggest a standardized approach to assessment and, if appropriate, completion of an SBT before noon each day (conditional recommendation, very low certainty); and (4) We suggest that F_{IO_2} should not be increased during an SBT (conditional recommendation, very low certainty). These recommendations are intended to assist bedside clinicians to liberate adult critically ill patients more rapidly from mechanical ventilation. *Key words: extubation; liberation; mechanical ventilation; rapid shallow breathing index; spontaneous breathing trials; weaning.* [Respir Care 0;0(0):1–●. © 2024 Daedalus Enterprises]

Introduction

Weaning from mechanical ventilation is the process of gradually reducing the level of mechanical ventilatory support, whereas liberation is termination of mechanical ventilation in patients for whom it is judged no longer necessary.[1] Beginning in the 1960s, weaning consisted of gradually increasing the time off the ventilator with oxygen delivered via a T-piece attached to the endotracheal tube.[2] Intermittent mandatory ventilation (IMV) and later synchronized IMV (SIMV) were introduced. These modes were used as part of a popular weaning strategy, albeit without the support of high-quality evidence. With SIMV weaning, a gradual reduction in the mandatory rate allowed for increasing the spontaneous breathing requirement of the patient. When pressure support ventilation (PSV) was introduced, spontaneous breaths during SIMV could be supported with PSV. Alternatively, PSV could be used as a stand-alone mode and weaning facilitated by a gradual reduction in the level of pressure support. A glossary of these and other terms is available in the online supplement (see related supplementary materials at http://www.rcjournal.com).

There has been much debate around these approaches to weaning. Two multi-center randomized controlled trials (RCTs) compared gradual rate reductions with IMV or SIMV with gradual inspiratory pressure reductions with PSV.[2,3] One RCT compared SIMV and PSV weaning with progressively longer T-piece trials and reported best outcomes with PSV.[3] Another RCT compared IMV and PSV weaning with once- or twice-daily spontaneous breathing trials (SBTs) conducted using progressively longer T-piece trials and reported best outcomes.[2] Both studies found worse outcomes with SIMV weaning, which delayed liberation from mechanical ventilation. Interestingly, these trials began with an assessment of readiness for ventilator liberation and a subsequent SBT lasting up to 2 h. In both, 75% of subjects successfully completed the first SBT, indicating that clinicians were slow to recognize readiness for liberation. RCTs have subsequently reported the benefits of respiratory therapist (RT)–driven protocols during which RTs assess patients with a safety screen and then, if the screen is passed, initiate an SBT.[4] This process is ideally in collaboration with the interprofessional ICU team to implement spontaneous awakening trials coordinated with SBTs.[5] Recognizing the importance of SBTs in

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the ventilator liberation process, the focus has shifted away from using gradual support reduction strategies and instead proceeding directly to extubation assessments in patients completing a successful SBT.

Successful extubation, removal of the endotracheal tube, is commonly recognized as the desired outcome. However, some patients are discontinued from mechanical ventilation but cannot be extubated and require tracheostomy before liberation from positive-pressure ventilation. Therefore, in the context of ventilator liberation, defined as discontinuation of invasive mechanical ventilation, it is important that liberation and extubation are not conflated. Ventilator-free days are defined as the number of days patients breathe without mechanical assistance during a fixed study period (often 28 d).[5] Passing an SBT does not necessarily result in ventilator liberation or extubation, for example if the patient has abundant secretions and weak cough. Notably, one study reported that only 55% of subjects who passed an SBT were liberated from the ventilator before another SBT was performed.[6]

Evidence-based clinical practice guidelines (CPGs) related to ventilator liberation published in 2001 by the American College of Chest Physicians (ACCP), the American Association for Respiratory Care (AARC), and the American College of Critical Care Medicine (Table 1)[7] continue to inform best practice. These CPGs emphasize the importance of regularly assessing the readiness for SBTs and performing SBTs in a timely fashion in appropriate patients. This approach not only includes using SBTs as the primary determinant of ventilator liberation potential but also requires clinicians to address the causes of a failed SBT and implement ventilator liberation and extubation protocols in those successfully completing an SBT. CPGs published by the ACCP and the American Thoracic Society (ATS) in 2017 provide additional evidence-based guidance (Table 2).[8-11] These recommendations relate to how SBTs are performed, the use of postextubation noninvasive ventilation (NIV) in patients at high risk for extubation failure, and the role of the cuff leak test. Also included were recommendations related to the use of protocols for sedation management, ventilator liberation, and rehabilitation.

Despite the available CPGs that inform practice related to ventilator liberation, there are areas of uncertainty and confusion. This CPG addresses questions related to the details of the SBT, which is an important part of the ventilator liberation process. For this CPG, we define an SBT as a period of spontaneous breathing with minimal or no positive-pressure ventilatory assistance, usually 30–120 min in duration. Using the Population, Intervention, Comparator, and Outcome (PICO) format, we address 4 questions posed by a committee convened by the AARC (Table 3).

Methods

Committee Composition

The guideline committee was composed of individuals with experience and knowledge of ventilator liberation. Members included RTs with varied clinical experiences (clinicians, educators, and managers) and two physicians who were authors of prior published ventilator liberation guidelines.[7,10] A methodologist conducted and prepared evidence table summaries following the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) approach.[12,13] GRADE allows for rating the quality of the best available evidence in developing recommendations for CPGs. A medical librarian oversaw literature reviews and reference management throughout the development of the CPG. Committee members disclosed all potential conflicts of interest according to the policies of the AARC.

Development of PICO Questions

During a one-day in-person meeting, the committee discussed and selected clinical PICO questions by consensus and then ranked the questions based on perceived relevant clinical outcomes and importance. Ratings, which considered the perspective of a patient in an acute care setting, ranged from "not important" to "critical" on a 1–9 scale.[13]

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Dr Goodfellow discloses a relationship with the American Association for Respiratory Care/Daedalus Enterprises. Ms Sorg discloses a relationship with Bunnell, Inc. Dr Hess discloses relationships with Northeastern University, Lungpacer, Jones & Bartlett, McGraw Hill, UpToDate, and the University of Pittsburgh. Dr Girard discloses relationships with the National Institutes of Health, the US Department of Defense, Liberate Medical, Ceribell, and Lungpacer. Dr MacIntyre discloses relationship with InspiRx, Inogen, Philips, Baxter, Roch/Genentech, Vyaire, Encore, and Medtronic.

Supplementary material related to this paper is available at http://www.rcjournal.com.

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Table 1. American College of Chest Physicians-Society of Critical Care Medicine-American Association for Respiratory Care 2001 Ventilator Weaning/Discontinuation Guidelines

1. In patients requiring mechanical ventilation for > 24 h, a search for all causes that may be contributing to ventilator dependence should be undertaken. Reversing all possible ventilatory and non-ventilatory issues should be an integral part of the ventilator discontinuation process.
2. Patients receiving mechanical ventilation for respiratory failure should undergo a formal assessment of discontinuation potential if the following criteria are satisfied: evidence for some reversal of the underlying cause for respiratory failure, adequate oxygenation and pH, hemodynamic stability, and capability to initiate an inspiratory effort.
3. Formal discontinuation assessments for patients receiving mechanical ventilation for respiratory failure should be done during spontaneous breathing rather than while the patient is still receiving substantial ventilatory support.
4. Removal of the artificial airway from a patient who has successfully been discontinued from ventilatory support should be based upon assessments of airway patency and the ability of the patient to protect the airway.
5. Patients receiving mechanical ventilation for respiratory failure who fail an SBT should have the cause for the failed SBT determined. Once reversible causes for failure are corrected, subsequent SBTs should be performed every 24 h.
6. Patients receiving mechanical ventilation for respiratory failure who fail an SBT should receive a stable, non-fatiguing, comfortable form of ventilatory support.
7. Anesthesia/sedation strategies and ventilator management aimed at early extubation should be used in postsurgical patients.
8. Weaning/discontinuation protocols designed for non-physician health care professionals should be developed and implemented by ICUs. Protocols aimed at optimizing sedation should also be developed and implemented.
9. Tracheostomy should be considered after an initial period of stabilization on the ventilator when it becomes apparent that the patient will require prolonged ventilator assistance.
10. Unless there is evidence for clearly irreversible disease (eg, high spinal cord injury, advanced amyotrophic lateral sclerosis), a patient requiring prolonged mechanical ventilatory support for respiratory failure should not be considered permanently ventilator-dependent until 3 months of weaning attempts have failed.
11. When medically stable for transfer, patients who have failed ventilator discontinuation attempts in the ICU should be transferred to those facilities that have demonstrated success and safety in accomplishing ventilator discontinuation.
12. Weaning strategy in the prolonged mechanically ventilated patient should be slow paced and should include gradually lengthening self-breathing trials.

From Reference 7.
SBT = spontaneous breathing trial

Table 2. American College of Chest Physicians/American Thoracic Society 2017 Guidelines for Liberation From Mechanical Ventilation

1. For acutely hospitalized patients ventilated > 24 h, the initial SBT should be conducted with inspiratory pressure augmentation (5–8 cm H_2O) rather than without (T-piece or CPAP).
2. For acutely hospitalized patients ventilated for > 24 h, use protocols attempting to minimize sedation.
3. For patients at high risk for extubation failure who have been receiving mechanical ventilation for > 24 h, and who have passed an SBT, extubate to preventive NIV.
4. For acutely hospitalized patients who have been mechanically ventilated for > 24 h, use protocolized rehabilitation directed toward early mobilization.
5. Manage acutely hospitalized patients who have been mechanically ventilated for > 24 h with a ventilator liberation protocol.
6. Perform a cuff leak test in mechanically ventilated adults who meet extubation criteria and are deemed at high risk for postextubation stridor.
7. For adults who have failed a cuff leak test but are otherwise ready for extubation, administer systemic steroids at least 4 h before extubation; a repeated cuff leak test is not required.

From Reference 10.
SBT = spontaneous breathing trial
NIV = noninvasive ventilation

Rankings of all outcomes were agreed upon through consensus of the committee. The critical outcomes for all PICOs were successful liberation and mortality.

Literature Search

All committee members worked together to create key search terms and inclusion and exclusion criteria. The librarian (JG) developed a search strategy for each PICO question using subject heading words and key words and used a web tool, Rayyan, to assist researchers in screening abstracts and titles of systematic reviews (https://rayyan.ai *Accessed February 29, 2024*). Inclusion criteria for screening included English language only, human studies only. Articles excluded were animal studies, non-ventilated subjects, literature reviews, case studies, case reports, and laboratory studies.

From the abstracts and titles recovered in the literature review (see related supplementary materials at http://www.rcjournal.com), at least two RTs independently reviewed their assigned PICO questions by screening first titles and then abstracts based on inclusion and exclusion criteria. The committee also searched articles based on prior

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Table 3. Population, Intervention, Comparator, and Outcome Questions Addressed in the Clinical Practice Guideline

In adult mechanically ventilated patients, does including an RSBI predict the successful completion of an SBT?
In adult mechanically ventilated patients receiving an SBT, does pressure support increase SBT and liberation success?
In adult mechanically ventilated patients receiving an SBT, does the time of day or night for the SBT affect successful liberation?
In adult mechanically ventilated patients receiving an SBT, does an increase in F_{IO_2} during the SBT increase successful liberation?

RSBI = rapid shallow breathing index
SBT = spontaneous breathing trial

knowledge or from the gray literature to the process. If any conflicts were found among the two reviewers, a third reviewer was asked to resolve the conflicts. Next the reviewers gathered full-text articles that met inclusion criteria to determine if the articles addressed the PICO question. If not, the article was excluded. For the included full-text articles, data were extracted for methodological and outcome(s) review. The databases searched were PubMed/MEDLINE, the Cochrane Database of Systematic Reviews, Embase (Elsevier), and CINAHL (Embase). The last update of the search was performed on January 18, 2023. The protocol was registered on PROSPERO (Identifier: CRD42023398411; February 2023).

Evidence Review and Recommendation Development

For each PICO question, the committee developed recommendations based on the GRADE methodology.[12] The certainty in effect estimates for each outcome was then categorized as high, moderate, low, or very low according to the GRADE process (https://gdt.gradepro.org/app/handbook/handbook.html *Accessed February 29, 2024*). When possible, evidence tables were created to assess the quality of the evidence (see related supplementary materials at http://www.rcjournal.com). The committee discussed recommendations and their strength until consensus on the final wording of each recommendation and rationale with qualifications for each recommendation. Each recommendation was designated as strong or conditional as outlined by GRADE (see online supplement). We used the phrasing "we recommend" for strong recommendations and "we suggest" for conditional recommendations. Further description and details of the methodology used to compose these guidelines can be found in the online supplement. The panel developed recommendations for each PICO question by working through the GRADE Evidence to Decision framework, which considers the quality of evidence, balance of desirable and undesirable effects, assumptions of patient values and preferences, resource use, health equity, acceptability of an intervention, and feasibility of implementation. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist is in the online supplement.

Recommendations

PICO 1

In adult mechanically ventilated patients, does including an rapid shallow breathing index (RSBI) predict the successful completion of an SBT?

Background. Yang and Tobin[14] introduced the RSBI, which calculates the ratio of breathing frequency (f) to tidal volume (V_T) during a short (< 5 min) period without mechanical ventilatory support. The authors reported that RSBI with a cutoff of < 105 more accurately predicted liberation success than integrative compliance, f, oxygenation, and pressure index and its individual components (f and V_T). Meade et al[15] identified 65 studies that included ventilator liberation in which pooled likelihood ratios predicted lower probability of successful extubation when f > 38 breaths/min and an RSBI > 100 breaths/min/L.[15] Subsequently, RSBI gained favor. However, an international survey of critical care physicians in 2018 reported that 51% did not use the RSBI.[16]

Summary of evidence. In a 2006 RCT, Tanios et al[17] compared 2 ventilator liberation protocols—one of which included the RSBI—to determine the effect of an RSBI on time to liberation from mechanical ventilation. Subjects ($n = 304$) were randomized into 2 groups. All subjects were managed with an SBT protocol, but in one group, an RSBI < 105 breaths/min/L was required before an SBT was conducted. The authors found that including RSBI to determine readiness for an SBT prolonged time on the ventilator by, on average, an additional day.

A 2022 systematic review and meta-analysis evaluated the usefulness of RSBI in predicting successful extubation.[18] The observational studies included a heterogeneous ICU population of subjects with COPD, postoperative subjects, and those with primary neurological issues. All pooled measurements displayed significant heterogeneity. After reviewing 48 studies including 10,946 subjects, they reported that an RSBI of < 105 has moderate sensitivity (0.83 [95% CI 0.78–0.87], moderate certainty) and poor specificity (0.58 [95% CI 0.49–0.66]) for predicting extubation success. An RSBI < 80 had a sensitivity of 0.84 (95% CI 0.75–0.90, low certainty) and a specificity of 0.62 (95% CI 0.53–0.70, low certainty). A subgroup analyses also evaluated measurement technique (T-piece vs CPAP vs pressure support; no significant effects) and timing of RSBI measurement relative to time of SBT (no differences found).[18] The authors concluded that, as a stand-alone test, the RSBI has moderate sensitivity and poor specificity for predicting extubation success.

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Recommendation. We suggest that an RSBI is not needed to determine readiness for an SBT (conditional; moderate certainty).

Justification and implementation. Based on systematic reviews of Trivedi et al[18] and Meade et al,[15] there is not strong support for the use of RSBI to predict readiness for an SBT. Moreover, the results of Tanios et al[17] suggest that the use of RSBI might unnecessarily delay an SBT. A simple screen is likely sufficient to identify readiness for an SBT: evidence for some reversal of the underlying cause for respiratory failure, adequate oxygenation, hemodynamic stability, and the capability to initiate an inspiratory effort.[7] That said, criteria to determine whether a patient is tolerating an ongoing SBT should include assessment (especially changes) of the respiratory pattern, hemodynamics, gas exchange, and patient comfort.

It is important again to make the distinction between liberation and extubation.[19] Tobin[19] argues that the RSBI is intended to predict liberation rather than extubation. Indeed, successful completion of an SBT does not necessarily lead to extubation.[6] The meta-analysis of Trivedi et al[18] focused heavily on RSBI as a predictor of successful extubation rather than a predictor of successful liberation. A successful SBT is just one factor identifying extubation readiness; additional factors predicting extubation success include airway protection and ability to clear secretions. Trivedi et al[18] suggests that RSBI might be useful as a screening tool for an SBT specifically in patients with intermediate pretest probability. However, this will need to be confirmed in clinical studies before a recommendation can be made.

Future research opportunities. Future studies should focus on the potential benefit of RSBI in focused subject populations, such as subjects with intermediate pretest probability, as suggested by Trivedi et al.[18] There is interest in the potential for noninvasive imaging techniques, such as diaphragmatic ultrasound[20,21] and electrical impedance tomography,[22] as predictors of ventilator liberation. The benefit of these, either alone or in combination with RSBI, is yet to be determined.

PICO 2

In adult mechanically ventilated patients receiving an SBT, does PSV increase liberation and extubation success?

Background. In 1997, Esteban et al[23] conducted an RCT comparing SBTs conducted with T-piece versus SBTs with 7 cm H_2O PSV. The percentage of subjects failing the SBT was significantly higher when a T-piece was used (22% vs 14%, $P = .03$). However, the percentage of subjects who remained extubated after 48 h was not different between the 2 groups (63% T-piece, 70% PSV, $P = .14$). Although the authors concluded that SBTs with either PSV or T-piece are suitable, this study led to widespread acceptance of low-level PSV during SBTs. In a prospective, multinational, observational study, Burns et al[24] found that initial SBTs most often used PSV with PEEP (49.1%) or T-piece (25.4%) and less frequently CPAP (10.8%) or PSV without PEEP (9.5%). SBTs with PSV and PEEP were commonly used in North America, whereas T-piece was more commonly used in Europe. The previously published ACCP/ATS CPG made a conditional (weak) recommendation for use of PSV for the initial SBT.[10]

Summary of the evidence. The evidence related to this PICO consists of 5 systematic reviews (Table 4)[25-29] and 4 RCTs.[23,30-32] Two of the systematic reviews used study-level meta-analysis, and two used network meta-analysis methodology. In aggregate, the systematic reviews support a small benefit for a fixed-level PSV or a variable level of PSV (tube compensation) in terms of SBT success and extubation success.

In a recent multi-center RCT, Subirà et al[30] randomized subjects to undergo a 2-h T-piece SBT ($n = 578$) or a 30-min SBT with 8 cm H_2O PSV ($n = 557$). Successful extubation occurred in 473 subjects (82%) in the PSV group and 428 subjects (74%) in the T-piece group ($P = .001$). Complicating the interpretation of this RCT was different durations of the SBTs. Thus, it is unclear whether the improved outcomes were attributable to mode (PSV or T-piece), duration (30 min or 120 min), or both.

Thille et al[31] conducted a multi-center RCT ($n = 969$) to determine whether SBT with PSV, using 8 cm H_2O and zero PEEP, results in a shorter time to successful extubation than SBT with T-piece. At day 28, the median number of ventilator-free days was 27 in both groups ($P = .31$). Though 5.5% more (95% CI 0.01–10.90) of the subjects in the SBT with PSV group were extubated within 7 d of randomization, this was a secondary end point, so the authors concluded that SBTs performed with PSV did not result in significantly more ventilator-free days at day 28 than SBTs performed with a T-piece.

Indirect evidence from a different population may inform this PICO question. Jubran et al[33] conducted an RCT ($n = 316$) in tracheotomized subjects transferred to a single long-term acute care hospital for liberation from prolonged ventilation. Unassisted breathing through a tracheostomy, compared to weaning with a gradual reduction in PSV, resulted in shorter liberation time.

Recommendation. We suggest that SBTs can be conducted with or without low-level PSV ($\leq$ 8 cm H_2O) (conditional recommendation, moderate certainty).

Justification and implementation. From our review of the literature, there is not compelling evidence supporting a large benefit of conducting SBTs with either PSV or T-piece

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Table 4. Systematic Reviews Evaluating Use of Pressure Support Ventilation With Spontaneous Breathing Trials

Authors	Year	Included Studies	Included Subjects	Major Findings
Pellegrini et al[28]	2016	12	2,161	SBT technique did not affect liberation success (RR 1.23 [95% CI 0.94–1.61]), ICU mortality (RR 1.11 [95% CI 0.80–1.54]), or re-intubation rate (RR 1.21 [95% CI 0.90–1.63]). Pre-specified subgroup analysis suggested that PSV might be superior to T-piece for liberation in simple-to-wean subjects (risk ratio 1.44 [1.11–1.86]). For the prolonged-weaning subgroup, however, T-piece was associated with a shorter weaning duration (weighted mean difference −3.08 [−5.24 to −0.92] d).
Burns et al[25]	2017	31	3,541	PSV compared with T-piece was as likely for successful initial SBT (RR 1.00 [95% CI 0.89–1.11] but more likely for successful extubation (RR 1.06 [95% CI 1.02–1.10]).
Li et al[26]	2020	10	3,165	There was no difference in successful extubation rate between the T-piece and PSV (OR = 0.91 [95% CI 0.78–1.07]). Compared to PSV, T-piece showed no difference in the rate of re-intubation (OR 0.99 [95% CI 0.78–1.26]), ICU mortality (OR 1.22 [95% CI 0.83–1.80]), hospital mortality (OR 1.36 [95% CI 0.99–1.87]), ICU length of stay (mean difference = −0.10 [95% CI −0.59 to 0.39] d), and hospital length of stay (mean difference −0.82 [95% CI −2.20 to 0.55] d).
Cardinal-Fernandez et al[27]	2022	7	705	In this network meta-analysis, a fixed level of PSV was associated with the highest probability of a successful SBT (P-score 0.90), but tube compensation was associated with the highest probability of extubation success (P-score 0.90).
Ye et al[29]	2023	9	3,115	In this network meta-analysis, the only significant difference was between PSV 30 min and T-piece 120 min for SBT success rate (RR = 0.91 [95% CI 0.84–0.98]). The cumulative rank probability showed that the rate of SBT success from best to worst was PSV 30 min, PSV 120 min, T-piece 30 min, and T-piece 120 min. PSV 30 min and PSV 120 min were more likely to have a higher rate of extubation (SUCRA 82.5% for 30 min PSV, 70.7% for 120 min PSV, 36.4% for T-piece 30 min, 10.4% for T-piece 120 min). T-piece 120 min (SUCRA, 62.9%) and PSV 120 min (SUCRA, 60.9%) may result in lower re-intubation rates, followed by T-piece 30 min (SUCRA, 41.8%) and PSV 30 min (SUCRA, 34.4%).

SBT = spontaneous breathing trial
RR = relative risk
PSV = pressure-support ventilation
OR = odds ratio
P-score = the probability of being the best when compared to alternatives in a network meta-analysis (Note that this is not the same as a *P* value)
SUCRA = surface under the cumulative ranking analysis

when comparing one to the other. At the time of this writing, a multi-center RCT, the Frequency of Screening and SBT Technique (FAST) trial (Clinical Trials.gov ID: NCT02969226), is currently ongoing and relates directly to this topic.[34] FAST is examining the effects of SBT screening frequency (once vs at least twice daily) and SBT technique (PSV + PEEP vs T-piece) on time to successful extubation. The target enrollment is 760 critically ill adults. The results of this trial will likely inform whether PSV should be used during an SBT. It is important to appreciate that PSV in this context is the setting of PSV at a low level during SBT, presumably to decrease the work imposed by the endotracheal tube. This differs from PSV weaning, where the level of PSV is gradually reduced over time.

One on-ventilator approach to conducting SBTs is to set PSV to 0 cm H_2O and PEEP to 0 cm H_2O. Many clinicians consider this approach to be a reasonable surrogate for a T-piece trial. PSV 0/PEEP 0 allows use of the monitoring and alarms present on the ventilator. Moreover, in the event of a failed SBT, return to ventilatory support can be quickly re-established. Gacouin et al[35] conducted a single-center prospective observational study comparing PSV 0/PEEP 0 versus T-piece SBTs on re-intubation rates. The re-intubation rate at day 7 was 14.6% with PSV 0/PEEP 0 and 17.5% with T-piece ($P = .40$). However, because effort is required to trigger ventilator gas delivery, PSV 0/PEEP 0 might more closely resemble PSV than T-piece. A bench study by Sameed et al[36] reported that modern ventilators, in an effort to maintain a constant circuit pressure, may apply some positive pressure when set for PSV 0.

A related question concerns the use of CPAP during an SBT. To our knowledge, this has not been studied. It is worth noting that the RCTs by both Subirà[30] and Thille[31] set PEEP to zero in the PSV arm of the RCT. In a physiologic meta-analysis, Sklar[37] reports that a CPAP of 0 cm H_2O and T-piece more accurately reflect the physiologic conditions after extubation compared to PSV. Conceptually,

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the addition of PEEP might improve triggering in obstructive diseases with auto-PEEP, but no trial focused only on PEEP exists.

There is one circumstance in which low-level PSV for the SBT makes clinical sense. In patients who will be extubated to NIV, such as those at risk for extubation failure (eg, COPD),[10] it is reasonable that the SBT be performed on the settings that will be used postextubation. Anecdotally, common postextubation NIV settings are PSV of 5–8 cm H_2O and PEEP 5 cm H_2O.

Future research opportunities. In the general population of mechanically ventilated patients, our recommendation is that either PSV or T-piece is acceptable for an SBT. But there might be populations for whom one or the other approach is better. In patients with cardiac failure, for example, there is the potential for acute cardiogenic pulmonary edema when positive pressure is removed. In patients with COPD and auto-PEEP, the removal of positive pressure might result in increased effort to breathe. For patients intubated with a small endotracheal tube, an SBT without PSV might result in excessive inspiratory muscle load. Whether these subgroups of patients might benefit from a PSV SBT is worthy of study.

PICO 3

In adult mechanically ventilated patients receiving an SBT, does the time of day or night for the SBT affect successful liberation?

Background. In 1996, Ely et al[4] published an RCT that became a primer for evaluating the readiness of patients for ventilator liberation. RTs conducted SBT screening between 6:30–7:00 AM. Subjects were progressed to the SBT if they successfully passed all 5 screening criteria. Compared with usual practice (physician-directed liberation), the RT-driven protocol resulted in significantly fewer number of days from the time the subject had a successful screening test to the liberation from mechanical ventilation. Following this RCT, there was widespread uptake of this protocol, including daily morning screenings and SBTs. With little evidence to oppose these practices, there is less impetus for teams to alter or expand the process. However, there is much variation in the implementation of the liberation process among critical care areas.

Summary of Evidence. Our literature review revealed a paucity of studies to further our understanding of this question. Only a few articles mentioned time of day when the SBT was performed, and we found no RCTs that directly assessed impact of SBT time of day. In the study by Ely et al,[4] subjects were screened each morning between 6:30–7:00 AM by an RT. In the Tanios et al study,[5,17] subjects were assessed every morning.

A corollary to this PICO is the frequency at which assessments of readiness and SBTs should be conducted. Esteban et al[2] reported that once-daily SBTs led to earlier ventilator liberation than SIMV or PSV weaning, but their RCT found no significant difference in speed of liberation between once-daily SBTs and multiple SBTs per day. In an observational study, Patel et al[38] compared RSBI measurements in the morning versus in the evening. The precise time of the 2 measurements was not specified in the protocol, except to say that they should be separated by > 4 h. They found no significant difference in RSBI measured in the morning versus the evening.

Recommendations. We suggest a standardized approach to assessment and, if appropriate, completion of an SBT before noon each day (conditional recommendation, very low certainty).

Justification and Implementation. Local ICU culture influences the timing of SBTs. Based on expert opinion and practices used (but not compared) in previous RCTs, morning screening followed by an SBT when appropriate should be adopted as a standard where possible, with other patient care routines coordinated around that timing. This requires coordination between nurses adjusting sedation and RTs performing SBTs.[5,39] Because multidisciplinary rounds typically occur in the morning, it may be more likely that a decision regarding liberation and extubation will occur following a successful SBT in the morning.

The time of assessments for readiness and performance of SBTs should be incorporated into protocols adapted to the ICU culture.[10,40,41] Such protocols should address sedation (SATs), SBTs, and the coordination of SATs with SBTs.[10] Unfortunately, adherence with existing guidelines is low, which causes delays in ventilator liberation.[42,43]

The ongoing FAST trial[34] is comparing SBT screening frequency (once vs at least twice daily). The intervention calls for an RT to screen subjects between 6:00–8:00 AM, and between 1:00–3:00 PM, with additional screens permitted at the clinician's discretion. The results of this study will inform this PICO question.

Future Research Opportunities. Common practice seems to be that SBTs are performed in the morning. However, this is based on very low-level evidence. Thus, additional studies are necessary to determine whether SBTs can be successful when performed at other times of the day. Anderson et al[44] implemented an automated real-time dashboard that facilitated information transfer regarding patients' readiness for liberation and alerted clinicians when acceptable parameters were established. This proof-of-concept study demonstrated a faster time to extubation and decrease in ICU

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Table 5. Management of Oxygenation in Randomized Controlled Trials of Ventilator Liberation

Authors	Study Objective	Oxygenation Criteria for SBT Initiation	F_{IO_2} During SBT	Oxygenation Criteria for SBT Termination
Brochard et al[2]	Comparison of 3 methods of weaning	$S_{pO_2} > 90\%$ with an F_{IO_2} 0.40	F_{IO_2} was kept at level used during mechanical ventilation	$P_{aO_2} < 50$ mm Hg
Esteban et al[3]	Comparison of 4 methods of weaning	$P_{aO_2}/F_{IO_2} > 200$ mm Hg	F_{IO_2} at same level as used during mechanical ventilation	$S_{pO_2} < 90\%$
Ely et al[4]	RT protocol to notify physicians when patients successfully complete SBT	$P_{aO_2}/F_{IO_2} > 200$ mm Hg	No change made in F_{IO_2}	$S_{pO_2} < 90\%$
Esteban et al[23]	SBT with T-piece or pressure support	$P_{aO_2} > 60$ mm Hg with $F_{IO_2} \leq 0.40$	F_{IO_2} at the same level as used during mechanical ventilation	$S_{pO_2} < 90\%$
Esteban et al[5]	Evaluation of SBT duration	$P_{aO_2} > 60$ mm Hg with $F_{IO_2} \leq 0.40$	F_{IO_2} at the same level as used during mechanical ventilation	$S_{pO_2} < 90\%$
Tanios et al[17]	Evaluate effect of including rapid shallow breathing index in a weaning protocol	$P_{aO_2}/F_{IO_2} > 150$ mm Hg or $S_{pO_2} > 90\%$ at $F_{IO_2} \leq 0.40$	Changes of ventilator setting only allowed at the discretion of the managing physician	$P_{aO_2} < 60$ mm Hg or $S_{pO_2} < 90\%$ on $F_{IO_2} \geq 0.40$
Girard et al[5]	Efficacy and safety of a paired sedation and weaning protocol	$S_{pO_2} > 88\%$ on $F_{IO_2} \leq 0.50$	F_{IO_2} at the same level as used during mechanical ventilation	$S_{pO_2} < 88\%$ for ≥ 5 min
Fernandez et al[46]	1 h reconnection of mechanical ventilation after successful SBT	$S_{pO_2} > 90\%$ on $F_{IO_2} \leq 0.50$	No change made in F_{IO_2}	$S_{pO_2} < 90\%$
Subirà et al[30]	Compare 30 min of pressure-support ventilation to 2 h of T-piece	$S_{pO_2} > 90\%$ with $F_{IO_2} \leq 0.40$	No change made in F_{IO_2}	$S_{pO_2} < 90\%$ with $F_{IO_2} > 0.50$
Thille et al[31]	SBT with pressure-support ventilation or T-piece	$S_{pO_2} \geq 90\%$ with $F_{IO_2} \leq 0.40$	$F_{IO_2} \leq 0.40$	$S_{pO_2} < 90\%$ with $F_{IO_2} \geq 0.40$

SBT = spontaneous breathing trial
RT = respiratory therapist

length of stay. Additional study is needed to determine whether real-time updates and notifications result in more rapid ventilator liberation rather than protocols tailored to clinician convenience.

PICO 4

In adult mechanically ventilated patients receiving an SBT, does an increase in F_{IO_2} during the SBT increase successful liberation?

Background. Acceptable oxygenation is a usual criterion assessed before initiating an SBT.[7] Common criteria to describe adequate oxygenation prior to initiation of SBT are $S_{pO_2} > 90\%$ with an F_{IO_2} of 0.40 or $P_{aO_2}/F_{IO_2} > 200$ mm Hg (Table 5). Adequacy of oxygenation is also evaluated to determine tolerance of an SBT.[2-5,17,23,30,31,45,46] Commonly, an SBT is terminated with the resumption of ventilator support if S_{pO_2} falls $< 90\%$ (Table 5). The practice in some ICUs is to increase the F_{IO_2} during an SBT, presumably to mitigate the potential for hypoxemia during the procedure. However, it is unclear whether such practice affects successful determination.

Summary of the evidence. Our search identified no literature evaluating the effect of an F_{IO_2} increase on the outcome of an SBT. Thus, we evaluated the F_{IO_2} used in what we consider 10 seminal RCTs (Table 5).[2-5,17,23,30,31,45,46] We considered this indirect evidence, in lieu of any RCTs directly addressing the question, to provide guidance and inform practice regarding the setting of F_{IO_2} during an SBT.

Recommendation. We suggest that F_{IO_2} should not be increased during an SBT (conditional recommendation, very low certainty).

Justification and implementation. In 10 RCTs that were used as indirect evidence, F_{IO_2} was not increased during the SBT.[2-5,17,23,30,31,45,46] We recognize that this identifies the practices used in these RCTs without confirming the correctness of this practice. But lacking higher levels of evidence, this suggests that the F_{IO_2} should not be increased during an SBT.

Of concern, an increase in F_{IO_2} might lead to an increase in S_{pO_2}, leading to false-positive SBT results. For example, if a patient has a baseline S_{pO_2} of 94% and desaturates to 88%, the SBT would likely be terminated. However, an

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increase in F_{IO_2} could result in an increase in S_{pO_2} from 94% to 100%, in this case masking the ongoing underlying cause of hypoxemic respiratory failure that otherwise might terminate the SBT. This could result in a false positive declaring an SBT as passed when it would have been classifying a failed SBT had the F_{IO_2} not been increased. On the other hand, perhaps the threshold of $S_{pO_2} > 90\%$ is too high, creating false negatives.

Future research opportunities. To the best of our knowledge, the effect of raising F_{IO_2} during an SBT on important patient outcomes has not been studied. From our search of the literature, it appears that RCTs evaluating SBTs adopted oxygenation criteria used in older trials, dating to the 1990s. Although there have been sufficient studies to support systematic reviews evaluating predictors of SBT success such as the RSBI,[18] there is an absence of high-level evidence to inform the management of oxygenation during an SBT.

The common practice of requiring an $S_{pO_2} > 90\%$ with an F_{IO_2} of 0.40 prior to SBT initiation may be too conservative. Conducting studies to establish an appropriate level of arterial oxygenation for the initiation of an SBT is important for future consideration. Studies should explore whether using higher F_{IO_2}, especially when employing NIV or high-flow nasal cannula after extubation, leads to earlier extubation. It is also important to determine whether increasing the F_{IO_2} impacts SBT success or whether the practice of using the same F_{IO_2} during the SBT as set on the ventilator during the acute phase of mechanical ventilation is optimal.

Discussion

This CPG complements previous CPGs related to ventilator liberation. These 4 PICOs questions are specific to issues related to SBTs. In North America, this is of particular interest to RTs, as they are the bedside clinicians who most commonly initiate and manage SBTs. Our recommendations should lead to more rapid implementation of SBTs, including no need for RSBI as a screening tool, pressure support or not per clinician/institutional preference, no need to adjust the F_{IO_2}, and implementation in the morning. Each of these recommendations can be easily incorporated into local protocols.

A notable observation is the relative absence of high-level evidence to support some of our recommendations. All the recommendations are conditional. This means that different choices are likely to be appropriate for different patients and therapy should be tailored to the individual patient's circumstances. Those circumstances may include the patient's or family's values and preferences.[47]

Our recommendation related to the use of PSV during an SBT differs from a previous CPG, which offered a conditional (weak) recommendation to use inspiratory pressure support in the initial SBT.[10] We offer a conditional (weak) recommendation that SBTs can be conducted with or without PSV. Our recommendation is influenced by more recently published evidence, such as Thille et al.[31] It is also important to note that the use of PSV for an SBT as previously recommended is consistent with our recommendation. We do not state that PSV cannot be used for an SBT, only that its use is not required.

There are many opportunities for additional research on these topics. Our recommendations are not intended as the final word but rather as a beginning. Hopefully additional evidence will strengthen our recommendations or, in some cases, might change what is recommended.

Summary

We have provided 4 recommendations related to performing SBTs and ventilator liberation. Our recommendations should assist bedside clinicians to discontinue mechanical ventilation more rapidly and extubate adult critically ill patients.

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