Liberation from Mechanical Ventilation

Michael C. Ferrera and Margaret M. Hayes

Division of Pulmonary and Critical Care Medicine, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, Massachusetts

ABSTRACT

Liberation from mechanical ventilation is one of the most important decisions in the intensive care unit (ICU), as extubation failure is associated with worse outcomes. Determining readiness to extubate can be challenging in complex patients and lead to provider stress. Here, we provide our approach to teaching liberation from mechanical ventilation for learners in the ICU. We use a case-based didactic session that purposefully introduces ambiguous cases without a clear answer, utilizing aspects of both cognitive load theory and adult learning theories.

The decision to liberate a patient from mechanical ventilation is an important and often stressful step in the process of progressing a patient's care in the intensive care unit (ICU). Trainees in the medical ICU (MICU) are frequently part of this decision and, because of the structure of academic medical teams, are often the first contact for other members of the multidisciplinary ICU team. Aside from critical emergencies, house staff are often the first to discuss patient management, including decisions around liberation from mechanical ventilation, with respiratory therapists or bedside nurses. If they are unsure what to do, the issue can be escalated to a more senior member of the team. The decision to extubate is often straightforward, although there are some cases that are more nuanced. We use a case-based didactic session in a controlled setting to decrease cognitive load, normalize uncertainty, and introduce learners to a series of cases that are intentionally designed to lack a clear answer, as is often the case in clinical medicine. This session is structured to use multiple learning theories, including generation, spaced learning, and retrieval practice, which help to reinforce the teaching points both during the session and afterward, when learners are working in the ICU.

This article is open access and distributed under the terms of the Creative Commons Attribution Non-Commercial No Derivatives License 4.0. For commercial usage and reprints, please e-mail Diane Gern.

Author Contributions: Concept design, drafting, and editing: M.C.F. Concept design, critical review, and editing: M.M.H.

Correspondence and requests for reprints should be addressed to Michael C. Ferrera, M.D., Division of Pulmonary and Critical Care Medicine, Beth Israel Deaconess Medical Center, Harvard Medical School, 330 Brookline Avenue, Boston, MA 02215-5400. E-mail: mferrera@bidmc.harvard.edu.

ATS Scholar Vol 4, Iss 3, pp 372–384, 2023
Copyright © 2023 by the American Thoracic Society
DOI: 10.34197/ats-scholar.2023-0037HT

WHAT IS THE SETTING?

At our hospital, approximately 45 minutes of each weekday morning in the MICU are devoted to a didactic session. These sessions, part of a structured and sequenced curriculum, are led by pulmonary/critical care attending physicians. Sessions are held in a conference room with a whiteboard. This is dedicated protected time for our learners in the ICU and, through collaborative work with our colleagues in nursing and respiratory therapy, we have worked to limit interruptions during this time. House staff will not be paged or called during this time, unless the reason is urgent. Although this cultural change can take significant time and effort to implement, we believe that it successfully limits interruptions during a protected learning time.

WHO ARE THE LEARNERS?

The learners at this session are trainees on their MICU rotation. These include internal medicine residents and interns, emergency medicine interns, and student health professionals (third- and fourth-year medical students as well as advanced practice provider students).

WHAT IS THE APPROACH?

At the beginning of the session, learners are paired with a partner of a different level (e.g., interns pair with a resident). They are provided with one short clinical scenario that describes an intubated patient. Because of the level of the learner, we focus on the initial ventilator liberation strategy of a patient with an endotracheal tube and do not include cases in which patients require prolonged liberation trials (defined for the purposes of this lecture as patients requiring more than two spontaneous breathing trials [SBTs] or who are not extubated within 7 days of their first SBT) (1). The different scenarios are listed in Table 1, along with proposed discussion points for the session leader. The learners are asked to consider two questions: *1*) Would you extubate this patient? (Please explain your reasoning.) and *2*) If you would not extubate this patient, please describe any further workup or treatment you would pursue at this time.

These cases are designed to be purposefully ambiguous, invoke cognitive dissonance, highlight uncertainty, and encourage critical thinking. After learners are given the time to discuss the case with their partner, the session pivots to a didactic session led by one or two pulmonary/critical care attending physicians.

WHAT IS THE CONTENT?

Readiness Testing

Limiting time on mechanical ventilation is essential to avoid complications. The benefits of early liberation must be weighed against the potential complications of extubation failure. Failure of a planned extubation is associated with prolonged mechanical ventilation as well as high ICU mortality (25–50%) (2). When assessing whether a patient is ready for liberation (“readiness testing”), we believe that the first and, arguably, most important question is whether the indication for intubation has resolved.

There are a wide variety of reasons why patients are intubated in the ICU. Resolution or reversal of the underlying cause has no precise definition and has never been used in clinical trials evaluating liberation from mechanical ventilation (3). The majority of patients receiving invasive mechanical ventilation

Table 1. Clinical scenarios describing an intubated patient with proposed topics of discussion and discussion points

Number and Topic of Discussion	Clinical Scenario	Discussion Points
1. Secretion management postextubation	A 65-yr-old woman with a history of hypertension is admitted with acute hypoxemic respiratory failure from influenza. She develops acute respiratory distress syndrome during the admission. She was intubated approximately 2 wk ago. She has been off paralytics for 1 wk. She was placed on an SBT this morning (continuous positive airway pressure, 5 cm H_2O; F_{IO_2}, 40%). Her RSBI was 42. She is hemodynamically stable, awake, and alert. She had a fever overnight, and a chest X-ray was obtained that shows a new left-sided infiltrate. Her nurse reports increased sputum production with more frequent suctioning.	• Primary indication for intubation has resolved and passing SBT • New secretions and infiltrate concerning for pneumonia • Will the patient be able to manage secretions?
2. Discussion of cuff leak test and SBT modalities	An 83-yr-old man with a history of ischemic cardiomyopathy (ejection fraction, 5–10%) was admitted with mixed hypercapnic and hypoxemic respiratory failure from a heart failure exacerbation. He had an uneventful intubation in the emergency department 5 d ago. He has been effectively diuresed during the admission. He is now 15 L negative and is at his previously reported dry weight. You are informed that he "passed" his SBT this morning (continuous positive airway pressure, 5 cm H_2O; F_{IO_2} 40%). He is awake and alert. His blood pressure is 89/50, which is his baseline. The respiratory therapist checked for a cuff leak, which was absent.	• Low risk for laryngeal edema so unclear whether cuff leak is clinically relevant • Consideration of steroids before extubation • Patient with severe cardiomyopathy, may be reasonable to SBT on T-piece
3. Highlight limitations of RSBI	A 43-yr-old woman with a history of rheumatoid arthritis and rheumatoid arthritis–associated interstitial lung disease on home oxygen is admitted for respiratory failure after an EGD, which was complicated by a suspected aspiration event. She has been intubated for 4 d. She has had daily SBTs (continuous positive airway pressure, 5 cm H_2O; F_{IO_2}, 50%) for the past 2 d, although her RSBI has been 120, and so she remains intubated. She has been afebrile and hemodynamically stable. She has no secretions. She is awake and alert. Her fluid balance has been around even for her stay in the hospital.	• RSBI is $>$105, so there is a question of extubation failure • Patient has known restrictive lung disease, and so this breathing pattern may be normal • Is there anything else that can be done to optimize her respiratory status?

Table 1. *Continued.*

Number and Topic of Discussion	Clinical Scenario	Discussion Points
4. Determination of liberation in patient with altered mental status	A 75-yr-old man with a history of cirrhosis is admitted with a urinary tract infection. He is initially on the floor, although he becomes increasingly hypotensive and altered, requiring transfer to the ICU for intubation and vasopressor support. He has been in the ICU for 7 d. His shock has resolved. He is passing his SBT (continuous positive airway pressure, 5 cm H_2O; $F_{I_{O_2}}$, 40%), although he remains minimally responsive (will withdraw to pain but is not following commands). Workup for his altered mental status has been unrevealing, and it is thought that it could be related to sedation in the setting of his liver disease. Lactulose is started.	• Mental status is poor, although he does have some response • Indication for intubation has partially resolved • Will this patient be awake enough to manage his secretions?
5. Assessment of vital sign abnormalities during SBT	A 79-yr-old woman with a history of systemic lupus erythematosus is admitted for a gastrointestinal bleed. Her course has been complicated by recurrent paroxysmal SVT, with rates in the 170 s–190 s. She remains hemodynamically stable during these episodes. She is transferred to the ICU for urgent EGD in the setting of ongoing gastrointestinal bleeding. She is intubated for the procedure. The EGD shows an ulcer with a visible vessel that is successfully intervened upon. After the procedure, sedation is weaned, and she is placed on an SBT (continuous positive airway pressure, 5 cm H_2O; $F_{I_{O_2}}$, 40%). She is doing well from a respiratory standpoint, although has gone back into SVT, with a heart rate of 175. She is otherwise hemodynamically stable, awake/alert, and writing on a whiteboard that she would like the breathing tube removed.	• Indication for mechanical ventilation has resolved • Patient has become tachycardic during SBT • Is this sign of excess stress or a coincident event?

Definition of abbreviations: EGD = esophagogastroduodenoscopy; $F_{I_{O_2}}$ = fraction of inspired oxygen ICU = intensive care unit; RSBI = rapid shallow breathing index; SBT = spontaneous breathing trial; SVT = supraventricular tachycardia.

in the ICU are intubated for acute respiratory failure (postoperative acute respiratory failure, pneumonia, congestive heart failure, etc.) (4). As such, resolution of the underlying process often correlates with a reduction in the amount of support the patient is receiving from the ventilator.

Physicians generally underestimate the probability of successful liberation from mechanical ventilation (5). In one small study of 32 clinical vignettes describing intubated patients (16 successfully liberated and 16 requiring reintubation) presented to critical care physicians, physician accuracy in identifying successful liberation was low, with an area under the curve of 0.35 (6). Many ICUs have now adopted structured readiness testing and liberation protocols, as they have been shown to reduce the duration of mechanical ventilation and ICU length of stay (LOS) (7). At this point, we engage the audience in discussing whether there are any criteria they use or have seen used to determine whether a patient is ready for liberation as one of the proposed reflection points during the didactic session (Figure 1).

The answers provided by learners to determine whether the patient is ready for a liberation trial often correspond to the criteria used in these large, randomized trials evaluating protocolized liberation, which provides a segue into a discussion of the SBT and its protocols. In general, patients should have adequate oxygenation (e.g., arterial oxygen pressure [Pa_{O_2}] $\geq$60 mm Hg on fraction of inspired oxygen [Fi_{O_2}] $\leq$0.4, positive end-expiratory pressure [PEEP] $\leq$5–10 cm H_2O), should have no significant respiratory acidosis, should be hemodynamically stable, and should ideally be awake or easily arousable (3).

SBTs

If the patient is deemed ready for a trial liberation from mechanical ventilation, we begin with an SBT. Previously, this process was referred to as weaning,

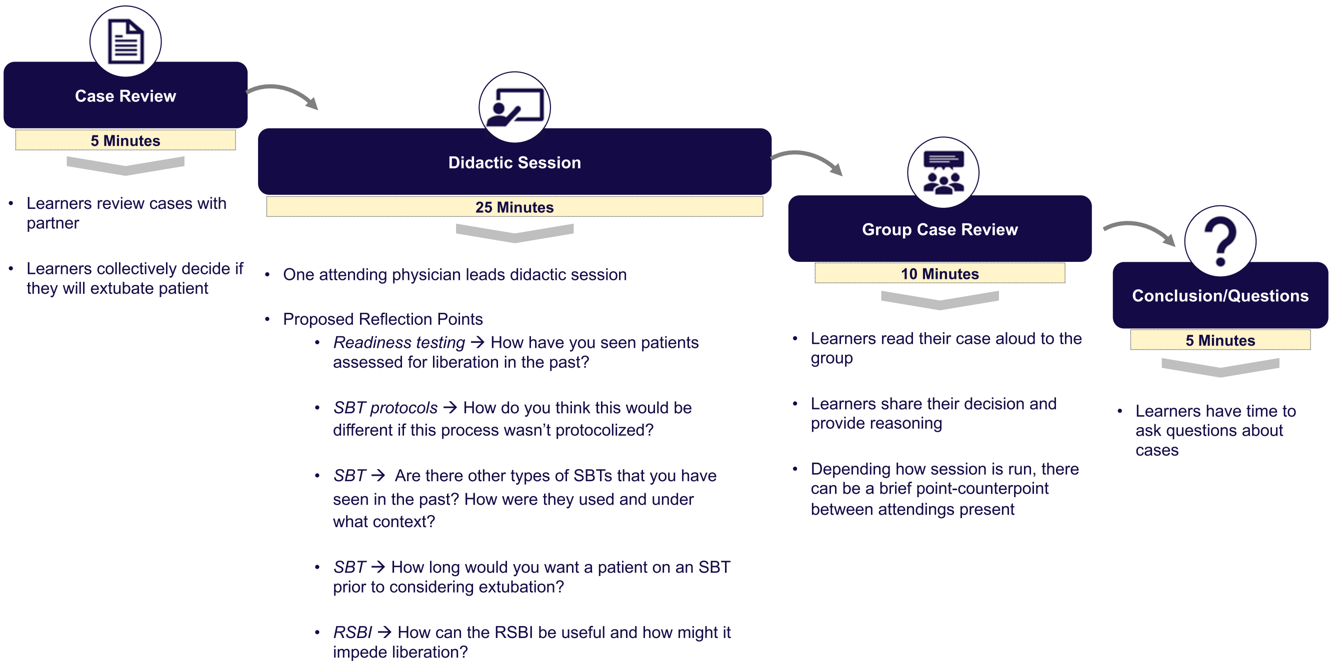

Figure 1. Timeline of session with proposed reflection points. RSBI = rapid shallow breathing index; SBT = spontaneous breathing trial.

although that is an antiquated term implying the gradual withdrawal of support. Many current SBT protocols are more akin to a stress test. This change is likely due, at least in part, to a study published in 1995 comparing four methods to liberate patients from mechanical ventilation, which showed that once-daily SBTs using a T-piece led to more ventilator-free days compared with gradual withdrawal of ventilator support (8).

The type of SBT is institution and/or clinician dependent. This allows an opportunity for learners to share other methods they have witnessed in the past, as the optimal method for performing an SBT is unknown. In general, there are three versions of SBTs: a T-piece trial, continuous positive airway pressure (CPAP), and pressure support ventilation (PSV). When using a T-piece, the endotracheal tube is disconnected from the ventilator and attached to a T-shaped tube allowing for oxygenation although no pressure augmentation. A CPAP trial will leave the patient connected to the ventilator and provide a continuous positive pressure without augmentation. Last, patients on PSV will generally receive a PEEP of 0–5 cm H_2O with an extra 5 cm H_2O provided during inspiration.

There is evidence that the work of breathing is reduced during PSV as compared with a T-piece trial, so some providers may prefer a T-piece trial as it is more “stressful” and may better predict successful extubation (9). A recent trial compared PSV (pressure support, 8 cm H_2O, $F_{I_{O_2}}$ 40%, no PEEP) to a T-piece trial with supplemental oxygen at ⩽6 L/min and showed no difference in ventilator-free days (10). Similarly, a meta-analysis of nine randomized control trials found no difference between PSV and T-piece trials with regard to successful liberation, ICU mortality, reintubation, or ICU LOS (11). As a result, it is unclear whether an SBT that requires more work of breathing correlates with more successful liberation attempts. This may be a time to share a more nuanced approach to the type of SBT if an attending physician tailors the type of SBT to the patient. It is also a time to note that the American Thoracic Society and American College of Chest Physicians recommend performing an initial SBT with pressure support augmentation (5–8 cm H_2O or automatic tube compensation) because of the higher rate of extubation success and a trend toward lower mortality (12).

Although the use of an SBT has been shown to limit time on mechanical ventilation, changing the ventilator settings was still a conscious decision that had to be made. A landmark study published in 1996 demonstrated the feasibility and efficacy of protocolizing the decision to place the patient on an SBT, allowing respiratory therapists to screen patients using a predefined checklist and proactively initiate an SBT using a T-piece or CPAP of 5 cm H_2O (13). After 3 hours on an SBT, physicians were notified of the results of the trial and were left to determine whether to liberate the patient. Patients in the intervention arm who received a protocolized SBT had 1.5 fewer days of mechanical ventilation, compared with the control group.

At our institution, we have a manual protocol (i.e., a respiratory therapist performs a daily assessment of all mechanically ventilated patients). Those who meet our institutional criteria—PEEP ⩽ 10, $F_{I_{O_2}}$ ⩽ 0.6, arterial oxygen saturation ⩾ 90%, pH ⩾ 7.35—are placed on an SBT (CPAP of 5 cm H_2O). Unless there is a specific contraindication, all patients who meet the criteria will be placed on an SBT at least once per day. Other institutions may use automated protocols. These are closed-loop control systems (e.g., SmartCare/PS, Draeger Medical Inc.; or INTELLiVENT-Adaptive Support Ventilation, Hamilton Medical), which use a combination of proprietary algorithms and patient data to adjust the ventilator settings (14). Two meta-analyses evaluating automated protocols failed to show a significant difference with ICU LOS or duration of mechanical ventilation (15, 16).

A review of sedation practices in the ICU is beyond the scope of this didactic session, but we do briefly discuss the importance of both keeping sedation as light as possible and daily sedation interruption through a spontaneous awakening trial (SAT). SATs have been shown to decrease the duration of mechanical ventilation and ICU LOS (17). Subsequent work has shown that a protocolized, paired daily SAT/SBT reduces time on mechanical ventilation and ICU LOS as compared with a control group of SBT and patient-targeted sedation (18).

Last, we also use this time to ask the learners how long the SBT should last. There can be a variety of answers, although at least one study has shown that both 30 minutes and 120 minutes have equal efficacy in terms of success or failure as defined by reintubation rate (19).

At this point, we will shift to discussing how to determine whether an SBT is successful. We use this time to enforce that the main question we need to ask ourselves is whether the patient will be able to maintain spontaneous respiratory support without the assistance of the ventilator. To answer this question, we focus on three things inside the room: the ventilator, the patient, and the monitor. This is a moment when we use the whiteboard to create a visual aid for the following discussion and can help serve as a reference in the minds of learners when discussing liberation at the bedside (Figure 2).

The Patient

During an SBT, it is crucial to assess the patient. If the patient is awake and alert, then providers have an opportunity to ask about shortness of breath, chest pain, or anxiety. Patients who have acute changes in mental status during an SBT (somnolence or agitation) should give a provider pause about extubation. Similarly, patients who appear to be in respiratory distress (e.g., tachypnea, use of accessory muscles, paradoxical breathing motion, or diaphoresis) should be reevaluated before a planned extubation. This is also a time to consider whether the patient has the combination of cough strength and neurologic status necessary to manage their oropharyngeal secretions. There is no single test or piece of objective data that can determine this, and so it is often determined by provider experience. One small study demonstrated that poor cough, increased sputum volume, and impaired consciousness all independently led to increased rate of extubation failure (20). The effect was synergistic, and if all three were present, then the rate of extubation failure was 100%.

Last, this is a time when one might consider testing for a cuff leak, although its utility in the absence of risk factors for laryngeal edema is unclear (12). Risk factors for laryngeal edema and subsequent postextubation stridor include traumatic intubation, intubation for more than 6 days, large endotracheal tube, female sex, and reintubation after unplanned

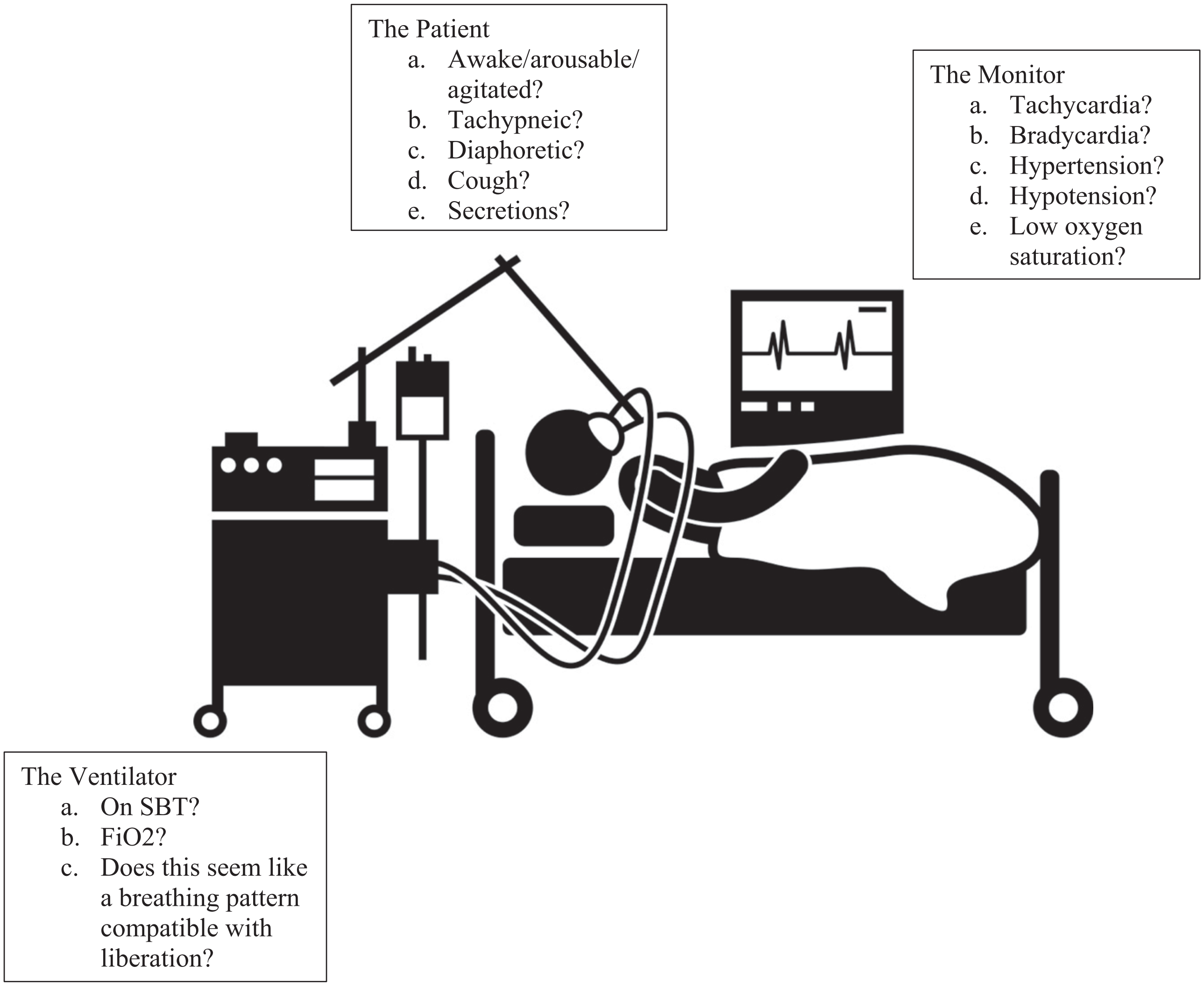

Figure 2. Drawing used to frame the discussion of whether a patient is passing their spontaneous breathing trial. Permission to reprint this image was secured through the purchase of a royalty-free license from The Noun Project. $F_{I_{O_2}}$ = fraction of inspired oxygen; SBT = spontaneous breathing trial.

extubation (12). As postextubation stridor is relatively infrequent (<10% of unselected critically ill patients), and cuff leak tests have limited predictive ability for postextubation stridor, routine cuff leak tests could lead to prolonged mechanical ventilation (21). If there is concern for postextubation stridor, one could consider empiric steroids. The optimal dose, duration, and wait time are unknown, but at least one study has shown that one dose of 40 mg intravenous methylprednisolone 4 hours before a planned extubation reduced the rate of postextubation stridor and reintubation (22).

The Monitor

Next, we ask the learners to focus on the patient's monitor. Although there has been no prospective study to analyze this, acute vital sign changes during an SBT should prompt the provider to consider whether the patient is ready for extubation or whether there are medical interventions that should be considered before extubation. Many of these abnormalities could be explained by sedation weaning, delirium, or anxiety related to critical illness, but they should trigger providers to consider interventions that could be initiated to avert extubation failure. For example, patients who become significantly hypertensive may need to have their blood pressure lowered by means of intravenous vasoactive medications with short half-lives to avoid acute pulmonary edema after removal of positive pressure ventilation. New and unexplained tachycardia while on SBT could be a sign that the patient may be in respiratory distress and could cue the provider to reevaluate the patient to look more closely for signs of respiratory distress.

The Ventilator

The last thing we ask the learners to focus on inside the room during an SBT is the patient's ventilator. When entering the room, we find that this is often the learner's focus when evaluating a patient on an SBT, although the information that can be gleaned from the ventilator is limited. Many respiratory parameters or ventilator maneuvers have been studied to determine whether they predict extubation success. These have included maneuvers such as minute ventilation, maximal inspiratory pressure, vital capacity, negative inspiratory force, and the rapid shallow breathing index (RSBI). None of these have been found to be sensitive or specific enough to be useful in predicting extubation success or failure (23). Of these parameters, the RSBI is used most in current practice. An international survey of adult intensivists showed that about one-third used the RSBI when deciding to extubate a patient (24). In our institution, the RSBI is frequently reported by the respiratory therapist during multidisciplinary rounds. The RSBI is the patient's respiratory rate divided by the tidal volume in liters during the SBT. An RSBI $\leqslant$105 has been suggested as the threshold below which extubation is likely to be successful (25). A recent meta-analysis of 48 studies including approximately 11,000 patients showed that the RSBI has a moderate sensitivity (0.83) but relatively poor specificity (0.58) to predict extubation success (26). Instead of focusing on one number, we ask the learners whether they think this breathing pattern, in this patient, will persist after extubation and whether they believe that this breathing pattern could be successfully maintained long-term off of positive pressure support. This is a moment for the learners to explore scenarios in which a patient could have a high RSBI during an SBT but still be safely liberated.

Although we treat these as discrete entities, it is important to remember that all data are ultimately derived from the patient. As such, all three should be assessed in the context of the patient. For instance, the ventilator may show a low tidal volume for a patient with small stature or thoracic cage deformity (e.g., scoliosis). The monitor may show tachycardia in a patient with known atrial fibrillation. Taken in isolation, these findings may suggest that the patient is not ready for liberation; however, a physician who takes a holistic approach—giving thought to the patient and their unique physiology—may decide to proceed with liberation.

At this point, we will return to the cases previously provided. We will ask the pairs of learners to read their case aloud to the group and to explain whether they would extubate the patient in the scenario. We also ask whether their opinion has changed after the didactic session. Last, the attending physician leading the session will share his or her opinion in a variety of ways to normalize uncertainty as described in the following text.

WHY IS THIS THE APPROACH?

We use this approach for multiple reasons. First, we believe that it uses multiple aspects of adult learning theory (27). The didactic session uses generation, which is the act of answering a question or problem as opposed to being given an answer (28). As such, the learners in this session are provided a clinical scenario and are asked to answer a clinical question requiring integration of multiple streams of information. The connections they make during the session related to this new material allow for deeper processing of the information, resulting in better encoding for long-term recall (28).

We also believe this strategy encourages retrieval practice. Retrieval practice is the recall of facts or concepts from memory, which helps reinforce memory formation (28). Senior trainees who have rotated through the MICU will need to draw on experience from previous MICU rotations during the initial case review. As the initial prompt encourages learners to explain their reasoning, the discussion often results in more senior learners sharing their experiences and understanding of the literature with more junior learners.

This didactic also allows for spaced learning, in which key points from this session can be spread out over the course of the ICU rotation for learners, allowing for long-term memory embedding (28). The attending physicians who lead these sessions are also on service throughout the week with the learners and are encouraged to reference this didactic during the week at the bedside while a patient is on an SBT or while they are on rounds (e.g., "I noticed that you reported the RSBI was 110. How does that affect your decision to extubate this patient?"). Given that there will likely be multiple patients liberated from mechanical ventilation during an ICU block, learning points from this session can be revisited multiple times.

We believe that this method also limits cognitive load among learners. Both extrinsic and intrinsic cognitive overload are common in critical care environments (29, 30). Extrinsic load refers to external distractions that do not contribute to learning, which can be very high in the ICU. Phone calls, pages, and other aspects of caring for critically ill patients often need to be completed or answered expediently, and so there can be little time for cognition. We attempt to limit extrinsic load on learners by using this protected didactic time. Intrinsic load is related to the complexity of the task. As we have discussed, the decision to liberate a patient from mechanical ventilation can require the synthesis of multiple streams of information. A novice learner may have difficulty with this complexity, which can quickly become overwhelming. We attempt to provide a structure or framework to approach liberation that is related to visual cues within the patient's room (i.e., the patient, the monitor, and the ventilator). As mentioned previously, we attempt to bring up learning points from this session multiple times throughout the block to promote long-term memory and help with intrinsic load.

Last, we use this session to normalize uncertainty. Physicians frequently need to often make judgments and decisions that are based on imperfect data. Survival as a medical professional requires comfort with some degree of diagnostic uncertainty, and medical educators much teach the importance of embracing uncertainty (31). Although we would prefer that every extubation is successful, we must acknowledge that the tools we have to evaluate patients are imperfect, and as such, extubation failure is a reality. This has been reflected in medical literature exploring the "optimal" rate of failed extubation (32). The cases used in this didactic were specifically designed to be without an obvious right answer and to generate a variety of answers from learners. Attending physicians during these sessions can use the examples to role-play diagnostic uncertainty.

WHAT CHALLENGES IN TEACHING THE MATERIAL SHOULD BE ANTICIPATED?

There are several challenges that can be encountered with this topic. This didactic was designed for a group of learners from different educational levels. It can be difficult to ensure that a session is relevant for both a third-year resident and a third-year medical student. It may be worthwhile to consider the level of learners present and tailor the didactic session appropriately. This can be done in a variety of different ways. We have provided a list of different clinical scenarios and discussion points that we use in our didactic session. Leaders could choose cases that seem comparatively simpler for more junior learners and reserve more difficult cases for senior learners. The cases themselves could be edited to adjust the difficulty level. For instance, the obtunded patient with cirrhosis could be arousable to voice although only awakening to a voice for <10 seconds.

Another challenge that we have addressed throughout the didactic is the fact that many aspects of liberation are institution dependent or even provider dependent. We believe that the use of purposefully ambiguous clinical scenarios, as well as a thorough discussion of the literature, can help learners discern the difference between evidence-based practices and provider-specific practices. Last, the ambiguity in the cases and with the topic in general can result in low participation and, occasionally, frustration from learners. Many learners just want the answer, and talking through uncertainty or ambiguity can be difficult for them. It is important to normalize this ambiguity and uncertainty at the beginning of the session to reinforce that this experience is formative without right or wrong answers.

As previously stated, we have used different approaches to help normalize uncertainty during the session. If only one attending physician is present, they can share their thought process in these specific cases and describe factors that might sway their decision. If two attending physicians are available, we will use a point-counterpoint at the end of the session to highlight uncertainty and different practice patterns. Each attending physician will pick a side and provide their rationale for liberating the patient or leaving the patient intubated. We have found that this discussion between two experts helps to demonstrate that different providers can arrive at different conclusions on the basis of the information provided.

CONCLUSION

The decision to extubate a critically ill patient in the ICU can be a complex and daunting task for learners, although liberation from mechanical ventilation remains a daily occurrence and an important step for the critically ill patient. In this paper, we have proposed a structured method to discuss extubation with learners in the ICU. This case-based didactic session is intended to incorporate aspects of cognitive load theory, adult learning theory, and the normalization of uncertainty.

Author disclosures are available with the text of this article at www.atsjournals.org.

REFERENCES

1. Boles JM, Bion J, Connors A, Herridge M, Marsh B, Melot C, *et al.* Weaning from mechanical ventilation. *Eur Respir J* 2007;29:1033–1056.

2. Thille AW, Richard J-CM, Brochard L. The decision to extubate in the intensive care unit. *Am J Respir Crit Care Med* 2013;187:1294–1302.

3. MacIntyre NR, Cook DJ, Ely EW Jr, Epstein SK, Fink JB, Heffner JE, *et al.*; American College of Chest Physicians; American Association for Respiratory Care; American College of Critical Care Medicine. Evidence-based guidelines for weaning and discontinuing ventilatory support: a collective task force facilitated by the American College of Chest Physicians; the American Association for Respiratory Care; and the American College of Critical Care Medicine. *Chest* 2001; 120(6, Suppl):375S–395S.

4. Esteban A, Anzueto A, Frutos F, Alía I, Brochard L, Stewart TE, *et al.*; Mechanical Ventilation International Study Group. Characteristics and outcomes in adult patients receiving mechanical ventilation: a 28-day international study. *JAMA* 2002;287:345–355.

5. Strickland JH Jr, Hasson JH. A computer-controlled ventilator weaning system. A clinical trial. *Chest* 1993;103:1220–1226.

6. Tulaimat A, Mokhlesi B. Accuracy and reliability of extubation decisions by intensivists. *Respir Care* 2011;56:920–927.

7. Blackwood B, Burns KEA, Cardwell CR, O'Halloran P. Protocolized versus non-protocolized weaning for reducing the duration of mechanical ventilation in critically ill adult patients. *Cochrane Database Syst Rev* 2014;CD006904.

8. Esteban A, Frutos F, Tobin MJ, Alía I, Solsona JF, Valverdú I, *et al.*; Spanish Lung Failure Collaborative Group. A comparison of four methods of weaning patients from mechanical ventilation. *N Engl J Med* 1995;332:345–350.

9. Sklar MC, Burns K, Rittayamai N, Lanys A, Rauseo M, Chen L, *et al.* Effort to breathe with various spontaneous breathing trial techniques. A physiologic meta-analysis. *Am J Respir Crit Care Med* 2017;195:1477–1485.

10. Thille AW, Gacouin A, Coudroy R, Ehrmann S, Quenot JP, Nay MA, *et al.*; REVA Research Network. Spontaneous-breathing trials with pressure-support ventilation or a T-piece. *N Engl J Med* 2022;387:1843–1854.

11. Ladeira MT, Vital FMR, Andriolo RB, Andriolo BNG, Atallah AN, Peccin MS. Pressure support versus T-tube for weaning from mechanical ventilation in adults. *Cochrane Database Syst Rev* 2014; 2014:CD006056.

12. Girard TD, Alhazzani W, Kress JP, Ouellette DR, Schmidt GA, Truwit JD, *et al.*; ATS/CHEST Ad Hoc Committee on Liberation from Mechanical Ventilation in Adults. An Official American Thoracic Society/American College of Chest Physicians clinical practice guideline: liberation from mechanical ventilation in critically ill adults. Rehabilitation protocols, ventilator liberation protocols, and cuff leak tests. *Am J Respir Crit Care Med* 2017;195:120–133.

13. Ely EW, Baker AM, Dunagan DP, Burke HL, Smith AC, Kelly PT, *et al.* Effect on the duration of mechanical ventilation of identifying patients capable of breathing spontaneously. *N Engl J Med* 1996;51:1864–1869.

14. Branson RD. Modes to facilitate ventilator weaning. *Respir Care* 2012;57:1635–1648.

15. Rose L, Schultz MJ, Cardwell CR, Jouvet P, McAuley DF, Blackwood B. Automated versus non-automated weaning for reducing the duration of mechanical ventilation for critically ill adults and children. *Cochrane Database Syst Rev* 2014;2014:CD009235.

16. Burns KEA, Lellouche F, Lessard MR, Friedrich JO. Automated weaning and spontaneous breathing trial systems versus non-automated weaning strategies for discontinuation time in invasively ventilated postoperative adults. *Cochrane Database Syst Rev* 2014;2014:CD008639.

17. Kress JP, Pohlman AS, O'Connor MF, Hall JB. Daily interruption of sedative infusions in critically ill patients undergoing mechanical ventilation. *N Engl J Med* 2000;342:1471–1477.

18. Girard TD, Kress JP, Fuchs BD, Thomason JW, Schweickert WD, Pun BT, *et al*. Efficacy and safety of a paired sedation and ventilator weaning protocol for mechanically ventilated patients in intensive care (awakening and breathing controlled trial): a randomised controlled trial. *Lancet* 2008;371:126–134.

19. Esteban A, Alía I, Tobin MJ, Gil A, Gordo F, Vallverdú I, *et al*.; Spanish Lung Failure Collaborative Group. Effect of spontaneous breathing trial duration on outcome of attempts to discontinue mechanical ventilation. *Am J Respir Crit Care Med* 1999;159:512–518.

20. Salam A, Tilluckdharry L, Amoateng-Adjepong Y, Manthous CA. Neurologic status, cough, secretions and extubation outcomes. *Intensive Care Med* 2004;30:1334–1339.

21. Schnell D, Planquette B, Berger A, Merceron S, Mayaux J, Strasbach L, *et al*. Cuff leak test for the diagnosis of post-extubation stridor: a multicenter evaluation study. *J Intensive Care Med* 2017;34:391–396.

22. Cheng KC, Chen CM, Tan CK, Chen HM, Lu CL, Zhang H. Methylprednisolone reduces the rates of postextubation stridor and reintubation associated with attenuated cytokine responses in critically ill patients. *Minerva Anestesiol* 2011;77:503–509.

23. MacIntyre N. Discontinuing mechanical ventilatory support. *Chest* 2007;132:1049–1056.

24. Burns KEA, Raptis S, Nisenbaum R, Rizvi L, Jones A, Bakshi J, *et al*. International practice variation in weaning critically ill adults from invasive mechanical ventilation. *Ann Am Thorac Soc* 2018;15:494–502.

25. Yang KL, Tobin MJ. A prospective study of indexes predicting the outcome of trials of weaning from mechanical ventilation. *N Engl J Med* 1991;324:1445–1450.

26. Trivedi V, Chaudhuri D, Jinah R, Piticaru J, Agarwal A, Liu K, *et al*. The usefulness of the rapid shallow breathing index in predicting successful extubation: a systematic review and meta-analysis. *Chest* 2022;161:97–111.

27. McSparron JI, Vanka A, Smith CC. Cognitive learning theory for clinical teaching. *Clin Teach* 2019;16:96–100.

28. Brown PC, Roediger HL, McDaniel MA. Make it stick: the science of successful learning. Cambridge, MA: Belknap Press of Harvard University Press; 2014.

29. Patel VL, Zhang J, Yoskowitz NA, Green R, Sayan OR. Translational cognition for decision support in critical care environments: a review. *J Biomed Inform* 2008;41:413–431.

30. van Merriënboer JJ, Sweller J. Cognitive load theory in health professional education: design principles and strategies. *Med Educ* 2010;44:85–93.

31. Simpkin AL, Schwartzstein RM. Tolerating uncertainty—the next medical revolution? *N Engl J Med* 2016;375:1713–1715.

32. Krinsley JS, Reddy PK, Iqbal A. What is the optimal rate of failed extubation? *Crit Care* 2012;16:111.