Spontaneous Awakening and Breathing Trials

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Objectives

- Review the rationales supporting spontaneous awakening and breathing trials in the ICU.
- Describe practical considerations in the approach to conducting spontaneous awakening and breathing trials in the ICU.
- Highlight issues and considerations in the coordination of spontaneous awakening and breathing trials.

Key words: sedation, mechanical ventilation, safety, protocol

The coordination of awakening and breathing trials is one of the cornerstones of liberation from mechanical ventilation. To begin, we define spontaneous awakening trial (SAT) as a period during which sedating medications that are being used to treat an ICU patient are held in order to determine whether the patient requires ongoing sedation or can be managed without sedatives for the near future. Likewise, we define spontaneous breathing trial (SBT) as a period during which mechanical ventilation to treat an ICU patient is held (or decreased to provide only minimal support) to determine whether the patient requires ongoing mechanical ventilation or can possibly breathe successfully without the assistance of a ventilator for the near future.

In critical care, a major paradigm shift has evolved over the last several decades regarding the use of SATs and SBTs. The previous norm was the gradual reduction of sedation and ventilator support (ie, “weaning”), an approach that has been rightfully challenged based on results of randomized clinical trials. Today, ICU care is more focused on “liberation”—the removal of sedation and mechanical respiratory support at the earliest opportune time. This is not to say that some patients do not benefit from the weaning process, but rather that the general focus on liberation likely better serves the critically ill population. Indeed, operationalizing the SAT and the SBT to examine different aspects of a patient’s condition—the former neurological function, the latter respiratory function—has been pivotal in this paradigm shift in critical care.

The SAT and SBT share some important principles:

- Both the SAT and SBT help to determine a patient’s need (or lack thereof) for ongoing intensive care with sedatives and/or mechanical ventilation.
- Both the SAT and SBT rely on the patient’s spontaneous trial—(ie, “occurring without apparent external influence, force, cause, or treatment”).
- Both more reliably predict a patient’s ongoing needs than does clinician judgment, which is often overly conservative.
- Both require careful coordination and communication by the care team, specifically highlighting the roles of interprofessional team members in a team approach to the care of an ICU patient.
This paradigm shift has been met with skepticism over the years and has entailed many operational hurdles to facilitation of safe and effective SATs and SBTs. Since then, substantial data have demonstrated that (1) these trials, when conducted as described in this chapter, are safe, (2) often lead to improved clinical outcomes, and (3) can improve operational efficiency.

Thus, the SAT-SBT combination is at the heart of the ICU Liberation Bundle, with both initiatives being sequenced and coupled. This chapter expands on the history, the evidence, and the pragmatic approach to the SAT-SBT in today’s critical care environment.

THE SPONTANEOUS AWAKENING TRIAL (SAT)

The SAT is designed to assess whether a patient who is being sedated (whether by continuous infusion or frequent boluses of a sedative) requires ongoing sedation or can be managed without sedatives for the near future. Moving from gradual reduction of sedating medications to rapid discontinuation has evolved substantially over the years and will continue to do so as practices, assessment instruments, and therapies evolve. Kress and colleagues labeled their approach “daily interruption of sedatives” when used in their seminal randomized trial, which first demonstrated the safety and efficacy of spontaneous awakening trials, but we now prefer the phrase “spontaneous awakening trial” because (1) it emphasizes the patient (who ideally is awake and comfortable during intensive care) rather than the treatment and (2) it calls to mind the close relationship that this approach to managing sedatives has with the SBT, its close correlate.

The main principle underlying the SAT is that the patient provides the safest and most accurate source of information about his or her need for ongoing treatment with sedatives. We as clinicians often believe that we can predict a patient’s ongoing need for sedation and other treatments in the ICU, but studies show we are often mistaken, perhaps because we are overly cautious. In one of the earliest and most important trials of ventilator weaning, for example, Esteban and coworkers found that 76% of the mechanically ventilated patients enrolled in their trial met objective criteria for liberation from the ventilator at the time of study entry (and nearly 90% of these were immediately extubated!). Physicians managing these patients had presumably assumed that mechanical ventilation was still required and therefore had not proceeded toward extubation. Similarly, in the Awakening and Breathing Controlled (ABC) Trial, patients in the intervention arm successfully passed 94% of 895 SATs conducted during the trial. In contrast, clinicians managing sedation in the control group believed that discontinuation of sedatives was warranted before an SBT in only 31% of patients.

Multiple lines of evidence have demonstrated that clinicians often underappreciate the ability of patients to undergo safe discontinuation of sedation. The dramatic results highlighted above, however, were met with much skepticism about patient safety, operations, and existing practice standards. Nonetheless, the evidence supports broad adoption of an SAT approach in critical care units. Later in the chapter we provide some advice regarding successful SAT practices.

THE SPONTANEOUS BREATHING TRIAL (SBT)

Mechanical ventilation, despite being a tremendous medical advancement and lifesaving measure, is also associated with many complications. Thus, discontinuation of mechanical ventilation at the earliest opportune time is an important goal and often a measure of institutional performance. The SBT is designed to assess whether the patient’s respiratory mechanics are favorable enough to consider liberation from mechanical ventilation. Weaning is generally considered to entail the gradual reduction of mechanical support, including the reduction of FiO₂ and ventilator parameters such as positive end-expiratory pressure (PEEP) and mechanical rate. Weaning may also include changing from nonconventional respiratory support (eg, airway pressure-release ventilation) to those modes that promote patient triggering and/or more spontaneous breathing. The spontaneous breathing component is often assessed through use of pressure support ventilation modes while the underlying condition that required mechanical ventilation improves. When the patient meets specific safety parameters, daily SBTs are used to determine the patient’s ability to sustain respirations with little to no ventilatory support.
The SBT has been shown to be a safe and effective method of determining a patient’s ability to maintain adequate oxygenation and ventilation without mechanical ventilator support. Early work by Esteban et al and Ely et al demonstrated the benefits of allowing patients to breathe spontaneously and establishing a process for daily assessment for liberation from the ventilator. In 2001, a collective task force of the American College of Chest Physicians, American Association for Respiratory Care, and American College of Critical Care Medicine formally recommended daily SBTs instead of gradual reduction of ventilator support to promote early discontinuation of ventilation. In 2008, Girard et al highlighted the benefits of pairing the SBT with the SAT.

THE EVIDENCE

Although a detailed discussion of the randomized trials supporting SATs and SBTs is beyond the scope of this chapter and is available elsewhere, several recent investigations documenting the effects of real-world implementation of spontaneous awakening warrant highlighting. In light of the robust evidence from early trials showing that SATs improve outcomes of mechanically ventilated ICU patients, and per the recommendations of authoritative clinical practice guidelines, a growing number of institutions across the United States and worldwide have implemented these practices in their ICUs. Published reports of these experiences are beginning to emerge in the literature.

In a single-center project, Balas and colleagues implemented an ABCDE bundle that included awakening and breathing trial coordination, delirium monitoring/management, and early exercise/mobility in 5 ICUs at the Nebraska Medical Center; the investigators compared the management and outcomes of 93 mechanically ventilated patients treated during the 8 months prior to ABCDE implementation versus 94 mechanically ventilated patients treated during the 7 months after implementation. Although compliance with SATs and SBTs did not approach 100%, patients managed with the ABCDE bundle were significantly more likely to undergo an SAT and an SBT and experienced a significant increase in days breathing without mechanical assistance. Additionally, across the entire ICU cohort studied (187 ventilated patients and 113 nonventilated patients), those managed with the ABCDE bundle were less likely to develop delirium, even after adjustment for potential confounders (odds ratio [OR] for delirium, 0.55; 95% confidence interval [CI], 0.33–0.93; P = 0.03).

In a large, multicenter, quality improvement collaborative carried out by the Centers for Disease Control and Prevention, Klompas and coworkers implemented coordinated SATs and SBTs in 12 ICUs (accounting for 5,164 consecutive episodes of mechanical ventilation using an opt-out model wherein nurses and respiratory therapists were responsible for conducting daily coordinated awakening and breathing trials as long as safety criteria were met. The project resulted in dramatic increases in the frequency of both SATs and SBTs (Table 1), which translated to significant improvements in several outcomes. After adjustment for

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Before&lt;sup&gt;a&lt;/sup&gt;</th>
<th>After&lt;sup&gt;b&lt;/sup&gt;</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SATs performed, % of days SAT indicated</td>
<td>14 (7.1-26)</td>
<td>77 (61-87)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>SBTs performed, % of days SBT indicated</td>
<td>49 (35-63)</td>
<td>75 (64-84)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>SBTs performed with sedatives off, % of all SBTs</td>
<td>6.1 (3.9-9.4)</td>
<td>87 (81-92)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Abbreviations: SAT, spontaneous awakening trial; SBT, spontaneous breathing trial.

<sup>a</sup>During first month of data collection.

<sup>b</sup>During last month of data collection.

Data from Klompas et al. Data in parentheses are ranges.
changes in case-mix, the rate of ventilator-associated events per episode of mechanical ventilation was reduced with implementation of SATs and SBTs (OR, 0.63; 95% CI, 0.42-0.97), duration of mechanical ventilation was shortened by 2.4 days (95% CI, 1.7-3.1 days), and lengths of stay in the ICU and hospital were shortened by 3.0 days (95% CI, 1.6-4.3 days) and 6.3 days (95% CI, 4.0-8.6 days), respectively.

Most recently, Pun and coworkers\textsuperscript{14} conducted the SCCM ICU Liberation Collaborative, a nationwide quality improvement initiative that implemented the ICU Liberation Bundle in 68 academic, community, and federal ICUs. In a project that involved 15,226 patients, Pun et al found that complete performance of the ICU Liberation Bundle was associated with improvements in numerous outcomes, including next-day mechanical ventilation (adjusted odds ratio [AOR], 0.28; 95% CI, 0.22-0.36), coma (AOR, 0.35; 95% CI, 0.22-0.56), delirium (AOR, 0.60; 95% CI, 0.49-0.72), use of physical restraint (AOR, 0.37; 95% CI, 0.30-0.46), ICU readmission (AOR, 0.54; 95% CI, 0.37-0.79), and hospital death within 7 days (adjusted hazard ratio, 0.32; 95% CI, 0.17-0.62).

One recent, negative randomized trial of SATs was instructive regarding the mechanism of benefit when implementing SATs. The SLEAP Investigators\textsuperscript{15} conducted a multicenter randomized trial comparing protocolized sedation alone versus protocolized sedation plus daily SATs and found no difference in outcomes. But, unlike the awakening trials conducted by Kress et al\textsuperscript{2} or those conducted in the ABC Trial,\textsuperscript{3} which both markedly reduced exposure to sedatives, the awakening trials conducted in the SLEAP trial had the opposite effect: Compared with patients managed without sedation interruption, the patients managed with SATs received significantly more benzodiazepines and opioids in terms of overall dose ($P = 0.04$ for benzodiazepine equivalents, $P < 0.001$ for fentanyl equivalents) and dose via intravenous boluses ($P = 0.007$ for benzodiazepine equivalents, $P < 0.001$ for fentanyl equivalents). These differences suggest that during the SLEAP trial, SATs (which occurred on 72% of eligible study days) were likely brief and often accompanied by additional bolus doses of sedatives. When these results are interpreted in the context of investigations showing that SATs resulted in reduced sedation and improved alertness, the message is that the mechanism of benefit for SATs is primarily avoidance of unnecessary sedation. Thus, awakening trials that are followed by (or concurrent with) additional sedation via intravenous boluses are likely to be of less benefit than those that result in discontinuation of sedatives.

In aggregate, these studies support that the SAT and SBT are of paramount importance in most ICUs. Additional evidence is accumulating that supports the use of SATs and SBTs in surgical, pediatric, neurological/neurosurgical, and cardiovascular/cardiothoracic critical care units and is constantly being updated on the Society of Critical Care Medicine’s resource page (https://www.sccm.org/ICULiberation/Resource-Library).

### APPROACHING SPONTANEOUS AWAKENING TRIALS

**Eligibility, Safety Screen of the SAT**

Every SAT should begin with a safety screen (Figure 1). This step is essential because on any given day in the ICU, each patient is unique not only compared with other patients but also compared with his or her own state on previous days. For example, it may have been unsafe to interrupt a patient’s sedation during the first day in the ICU when he or she was having ongoing agitation, but an SAT may be safe today if the patient’s agitation has resolved. The safety screen gives the provider who is managing sedation, typically the bedside nurse, objective criteria by which to determine whether an SAT should be conducted on a given day.

During the ABC Trial,\textsuperscript{3} spontaneous safety screen criteria were operationalized. Seizures or alcohol withdrawals were considered “active” if a sedative infusion was currently being used by the ICU team to specifically treat one of these conditions. Thus, any uncertainty about the indication for a sedative infusion should be resolved via communication between the bedside nurse and the treating physician. Agitation was considered present if sedative doses had been escalated (via either infusion or bolus dosing) during the 6 to 8 hours before assessment with the safety screen. Paralytics resulted in failure of the safety screen if they were still being administered or if their effect had not yet worn off, according to the bedside nurse. Myocardial ischemia was considered active if, in the
Figure 1. Wake up and breathe protocol flowchart

“Wake Up and Breathe” Protocol
Spontaneous Awakening Trials (SATs) + Spontaneous Breathing Trials (SBTs)

SAT Safety Screen
- No active seizures
- No alcohol withdrawal
- No agitation
- No paralytics
- No myocardial ischemia
- Normal intracranial pressure

SAT Failure
- Anxiety, agitation, or pain
- Respiratory rate > 35/min
- SpO2 < 88%
- Respiratory distress
- Acute cardiac arrhythmia

SAT Safety Screen
- No agitation
- Oxygen saturation ≥ 88%
- FiO2 ≤ 50%
- PEEP ≤ 7.5 cm H2O
- No myocardial ischemia
- No vasopressor use
- Inspiratory efforts

SAT Failure
- Respiratory rate > 35/min
- Respiratory rate < 8/min
- SpO2 < 88%
- Respiratory distress
- Mental status change
- Acute cardiac arrhythmia

Abbreviations: PEEP, positive end-expiratory pressure; SpO2, oxygen saturation.
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previous 24 hours, cardiac enzymes had increased, or changes indicative of ischemia were noted on electrocardiography. Finally, intracranial pressure (ICP) was considered elevated if ICP elevation was noted by the treating ICU team. As shown in Table 2, agitation requiring escalating sedatives doses accounted for 75% of SAT safety screen failures; all other criteria were rarely observed. It should be noted, however, that the frequencies of these conditions will vary depending on the patient population being managed.

When designing the ABC Trial protocol and developing the safety criteria shown in Figure 1, the investigators targeted the medical ICU patient population. Some conditions or circumstances that could make an SAT unsafe are not listed in the figure because they are typically encountered only in the care of surgical patients. However, the ICU Liberation Collaborative featured many institutions with successful SAT-SBT experience in surgical patients and those patients in specialized critical care units such as cardiovascular/cardiothoracic and neurological/neurosurgical units. The ICU Liberation website provides many resources for these specialized units (https://scm.org/Education-Center/Clinical-Resources/ICU-Liberation).

Before implementing an SAT protocol in an ICU or institution where SATs are not regularly conducted, local stakeholders should consider the conditions in their patient population that could make an SAT unsafe and modify the safety criteria accordingly. Prior to implementing SATs throughout the ICUs at Vanderbilt University Medical Center (VUMC), for example, representatives from all of the institution's ICUs jointly developed a safety screen considered appropriate for the patient population at VUMC, which includes medical, surgical, cardiac, neurological, and burn ICU patients. This process resulted in the addition of several additional safety screen criteria, including absence of open abdomen/chest, unsecured cerebral aneurysm, unstable spine, difficult airway, volumetric diffusive ventilation, surgical procedures requiring immobilization, or comfort care orders. Similar experiences were noted in other ICU Liberation Collaborative institutions whereby local units and leadership defined their criteria collectively.

Daily, any eligible ICU patient receiving sedating medications is assessed with the SAT safety screen. This applies to patients being sedated via continuous infusion and those receiving intermittent boluses. A common misconception is that SATs are indicated only in the setting of continuous sedative infusions. SATs can and should be conducted for patients receiving intermittent boluses of sedating medications, in which case the trial involves delaying (or never giving) the next scheduled bolus. The timing of the safety screen and the SAT itself should be determined by local stakeholders, who can best identify the schedule that will be most beneficial to patients and most practical for providers. Because many institutions are in the habit of conducting SBTs in the morning before rounds, we recommend scheduling SATs in the morning prior to SBTs. If local practices make this time of day an inopportune time for awakening trials, other options may be appropriate.

<table>
<thead>
<tr>
<th>Table 2. Reasons for SAT Safety Screen Failure During the Awakening and Breathing Controlled Trial</th>
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<tbody>
<tr>
<td><strong>Criteria</strong></td>
</tr>
<tr>
<td>Sedative infusion for seizures or alcohol withdrawal</td>
</tr>
<tr>
<td>Agitation requiring escalating sedative doses</td>
</tr>
<tr>
<td>Paralytics</td>
</tr>
<tr>
<td>Active myocardial infarction</td>
</tr>
<tr>
<td>Elevated intracranial pressure</td>
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</tbody>
</table>

Abbreviation: SAT, spontaneous awakening trial.

Previously unpublished data from the Awakening and Breathing Controlled Trial.3
Upon passing the safety screen, a patient should undergo the SAT, which consists of discontinuing medications given for sedation. Sedative infusions should be held, as should any scheduled boluses, so that the patient’s ability to tolerate being off sedation can be determined during the trial. Analgesics that are being used for sedation (eg, fentanyl infusions) should be held as well. Although some commonly used sedatives (eg, propofol or dexmedetomidine) have short elimination half-lives, the pharmacokinetics of these drugs are often altered during critical illness such that discontinuing them abruptly during an SAT does not equate to a sudden decrease in plasma concentrations. For this reason, we do not recommend gradually lowering the dose (eg, by 50%) before proceeding to hold the sedative, an approach that will delay the SAT.

Once sedatives are held, the SAT continues until the trial fails (the patient demonstrates symptoms or signs indicating that sedatives should be restarted) or succeeds (the patient opens his or her eyes to verbal stimuli or tolerates sedative interruption for ≥4 hours without exhibiting failure criteria). In the ABC trial, 837 (94%) of 895 SATs were passed, a very high percentage attributed to the ability of the safety screen to identify circumstances in which sedatives should not be held. Of the 58 (7%) trials that failed, most ended with the patient exhibiting signs of anxiety, agitation, or pain, which were promptly treated by restarting sedation. Importantly, when sedatives are restarted after an SAT, half the previous dose (whether via infusion or bolus) should be used initially since patients often do not need as much sedative as they were previously receiving.

Subsequent Steps: Pass, Fail, or Repeat

The next steps taken after an SAT are no less important to improving outcomes than the trial itself. As previously mentioned, patients for whom the trial fails should have sedatives restarted at half their previous dose. Then, the sedative doses should be adjusted as needed to achieve the desired level of sedation ordered by the ICU team. As noted in multiple clinical practice guidelines, light levels of sedation are associated with better outcomes than moderate to deep sedation, and the Richmond Agitation-Sedation Scale or the Sedation-Agitation Scale should be used to monitor level of sedation. Pain should be adequately treated before sedation is used, and nonbenzodiazepine sedatives (either propofol or dexmedetomidine) should be used rather than benzodiazepines for general sedation (with benzodiazepines being reserved for specific medical indications, such as seizures). A detailed description of the evidence supporting these recommendations is available elsewhere. Patients for whom an SAT fails on one day should not be assumed to have the same need for sedation on the following day; they should be reassessed with the safety screen and, if they pass the safety screen, should undergo another SAT, every day until sedation is successfully discontinued.

When a patient passes the SAT, two steps should be implemented. First, an SBT safety screen should be used to determine whether an SBT can be safely conducted. Second, patient management without sedatives should continue until a provider notes signs or symptoms suggesting that sedatives should be restarted. A common misunderstanding about SATs is that the trial should be time limited, that is, that sedatives should be restarted once a patient has become alert. To the contrary, the goal is not to temporarily discontinue sedatives but rather to determine whether the patient can be managed without the use of sedatives. If adequate analgesia is provided, a majority of mechanically ventilated ICU patients can be successfully managed without sedatives, as shown by Strom and colleagues in a randomized trial where less than 20% of mechanically ventilated patients managed with a “no sedation” protocol required continuous sedation (Table 3).

APPROACHING SPONTANEOUS BREATHING TRIALS

Eligibility, Safety Screen of the SBT

Any patient receiving mechanical ventilation can be screened and assessed with the SBT safety screen. Generally, patients ventilated for more than 24 hours should be evaluated at least daily. Like the SAT, the SBT has two phases. Every patient being considered for the SBT should be screened for eligibility. Table 4 shows the components of the SBT safety screen. Review of these safety screen components reduces the likelihood that the patient will not tolerate the SBT. Although the components are straightforward, providers might need to consider a patient’s underlying condition. For example, the SBT might be performed at a higher Fio₂
if the patient has a chronic oxygenation disorder, such as underlying pulmonary fibrosis. Although reduction in sedation is ideal, patients may still be considered for SBTs while receiving drugs such as dexmedetomidine or anxiolytics. Additionally, comatose patients with intact spontaneous breathing can undergo the SBT. The stability of the underlying respiratory problem is somewhat ambiguous. Generally, if the patient is improving physiologically, then the patient’s condition is resolving. If the patient reaches the thresholds of Fio2 less than 0.6 and PEEP less than 8 cm H2O, the condition may warrant an SBT.

Original work with SBTs used a T tube with the patient off the ventilator. Studies conducted since 2000 have used the ventilator to perform the SBT. Using the ventilator has the advantages of enhanced monitoring of parameters, adjustable alarms, and back-up mode in the event of prolonged or frequent apneas. In 2017, the American Thoracic Society (ATS) and the American College of Chest Physicians (ACCP) provided guidance in their clinical practice guidelines.17 The guidelines recommended that for patients ventilated more than 24 hours, the initial SBT should be performed with inspiratory pressure augmentation of 5 to 8 cm H2O rather than a T tube.

Most institutions use 5 cm H2O PEEP and 5 cm H2O pressure support at the same Fio2 that the patient is currently receiving or a slightly elevated Fio2. The rationale for this practice is the concept that the endotracheal tube poses additional resistance to airflow, and pressure support helps to overcome that resistance. The smaller the endotracheal tube and the higher the patient’s minute volume, the more resistance becomes a factor.

In 1991, Brochard et al23 demonstrated that pressure support reduces the work of breathing significantly over a T tube and provides more comfortable breaths. The added comfort may help reduce anxiety and reduce the need for sedation. This is accomplished by allowing the patient to have more control over the breath characteristics such as flow rate, inspiratory time, and inspiration endpoint. For SBTs, a pressure support of 5 to 8 cm H2O is generally used.

Tubing compensation (TC) is used at some institutions to automatically decrease pressure support, but data are still accumulating as to the overall utility of TC. TC is also called automatic tubing compensation and tubing resistance compensation depending on the ventilator manufacturer. This feature is a type of automatic pressure that self-adjusts the amount of physiological support throughout the respiratory cycle based on predefined

### Table 3. Management and Outcomes of Patients in a Randomized Trial of a “No Sedation” Protocol

<table>
<thead>
<tr>
<th>Variable</th>
<th>No Sedationa (n = 55)</th>
<th>Controlb (n = 58)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Received continuous sedation, n (%)</td>
<td>10 (18)</td>
<td>58 (100)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Sedative doses, mg/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Propofol, per hour of infusion</td>
<td>0 [0.0-0.52]</td>
<td>0.77 [0.15-1.65]</td>
<td>0.0001</td>
</tr>
<tr>
<td>Midazolam, per hour of infusion</td>
<td>0 [0-0]</td>
<td>0 [0-0.02]</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Ventilator-free days, intubation to day 28</td>
<td>18.0 [0-24.1]</td>
<td>6.9 [0-20.5]</td>
<td>0.02</td>
</tr>
<tr>
<td>Hospital length of stay, days</td>
<td>34 [17-65]</td>
<td>58 [33-85]</td>
<td>0.004</td>
</tr>
</tbody>
</table>

1Boluses of intravenous morphine were given for pain, and intravenous haloperidol was given for agitated delirium. If discomfort persisted despite these medications and nonpharmacological efforts to address discomfort, continuous propofol was used for sedation.

2In addition to boluses of intravenous morphine for pain, continuous propofol was used for sedation for up to 48 hours, after which continuous midazolam was used. Spontaneous awakening trials were performed daily, but sedatives were restarted after successful trials.

Data from Strom et al. Values are expressed as median [interquartile range] unless otherwise noted.
goals and machine algorithms. The ventilator uses the patient effort, internal diameter, and type of tube (endotracheal or tracheostomy) to calculate the pressure necessary to overcome resistance at the continually varying flowrate. TC works on mandatory breaths as well as spontaneous breaths and the expiratory phase as well as the inspiratory phase. During the expiratory phase, TC allows pressure to decrease to the baseline more rapidly by manipulating the active exhalation valve. TC is mostly used during routine ventilation and weaning. The amount of the compensation can be adjusted with the ventilator settings to make the work of breathing easier or harder. This adds complexity to the use of TC. Several studies have used TC instead of pressure support during the SBT.\textsuperscript{24,25} In a vigorously breathing patient, TC will generate inspiratory pressures above 10 cm H\textsubscript{2}O. Cohen et al\textsuperscript{26} compared TC versus continuous positive airway pressure alone and

<table>
<thead>
<tr>
<th>Table 4. Criteria for a Spontaneous Breathing Trial</th>
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<tbody>
<tr>
<td><strong>Safety Screen Eligibility Criteria</strong></td>
</tr>
<tr>
<td>No airway pressure-release ventilation or high-frequency oscillatory ventilation</td>
</tr>
<tr>
<td>Capable of spontaneous breathing</td>
</tr>
<tr>
<td>Respiratory condition stable or improving</td>
</tr>
<tr>
<td>Fi\textsubscript{o} \textsubscript{2} \textless{} 0.5 cm H\textsubscript{2}O</td>
</tr>
<tr>
<td>Positive end-expiratory pressure \textless{} 8 cm H\textsubscript{2}O</td>
</tr>
<tr>
<td>Oxygen saturation \textgreater{} 88</td>
</tr>
<tr>
<td>No arrhythmia, no tachycardia</td>
</tr>
<tr>
<td>No agitation</td>
</tr>
<tr>
<td>Respiratory rate \textless{} 35 breaths/min</td>
</tr>
<tr>
<td>Minute volume \textless{} 5 L/min</td>
</tr>
<tr>
<td>No or minimal vasopressor use</td>
</tr>
<tr>
<td>Mean arterial pressure \textgreater{} 60 mm Hg</td>
</tr>
<tr>
<td>Stable intracranial pressure in neurology patients</td>
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<table>
<thead>
<tr>
<th><strong>Failure Criteria</strong></th>
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<tbody>
<tr>
<td>Respiratory rate \textgreater{} 35 breaths/min for 5 minutes or \textless{} 6 breaths/minute</td>
</tr>
<tr>
<td>Tidal volume \textless{} 325 mL</td>
</tr>
<tr>
<td>Oxygen saturation \textless{} 88% for 5 minutes</td>
</tr>
<tr>
<td>Heart rate \textgreater{} 140 beats/min or increase 25% above baseline</td>
</tr>
<tr>
<td>Heart rate \textless{} 60 beats/min</td>
</tr>
<tr>
<td>Acute arrhythmia</td>
</tr>
<tr>
<td>Systolic blood pressure increase 40 mm Hg above baseline</td>
</tr>
<tr>
<td>Sustained anxiety or agitation</td>
</tr>
<tr>
<td>Change in mental status</td>
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<tr>
<td>Change in intracranial pressure in neurology patients</td>
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</table>
found a tendency for more patients to pass the SBT with TC. Other studies have found equal results for TC and pressure support or no superiority of using TC over pressure support for SBTs. Although performance of an SBT with PEEP and pressure augmentation (pressure support or TC) is the recommended method by guidelines, these settings make it easier for a patient to breathe and will mask a small number of issues that could cause a patient to experience failure after extubation. These settings do not replicate what the patient will experience after removal of the tube.

Regardless of an institution’s definition of “minimal support” and the method used, for some patients, the SBT safety screen may not reflect underlying physiological derangements.

**Logistics of the SBT**

Ideally, the SBT is performed in conjunction and coordination with the daily SAT. The ICU Liberation Collaborative highlighted the benefits of ICU Liberation with both daily SATs and daily SBTs (the B element of ABCDE). This element focuses on setting a time each day to stop sedative medications, orient the patient to time and day, and conduct an SBT in an effort to liberate the patient from the ventilator. During the ICU Liberation Collaborative, a common concern was whether the responsibility for conducting the SAT-SBT would belong to the daytime or nighttime staff. Many factors at each institution naturally affect the timing and performance of the SAT-SBT. Workloads, nursing and respiratory staff, patient availability, and access to the decision-maker for extubation all influence the best timing of SAT-SBT.

Communication and coordination between caregivers are essential. All caregivers involved (nurses, respiratory therapists, pharmacists, advanced practice providers, and physicians) should be knowledgeable about patient eligibility and the timing of the SAT-SBT. At the beginning of the shift a discussion needs to be coordinated between nursing and respiratory care as to when the SAT is scheduled followed by the SBT. In large ICUs with multiple patients receiving ventilation, SAT and SBTs may not be able to be performed on all patients at the same time. Coordination is essential to manage the workloads. Institutions that have a clinical pharmacist available have successfully used the pharmacist to assist in coordination of SBTs. SBTs are generally done once per day but can be performed on the same patient multiple times if clinical conditions change. Patients who are out of the unit for procedures may miss the standard time for an SBT. For example, for a patient who receives dialysis in the morning, the SBT may be performed later in the day.

**Subsequent Steps: Pass, Fail, or Repeat**

Assessing success of the SBT is important; criteria that define success or failure (Table 4) should be readily available and understood by the staff. Patients in whom the SBT fails generally resume ventilation at the settings they had prior to the SBT. Some have argued that alternative modes such as pressure support should be used instead of returning a patient to full support; however, evidence is currently inconsistent. Providers should investigate the reason for failure of the SBT and implement treatments to improve the patient’s condition.

Patients who pass the SBT should be extubated as soon as possible. Patients should be assessed for their ability to adequately cough and handle secretions. Patients with excessive secretions and those who have required suctioning more than every hour require caution. The ATS/ACCP guidelines recommend that a cuff leak evaluation only be performed for high-risk patients because false positive results are common and should not delay extubation for low-risk patients. High-risk patients with no cuff leak or insufficient cuff leak (<10%-15% or <115-130 mL) may be at risk for postintubation stridor and reintubation, the ATS/ACCP recommendation is that high-risk patients with an insufficient cuff leak be treated with steroids.

The ATS/ACCP guidelines also recommend that patients at high risk for reintubation be considered for noninvasive ventilation. “At risk” includes patients with congestive heart failure, chronic obstructive pulmonary disease, identified or previous difficult intubation, and hypercapnia. Most modern ventilators are equipped with a noninvasive mode that simply requires the application of a mask to the existing tubing circuit, thus eliminating the cost of a separate device.
SUMMARY

It has taken some time for institutions to broadly adopt the principles of the ICU Liberation Bundle, but the process seems to be accelerating. Daily assessments for awakening and breathing trials in mechanically ventilated patients lie at the forefront of the bundle. Evidence is accumulating regarding the overall impact of SATs and SBTs on important outcomes such as duration of mechanical ventilation, ICU and hospital length of stay, and costs. We expect this evidence to expand over the coming years as we learn more about how the SAT and SBT work best in specialized units, general units, different patient demographics, and different populations and health systems across the globe. We will also continue to learn more through the development of sedation strategies and medications as well as alternatives to invasive mechanical ventilation for respiratory support.

REFERENCES


