EXECUTIVE SUMMARY

- Patient surveillance technology can improve adherence to and optimization of ventilator protocols, shorten the time on the ventilator, and reduce the likelihood of acute lung injury.8,9,22,23
- Patient surveillance technology can aid clinicians in preventing or reducing the incidence of adverse ventilator associated events, including ventilator-associated pneumonia, and ultimately, help improve patient outcomes.8,9,30
- Patient surveillance technology can assist clinicians in weaning patients off the ventilator by promoting more effective use of spontaneous breathing trial protocols, thus shortening the time on the ventilator, reducing the incidence of ventilator associated events, and reducing the cost of care.31,32,34-40

One of the most common interventions in the intensive care unit (ICU) is mechanical ventilation, which provides live-saving ventilation support to critically ill patients but which also carries with it the potential for serious risks and complications. Despite advances in care, the in-hospital mortality of ventilated patients remains high, with a recent study by Wunsch et al. indicating that 35% of mechanically ventilated patients died in the hospital and only 31% were discharged to home.1 In addition to poor outcomes, mechanical ventilation is associated with a disproportionate amount of resource use and high costs in the United States, with estimated yearly national costs of $27 billion, representing 12% of all hospital costs.3

OPTIMIZING PATIENT SURVEILLANCE TO INCREASE PROTOCOL ADHERENCE, IMPROVE VENTILATOR SETTINGS, AND PREVENT ACUTE LUNG INJURY

SURVEILLANCE VS. MONITORING

In the ICU, critical patients require continuous surveillance to rapidly and effectively identify acute deterioration and guide overall clinical decision-making. Though the terms surveillance and monitoring are often used interchangeably, the Nursing Intervention Classification has proposed to define patient surveillance as the “purposeful and ongoing acquisition, interpretation, and synthesis of patient data for clinical decision-making”.2 While patient monitoring is a key activity in the surveillance process, monitoring alone is insufficient for conducting effective surveillance.2 Thus, clinical decision support technology could provide the patient monitoring tools required for optimal surveillance of high-risk ICU patients.

PROTOCOL ADHERENCE

Despite the importance of close patient monitoring in the ICU, many studies have indicated that protocol adherence remains suboptimal for a number of parameters that can directly influence outcomes in ventilated patients. Importantly, sedation use in the ICU is associated with adverse patient outcomes, including prolonged mechanical ventilation, ventilator-associated pneumonia (VAP), and cognitive abnormalities.3-5 While sedation vacation (SV) or daily awakening (DA) strategies have been shown to improve outcomes, compliance to these protocols remains
suboptimal. In a 2012 review, Burns et al found that protocol compliance was often less than 30% and noted large discrepancies between clinician perceptions of adherence rates and actual adherence rates. These authors concluded that protocol adherence remains poor, in part due to the complexity of sedation management and the complexity of associated guidelines and decision-making steps. In a 2011 analysis, Kher et al demonstrated that despite implementing a daily awakening-spontaneous breathing protocol (DA-SBT) that was individualized to clinician preferences and institutional resources and accompanied by education and use reminders, compliance to the DA portion of the protocol was only 44%.4 A number of studies have demonstrated the benefits of clinical decision support tools specifically designed to improve ICU protocol implementation and utilization. In a 2003 study, Burns et al demonstrated that the implementation of a multidisciplinary outcomes management (OM) process for mechanically ventilated patients, including standardized protocols for weaning and sedation use, resulted in significant reductions in median ventilator duration (9 days vs. 10 days; \( p = 0.0001 \)), median ICU length of stay (12 days vs. 15 days; \( p = 0.0008 \)), median hospital length of stay (20 days vs. 22 days; \( p = 0.0001 \)), and mortality rate (31% vs. 38%; \( p = 0.02 \)). Based on these clinical benefits, the authors calculated that implementation of the OM process resulted in more than $3 million in cost savings the first year of OM implementation, with an average savings of over $3,000 per case.5 Similarly, in a 2015 Boston Medical Center study, Ackrivo et al demonstrated that an automated sedation vacation strategy could be implemented in the ICU with a 70% adherence rate over a 6-month period, with promising trends towards reduced ICU length of stay and duration of ventilation.10 These authors concluded that an automated SV protocol could be successfully implemented and sustained and that further subgroup analysis was necessary to elucidate patient outcome improvements.10 Overall, the results from these studies and others suggest that the further use and integration of clinical decision support tools in the ICU to simplify the process of patient management could help improve protocol adherence, improve patient outcomes, and lower the cost of care.

**ACUTE LUNG INJURY**

While mechanical ventilation provides a life-saving intervention in patients with acute respiratory failure, mechanical ventilation can also induce acute lung injury (ALI). In patients with acute respiratory distress syndrome (ARDS), ventilator-associated lung injury is a frequent complication of mechanical ventilation, which has been shown to increase patient morbidity and mortality. In the United States, ALI has been associated with over 70,000 deaths per year, with mortality estimates from 24% in younger patients to 60% for older patients.11 A primary cause of ventilator-associated lung injury is thought to be over-distension of alveoli in aerated lung tissue, a process also known as volutrauma.11 Several studies have suggested that lung protective strategies focusing on lower tidal volumes (\( V_T \)) and/or higher levels of positive end-expiratory pressure (PEEP) can aid in the prevention of ALI and associated postoperative complications.12-13 In a landmark 2000 study, the NIH-NHLBI ARDS Clinical Network (ARDSnet) demonstrated that low tidal volume ventilation (LTVV) resulted in decreased mortality and an increased number of days off the ventilator.14 Similarly, Futier et al demonstrated that in 400 abdominal surgery patients, randomization to a strategy of lung-protective ventilation (\( V_T = 6-8 \) ml/kg; PEEP = 6-8 cm H₂O) vs. non-protective ventilation (\( V_T = 10-12 \) ml/kg; PEEP = 0 cm H₂O) significantly reduced the likelihood of noninvasive ventilation or intubation for acute respiratory failure (5% vs. 17%; \( p = 0.001 \)) and shortened the length of hospital stay (mean difference, -2.45 days; \( p = 0.006 \)). Furthermore, in a prospective randomized open-label trial, Severgnini et al evaluated the clinical benefits of protective ventilation (\( V_T = 7 \) ml/kg ideal body weight; PEEP = 10 cm H₂O) versus a standard ventilation strategy (\( V_T = 9 \) ml/kg ideal body weight; PEEP = 0) in 56 patients undergoing elective abdominal surgery lasting more than 2 hours.13 In this patient cohort, the protective ventilation strategy improved respiratory function and reduced the modified Clinical Pulmonary Infection Score. Overall, the favorable results of these studies and others are reflected in the recommended ARDSnet ventilator settings depicted in Table 1.

Importantly, while the clinical value of the recommended ARDSnet ventilator settings is well established, widespread adoption of these lung protective strategies has been slower than anticipated and less comprehensive protocols continue to be used, possibly due to the fact that these alternative protocols may be perceived to be easier to implement and follow.16 In fact, in a 2012 analysis of 485 ventilated patients by Needham et al, only 41% of eligible ventilator settings were adherent to lung protective strategies and 37% of patients never received lung protective ventilation.12 In this analysis, after adjusting for the total duration of ventilation and other relevant covariates, each additional ventilator setting adherent to lung protective ventilation was associated with a 3% decrease in the risk of mortality over a 2-year period. Strikingly, average \( V_T \) showed an independent linear relationship with 2-year survival, such that each 1 ml/kg predicted body weight increase in \( V_T \) was associated with an 18% increase in mortality.12 These data indicate that relatively small changes in ventilator settings could have dramatic effects on patient outcomes, further highlighting the need for continuous monitoring of ventilated patients in order to optimize ventilator settings and protect against acute lung injury. In addition, it would appear that integration of clinical decision support technology with ventilated patients could help to simplify and streamline the implementation of validated lung protective protocols, resulting in increased protocol adherence, and improved patient outcomes.
### TABLE 1. ARDSNET MECHANICAL VENTILATION SUMMARY.

#### INCLUSION CRITERIA - ACUTE ONSET OF:
1. Partial pressure of arterial oxygen (PaO$_2$) / fraction of inspired oxygen (FiO$_2$) ≤ 300 (corrected for altitude)
2. Bilateral (patchy, diffuse, or homogenous) infiltrates consistent with pulmonary edema
3. No clinical evidence of left arterial hypertension

#### PART I: VENTILATOR SETUP AND ADJUSTMENT
1. Calculate predicted body weight (PBW)
   - Males = 50 + 2.3 [height (inches) – 60]
   - Females = 45.5 + 2.3 [height (inches) – 60]
2. Select any ventilator mode
3. Set ventilator settings to achieve initial V$_T$ = 8 ml/kg PBW
4. Reduce V$_T$ by 1 mL/kg at intervals ≤ 2 hours until V$_T$ = 6 mL/kg PBW
5. Set initial rate to approximate baseline minute ventilation (not > 35 bpm)
6. Adjust V$_T$ and RR to achieve pH and plateau pressure goals below
   - Oxygenation Goal: PaO$_2$ 55-80 mmHg or SpO$_2$ 88-95%; use a minimum PEEP of 5 cm H$_2$O; consider use of incremental FiO$_2$/PEEP combinations to achieve goal
   - Plateau Pressure Goal: ≤ 30 cm H$_2$O; check Pplat (0.5 second inspiratory pause), at least q 4h and after each change in PEEP or VT
   - pH Goal: 7.30-7.45

#### PART II: WEANING
1. Conduct a spontaneous breathing trial daily when:
   - FiO$_2$ ≤ 0.40 and PEEP ≤ 8 OR FiO$_2$ ≤ 0.50 and PEEP ≤ 5
   - PEEP and FiO$_2$ ≤ values of previous day
   - Patient has acceptable spontaneous breathing efforts
   - SBP ≥ 90 mmHg
   - No neuromuscular blocking agents of blockade
2. Initiate a spontaneous breathing trial of UP TO 120 minutes with FiO$_2$ ≤ 0.5 and PEEP ≤ 5 if all above criteria are met and subject has been in the study for at least 12 hours
   - Place on T-piece, trach collar, or CPAP ≤ 5 cm H$_2$O with PS ≤ 5
   - Assess for tolerance as below for up to 2 hours
     - SpO$_2$ ≥ 90: and/or PaO$_2$ ≥ 60 mmHg
     - Spontaneous V$_T$ ≥ 4 mL/kg PBW
     - RR ≤ 35/min
     - pH ≥ 7.3
     - No respiratory distress
   - If tolerated for at least 30 minutes, consider extubation
   - If not tolerated, resume pre-weaning settings

Modified from 17; www.ardsnet.org
VENTILATOR SETTINGS AND ASYNCHRONY

While LTVV can protect against acute lung injury, LTVV coupled with increased ventilatory drive, as in cases of sepsis and metabolic acidosis, can result in patient-ventilator asynchrony. Asynchrony can include ineffective efforts (i.e. untriggered breaths), delayed triggering, auto-triggering, double-triggering (i.e. breath-stacking), premature cycling, delayed cycling, or flow asynchrony. In a 2006 study, Thille et al demonstrated that in a cohort of 62 patients, 24% exhibited patient-ventilator asynchrony, with ineffective triggering and double-triggering accounting for 98% of all asynchrony events. For these patients, asynchrony was associated with a longer duration of mechanical ventilation (25.5 days vs. 7.5 days). Breath-stacking can occur when a patient’s inspiratory effort occurs near the end of ventilator VT delivery, resulting in the rapid delivery of a second breath. Unfortunately, breath-stacking can potentially negate the benefits of LTVV by delivering significantly higher volumes than intended. In a 2008 study, Pohlman et al demonstrated that breath-stacking occurred frequently during LTVV, despite deep sedation, resulting in delivered volumes substantially higher than the set VT. For this patient cohort, breath-stacking occurred at a mean of 2.3 times per minute, resulting in a median delivered volume that was 1.62 times the set VT. Importantly, these authors noted that 42% of all sedation increases were in response to asynchrony, which as described above, can further introduce greater risks to the patient. While ventilator asynchrony appears to be relatively common, consistent identification of asynchrony when it occurs remains challenging. In the last few years, the development of automated tools to detect asynchrony has shown promise, indicating that these tools may be as efficient as expert clinicians. These preliminary results suggest that the use of clinical decision support tools in this arena may effectively aid the clinician in detecting and reversing asynchrony before the patient suffers preventable harm.

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<th>TABLE 2: VENTILATOR-ASSOCIATED EVENTS SURVEILLANCE DEFINITION ALGORITHM</th>
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**VENTILATOR-ASSOCIATED CONDITION (VAC)**
- At least 2 days of worsening oxygenation following at least 2 days of stability on a ventilator; defined by changes in the daily minimum FiO2, or PEEP
  - Minimum daily FiO2 values increase ≥ 0.20 (20 points) over the daily minimum FiO2 in the preceding 2 calendar days (baseline) for ≥ 2 calendar days.
  - Minimum daily PEEP values increase ≥ 3 cmH2O over the daily minimum PEEP in the preceding 2 calendar days (baseline) for ≥ 2 calendar days.

**INFECTION-RELATED VENTILATOR-ASSOCIATED COMPLICATION (IVAC)**
- VAC plus abnormal white blood cell count or temperature along with initiation of new microbial agent:
  - On or after calendar day 3 of mechanical ventilation and within 2 calendar days before or after the onset of worsening oxygenation, the patient meets BOTH of the following:
    - Temperature > 38 °C or < 36 °C, OR white blood cell count ≥ 12,000 cells/mm3 or ≤ 4,000 cells/mm3 AND
    - A new microbial agent(s) is started and is continued for ≥ 4 calendar days

**POSSIBLE VENTILATOR-ASSOCIATED PNEUMONIA (PVAP)**
- IVAC plus laboratory and/or microbial evidence of infection
  - On or after calendar day 3 of mechanical ventilation and within 2 calendar days before or after the onset of worsening oxygenation, ONE of the following criteria is met:
    - Positive culture of endotracheal aspirate, bronchoalveolar lavage, lung tissue, or protected specimen brush
    - Purulent respiratory secretions plus a positive culture of sputum, endotracheal aspirate, bronchoalveolar lavage, lung tissue, or protected specimen brush
    - One of the following: positive pleural fluid culture, positive lung histopathology, positive diagnostic test for Legionella species, or positive diagnostic test on respiratory secretions for influenza virus, respiratory syncytial virus, adenovirus, parainfluenza virus, rhinovirus, human metapneumovirus, or coronavirus.

Modified from 25,30.
OPTIMIZING PATIENT SURVEILLANCE TO REDUCE THE RISK OF VENTILATOR-ASSOCIATED COMPlications

Ventilator-associated complications (VAC) such as ARDS, ventilator-associated pneumonia (VAP), sepsis, pulmonary embolism, barotrauma, and pulmonary edema are some of the serious complications that can occur in patients receiving mechanical ventilation.21 Unfortunately, the development of these complications can lead to longer duration of mechanical ventilation, longer stays in the ICU and hospital, increased healthcare costs, and increased risk of disability and death. In the United States, each case of VAP has been estimated to add an additional $40,000 in hospital costs, resulting in approximately $1.2 billion in total costs per year.36

Surveillance criteria for diagnosing VAP can be problematic and onerous, in that these criteria have traditionally required radiologic, systemic, and pulmonary evidence. As such, applying these criteria in a real-world setting can be time consuming and complicated.27,28 Given these challenges, in 2013, the National Healthcare Safety Network (NHSN) of the Centers for Disease Control and Prevention (CDC) implemented a new approach to surveillance of mechanically ventilated patients focused on identifying ventilator-associated events (VAEs) rather than VAP.25 This system is based on objective, streamlined, and potentially automatable criteria that identify a broad range of conditions and complications occurring in mechanically-ventilated adult patients and provides a three-tier surveillance definition algorithm for VAEs: 1) ventilator-associated condition (VAC); 2) infection-related ventilator-associated complication (iVAC); and 3) possible VAP (PVAP) (Table 2).21,10,11

In support of this CDC-NHSN algorithm, in 2011, Klompas et al. described a novel surveillance paradigm for identifying complications of mechanical ventilation.11 For this work, the authors assessed 600 mechanically ventilated medical and surgical patients across three hospitals. Patients were independently assessed for VAP and for VAC and the authors compared incidence-density, duration of mechanical ventilation, intensive care and hospital lengths of stay, hospital mortality, and time required for surveillance for VAP and for VAC.11 The authors manually assessed VAC using electronically generated tables with a single line for each calendar day the patient was on mechanical ventilation. Each line listed the patient’s minimum PEEP and FiO2 for that calendar day. For this analysis, VAC was defined as an increase in the patient’s daily minimum PEEP by ≥ 2.5 cm H2O sustained for ≥ 2 days or an increase in the daily minimum FiO2 by ≥ 15 points sustained for ≥ 2 days after a minimum of 2 days of stable or decreasing daily minimum PEEP and FiO2, respectively; while a diagnosis of VAP was based on a combination of radiographic, systemic, and pulmonary criteria.31

For the 597 evaluable patients in this study, the incidence of VAP was 9.3% (8.8 per 1000 ventilator days) while the incidence of VAC was 23% (21.2 per 1000 ventilator days). Compared to matched controls, both VAP and VAC prolonged days to extubation (5.8 [95% CI: 4.2–8.0] and 6.0 [5.1–7.1], respectively), days to intensive care discharge (5.7 [4.2–7.7] and 5.0 [4.1–5.9]), and days to hospital discharge (4.7 [2.6–7.5] and 3.0 [2.1–4.0]). Overall, VAC was associated with increased mortality (OR 2.0 [1.3–3.2]) but VAP was not (OR 1.1 [0.5–2.4]).11 Importantly, using the established criteria, VAC assessment was considerably faster as compared to VAP assessment, averaging 1.8 minutes versus 39 minutes per patient. Both VAP and VAC events were predominantly attributable to pneumonia (23% for VAC; 33% for VAP), pulmonary edema (18% for VAC; 22% for VAP), ARDS (16% for VAC; 11% for VAP), and atelectasis (11% for both VAC and VAP). The authors concluded that screening ventilator settings for VAC captured a similar set of complications to VAP, but that VAC screening was faster, more objective, and a better predictor of patient outcomes.11 Together, these results and others suggest that using clinical decision support tools to help automate and simplify the surveillance of ventilated patients can aid the clinician in the early identification of ventilator-associated complications, improve outcomes, and reduce the cost of care.

OPTIMIZING PATIENT SURVEILLANCE TO IMPROVE VENTILATOR WEANING

For mechanically ventilated patients, the length of time on the ventilator is directly correlated with the incidence of potentially serious complications such as VAP and airway trauma.35,36 Unfortunately, accurately identifying patients who are ready to be weaned off mechanical ventilation can be challenging. In addition, the weaning process itself can be quite lengthy, often accounting for approximately 40% of the total time on the ventilator.14 Thus, using effective protocols to better identify patients who are ready for weaning and to better manage the weaning process itself can significantly reduce the duration of ventilation and number of complications.32,33–35

In a randomized, controlled study in 300 mechanically ventilated ICU patients, Ely et al. studied the clinical benefits of a systematic weaning strategy involving daily screenings by clinical staff followed by 2-hour spontaneous breathing trials in patients meeting predefined criteria.32 For the screening portion of the intervention, all patients had to meet the following criteria: PaO2 / FiO2 > 200, PEEP ≤ 5 cm H2O, adequate airway reflexes, respiratory rate / Vt ≤ 105 breaths/min/L, and no infusions of vasopressor or sedatives.
For the spontaneous breathing trials, ventilatory support was removed and the patient was allowed to breathe either through a T-tube circuit or a ventilatory circuit using “flow triggering” and continuous positive airway pressure of 5 cm H₂O. Spontaneous breathing trials were terminated if a patient demonstrated any of the following: respiratory rate > 35 breaths per minute for ≥ 5 minutes, SaO₂ < 90%, HR > 140 bpm, sustained changes in SBP > 180 mmHg or < 90 mmHg, increased anxiety, and diaphoresis. The authors found that patients in the intervention group had a significant reduction in median days of ventilation (4.5 days vs. 6.0 days; p=0.003) along with a significant reduction in complications (20% vs. 41%; p=0.001). In addition, total ICU costs were approximately $5,000 less in the intervention group ($15,740 vs. $20,890; p=0.03). Similarly, in a randomized, controlled study by Lellouche et al, use of a computerized weaning protocol significantly reduced weaning duration from a median of 5 days to 3 days (p=0.01) and total duration of mechanical ventilation from 12 days to 7.5 days (p=0.003). Computer-driven weaning also decreased median ICU stay from 15.5 days to 12 days (p=0.02) and caused no adverse events.

While weaning protocols have been shown to improve outcomes, adherence to these protocols remains poor. In a study by McLean et al, the authors noted that despite multiple reminders, education sessions, and multidisciplinary team involvement, adherence to the institutional mechanical ventilation weaning protocol in a 29-bed teaching hospital ICU was only 1.6%. These authors instituted a 4-step process improvement model with the goal of improving protocol adherence and clinical outcomes. After implementing the model, the authors reported that protocol adherence improved to 21.2% coinciding with a significant reduction in the rate of unsuccessful extubation (3.0% vs. 12.7%; p=0.05) and a non-significant reduction in the incidence of VAP (19.7% vs. 34.9%; p=0.14).

Similarly, Silva et al studied the adoption of a specific weaning protocol in 252 ICU patients with a median mechanical ventilation time of 3.7 days. For this protocol, patients were assessed daily to determine their potential for weaning, and evaluated parameters included: PaO₂ > 60 mmHg, FiO₂ ≤ 40%, PEEP = 5-10 cm H₂O, hemodynamic stability, hemoglobin levels above 8 g/dL, corrected metabolic and electrolyte disorders, control of infection, and a body temperature < 38 °C. Acceptable weaning candidates were then submitted to a spontaneous breathing test (SBT), which was performed in the ventilatory mode with pressure support ventilation (PSV) between 5 and 7 cm H₂O, PEEP levels between 5 and 10 cm H₂O and FiO₂ values between 30 and 40% for 30 to 120 minutes. Patients who tolerated the SBT without any signs of distress were then extubated. The authors found that in this patient population, the use of a systematic weaning protocol resulted in a relatively low mechanical ventilation time and an acceptable reintubation rate (12.7%). The authors concluded that the protocol could be used as a “comparative index in hospitals to improve the weaning system, its monitoring and the informative reporting of patient outcomes and may represent a future tool and source of quality markers for patient care.”

In a 2002 study by Iregui et al, the authors studied the benefits of using a handheld computer to guide weaning in 352 medical ICU patients. For this study, a protocol-based SBT was conducted when the following predetermined criteria were met: a) PaO₂/FiO₂ ratio of > 200, b) PEEP ≤ 5 cm H₂O, c) heart rate of < 140 beats/min, d) patient awake and oriented to person and place, e) patient not requiring vasoactive or inotropic agents, f) respiratory rate of < 35 breaths/min, and g) minute ventilation of < 15 L/min. For the control period, patients were weaned using this weaning protocol available at each patient’s bedside in a laminated covering. For the intervention period, the weaning protocol was programmed on a handheld computer. For the intervention period, the time to onset of the first SBT was significantly shorter compared to the control period (50 hours vs. 73 hours; p=0.018). Similarly, the number of patients undergoing an SBT when first meeting the clinical criteria for the trial was significantly greater for the intervention period compared to the control period (90% vs. 64%; p<0.001). Importantly, the ICU length of stay was significantly shorter for patients in the intervention period compared with the control period (6 days vs. 8 days; p=0.018) and intervention patients had fewer cases of VAP (25 cases vs. 42 cases; p=0.021). No significant differences in hospital mortality, duration of mechanical ventilation, hospital length of stay, or disposition for survivors following hospital discharge were observed between the two treatment groups.

Thus, strategies to address common unmet needs and challenges of weaning may provide a number of benefits, including increased process standardization, increased SBT success rates, time-savings, and cost-savings. The increased standardization of SBT protocols may aid in adoption of more aggressive protocols that hasten extubation, while allowing for increased objectivity and accountability, and can also aid in training new personnel while increasing staff comfort levels and improving workflow. In a 2012 review, Branson noted that physician availability can delay weaning and that staffing limitations “have created an environment where automated weaning may play a role.” In support of this, a study by Thorens et al demonstrated a clear relationship between the duration of mechanical ventilation and an “index
of nursing” designed to reflect the quantity and quality of available nurses in relation to the number and severity of their ICU patients. In this study, there was a sharp increase in the duration of mechanical ventilation when the nursing index fell below a critical threshold of 0.8, a point at which the available nursing workforce was less than 80% of the ideal workforce given the current patient load. Thus, given these workforce constraints on the weaning process and duration of mechanical ventilation on the whole, more effective SBT implementation and protocolization via improved integration of clinical decision support technology may help streamline and shorten the process itself while reducing clinician workload.

CONCLUSIONS

Mechanical ventilation is a life saving intervention but is associated with a number of risks and challenges. Inattention to ventilator settings and patient response can result in patient-ventilator asynchrony and acute lung injury, increasing the likelihood of adverse events. The longer patients are on the ventilator, the more likely they are to have serious ventilator-associated adverse events, which drastically increase patient morbidity, mortality, and cost of care. Accelerating weaning off the ventilator has been shown to improve outcomes, yet acceptance and adoption of weaning protocols remains poor. For mechanically ventilated patients in the ICU, the continued advancement and acceptance of clinical decision support tools can assist clinicians in the management of these challenging patients by helping to optimize protocol adherence, effectively manage ventilator settings and sedation to reduce the incidence of preventable harm, reduce the incidence of ventilator-associated adverse events, and accelerate weaning.
REFERENCES


