Respiratory Knowledge Portal Application to Reduce Ventilator Associated Events, Ventilator Induced Lung Injury and Alarm Parameter Variance

Brian K. Walsh, PhD, RRT, RRT-NPS, RRT-ACCS, RPFT, FAARC
Professor
Respiratory Therapy
301 University Blvd
Galveston, Texas 77555-1146

NCT06737432
13-April-2026

Sachin Patel
Assistant Professor
Respiratory Therapy

Table of Contents:

Study Schema
1.0 Background
2.0 Rationale and Specific Aims
3.0 Inclusion/Exclusion Criteria
4.0 Enrollment/Randomization
5.0 Study Procedures
6.0 Potential Risk
7.0 Potential Benefits
8.0 Subject Safety and Data Monitoring
9.0 Study Product Description
10.0 Reporting of Adverse Events or Unanticipated Problems involving Risk to Participants or Others
11.0 Study Withdrawal/Discontinuation
12.0 Statistical Considerations
13.0 Ethical Considerations and Privacy/Confidentiality Issues
14.0 Record Retention
15.0 References

SIGNATURE PAGE

The signature below constitutes the approval of this protocol and the attachments, and provides the necessary assurances that this trial will be conducted according to all stipulations of the protocol, including all statements regarding confidentiality, and according to local legal and regulatory requirements and applicable US federal regulations and ICH guidelines.

Site Investigator:*

Signed: Brian K. Walsh Date: 5/19/25

Name: Brian K. Walsh
Title: PI, Associate Professor

** The protocol should be signed by the local investigator who is responsible for the study implementation at his/her specific site; i.e., if Investigational New Drug study, the individual who signs the Form FDA 1572.*

1.0 Background

Ventilator-Associated Events

Mechanical ventilation is an essential and lifesaving therapy for patients suffering from critical illnesses and respiratory failure. Wunsch et al. have demonstrated that over 300,000 US patients require mechanical ventilation per year.[1] It is well understood that these patients are at high risk for complications and poor outcomes, including death.[2, 3] Ventilator-associated pneumonia (VAP), sepsis, acute respiratory distress syndrome (ARDS), pulmonary embolism, ventilator-induced lung injury (volutrauma, barotrauma), and pulmonary edema are among the most common complications. Complications lead to longer duration of mechanical ventilation, longer hospitalization, and increased risk of mortality and/or disability healthcare costs. Overall, there is a 35% mortality rate in patients suffering lung injury. 24% in younger persons (15-19 yrs) and up to 60% in elderly patients (>85 yrs)[4]

Historically, surveillance for ventilator-associated events (VAE) was limited to VAP prior to 2013. However, VAP incidences varied widely, and there was no valid nor reliable definition that was sensitive or specific. Therefore, VAE was redefined to include ventilator-associated conditions (VAC), infection related ventilator-associated conditions (IVAC), and VAP. VAC in the past were often related to pneumonia, pulmonary edema, atelectasis, or ARDS and have a strong association with prolonged mechanical ventilation, length of stay, and mortality. VAE has attributed mortality between 8-12%. Therefore, prevention is key to improving quality of care.

Ventilator Alarm Surveillance

If you have worked with ventilators, you have likely heard them alarm. Mechanical ventilators incorporate monitors and alarms to alert care providers of a potential life-threatening condition. Unlike bedside physiologic monitors, ventilator alarms or alerts can prevent a negative physiologic consequence of improper ventilation received by the patient. In 2019 Top 10 Health Technology Hazards,[5] "Improperly set ventilators alarms put patients at risk for hypoxic brain injury or death." Issues cited in alarm related injury or death include caregivers ignoring alarms due to alarm fatigue or the alarm having been set inappropriately.[6] To our knowledge, there are no acceptable standards for mechanical ventilation alarm parameters, monitoring frequency, and response expectations. In an Issue Paper released by the American Association for Respiratory Care on *Safe Initiation and Management of Mechanical Ventilation* it was recommended that alarms should support individualized settings to create specific safety parameters while attempting to mitigate nuisance alarms and alarm fatigue.[7]

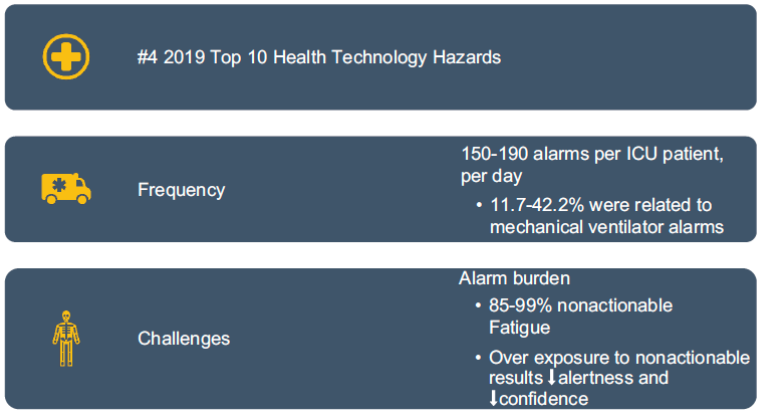


Figure 1 - Highlights mechanical ventilation alarm scope and challenges adapted from Walsh, et al.

Ventilator-Induced Lung Injury

Ventilator-induced lung injury (VILI) is the acute injury inflicted by mechanical ventilation during therapy. The contribution to morbidity and mortality impact of VILI is being increasingly recognized. Through large, randomized control trials, we have been able to identify mechanical ventilation practices associated with better outcomes. Such practices include but are not limited to; tidal volumes of 4-8 mL/Kg IBW, plateau pressures < 30 cmH_2O, avoidance of high FIO_2 (>50-60%), delta pressure < 15 cmH_2O and end-inspiratory transpulmonary pressure < 25 cmH_2O.[8, 9]

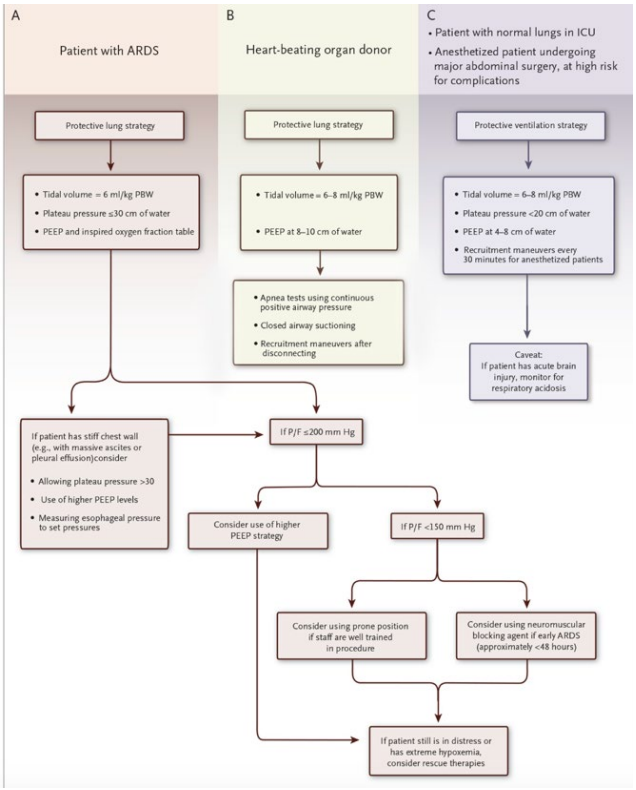


Figure 2 - Prevention of VILI as proposed by Slutsky et al

Mechanical Ventilation Liberation

There is no better way to prevent VAEs than by reducing ventilator therapy exposure. A well-accepted weaning strategy is to perform daily spontaneous breathing trials (SBT). In fact, it is the second step in the A-F bundle standard of critical care.[10] Yet, mechanical ventilation liberation remains a fine balance as if you leave a patient on mechanical ventilation too long or if you take them off too soon, you increase their risk of a poor outcome.

2.0 Rationale and Specific Aims

Operationalizing all the standards of care known to improve outcomes of those requiring mechanical ventilation in the critical care environment requires a comprehensive approach. ICU teams are encouraged to follow best practice protocols to help liberate and prevent VAEs.[11-13] Yet, compliance with protocols in most ICUs is suboptimal for multiple reasons. With the advent of computerized mechanical ventilators capable of streaming data from breath to breath and biomedical integration systems (BMDI) such as Capsule (UTMB's BMDI system), software systems have been developed to help identify variances in the standard of care. Automation in near real-time ventilator data feedback has been shown to reduce the incidences of VAEs.[14]

Preliminary data:

UTMB serves a wide variety of severely ill patients from neonates to adults. In a recent review of adult mechanically ventilated patients our team found our mortality ranges slightly higher than peer reviewed publication of 27-45% in non-COVID ARDS and 60% for COVID ARDS.[15] Currently UTMB is not monitoring VAE, VAP, VILI or alarm compliance so no baseline is available for immediate comparison. There is a plan to start to monitor these components in 2024. Therefore, our study will require a 3-month baseline study.

This research project will leverage Zoll's Respiratory Knowledge Portal (RKP) to collect and store meaningful data regarding ventilator-associated events (VAE), alarm policy compliance, ventilator weaning, and lung protective analytics. RKP and RKP Messenger is a clinical decision

support software that are not regulated by the FDA as a medical device. This study involves the use of RKP and RKP Messenger, which have not received FDA clearance or approval and are therefore investigational for the end points studied in this protocol.

Specific aim 1: To prospectively collect quality metrics utilizing RKP from patients requiring mechanical ventilation over a 3-month period for a retrospective baseline analysis.

- Hypothesis: Will be able to establish a baseline of ventilator-associated events (VAE), alarm policy compliance, ventilator weaning, and lung protective analytics.

Specific aim 2: To determine if the use of RKP's Messenger Zebra phone app improves VAEs, liberation from mechanical ventilation, alarm policy compliance and lung protective strategies as compared to aim 1.

- Hypothesis:
  - RKP use will reduce CDC reportable VAE events by 25%
  - RKP use will improve alarm policy compliance by 30%
  - RPK use will improve lung protective strategies by 25%
  - RKP use will improve compliance with unit established weaning strategies by 20%
  - RKP will decrease the time to extubation readiness by 20%

Specific aim 3: To determine a return on investment (ROI) for a software system like RKP.

- Hypothesis: Using improvements in quality metrics and the published or typical subscription-based models cost we will be able to develop a ROI calculator for software packages geared toward improvements in ventilator care.

3.0 Inclusion/Exclusion Criteria

Subjects must meet all the inclusion criteria to be eligible to participate in the study.

Inclusion criteria are:

1. Subjects requiring invasive mechanical ventilation.
2. Subjects is in one of the monitored UTMB campus ICUs (Galveston, Clearlake or League City).
3. Age 0 to 100 years.

Subjects meeting any of the exclusion criteria at baseline will be excluded from study participation.

Exclusion Criteria are:

1. Is in an ICU not monitored by RKP.
2. Adults on high frequency ventilation (pediatric patients are NOT excluded).
3. Any patient requiring ECMO.
4. Prisoners

4.0 Enrollment/Randomization

Phase 1: Prospective data collection with retrospective review. During the collection of 1,500 patients (approximately 6months) baseline data collecting period any subject requiring mechanical ventilation will have their ventilator data recorded for retrospective analysis. There will be no randomization.

Phase 2: Prospective use of RKP Messenger use in all ICUs and will stop after 1,500 patients (approximately 6 months). There will be no randomization.

The subjects may be patients of the investigators as this will be blanketed across the ICU setting and there is no way to insulate the investigator from this function of their responsibility.

The research involves no more than minimum risk as detailed in section 6.0 and could not practicably be carried out for several reasons.
1. This project involves the monitoring of severely ill subjects who due to their illness or injury cannot give consent at the initialization of mechanical ventilation therapy.
2. Proxy consent could not reasonably be obtained at initialization of mechanical ventilation.
3. Most courses of mechanical ventilation are short in duration and do not meet the VAE definition. Longer courses of mechanical ventilation cannot be easily predicted and would require consent of double the number of participants than could be enrolled.

Name and MRN are used to record outcomes of their mechanical ventilation course. Recording the outcomes without the name and MRN would be impossible. These two items will be identified in RedCap as identifiable information so that it will be excluded during data export.

The waiver of consent will in no way affect the rights and welfare of subjects. Subjects or legal representatives attending ICU rounds will be provided if appropriate verbal summaries of the RKP findings. Currently no additional information will be provided to subjects.

A waiver of HIPAA authorization is being requested for UTMB research purposes. A data sharing agreement with Zoll (makers of RKP) will be executed.

5.0 Study Procedures

<u>Phase 1: Data collection and analysis:</u>
RKP will collect data received by our biomedical device integrator (Capsule) from mechanical ventilators in use and pair the data with patient data from the admission, discharge, and transfer (ADT) data with room location and analyze for the following conditions. If any of the below criteria is met, the data will be recorded.

Ventilator-associated events, adult and pediatric are preprogrammed into the RKP software and according to CDC definition and briefly defined below.[16]
<u>Adult Ventilator-associated events (VAE):</u>

- Patient intubated for >2 calendar days (earliest day of event is calendar day 3)
  - Baseline stability
    - Stable or improving baseline period.

- The 2 calendar days immediately preceding the first day of increased oxygen requirement, defined as an increased daily minimum PEEP or FiO_2.

- After period of stability or improvement on the ventilator, the patient exhibits at least one of these indicators of worsening oxygenation:
  - Daily minimum PEEP values increase ≥ 3 cm H_2O over daily minimum for the preceding 2 calendar days.
  - Daily minimum FiO_2 values increase ≥ 0.20 over daily minimum for preceding 2 calendar days.

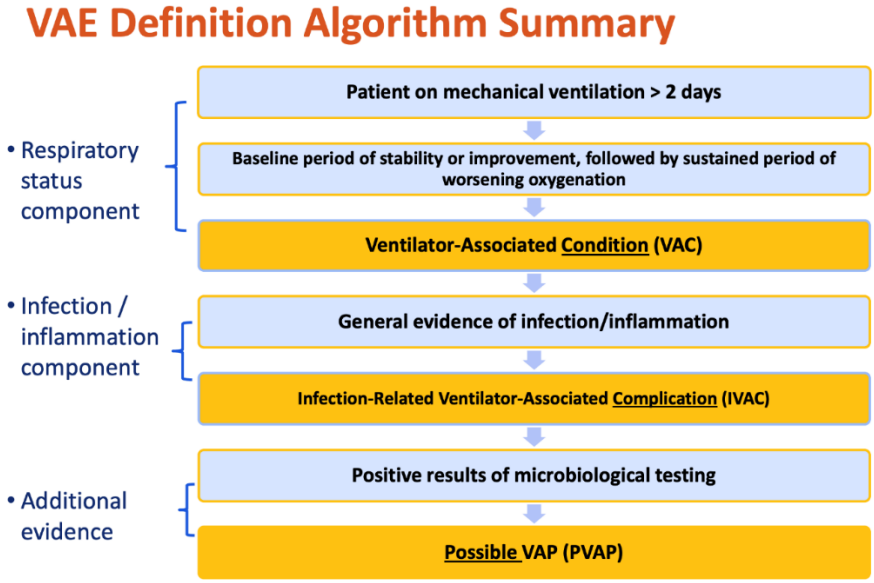


Figure 3 - The respiratory status component of this algorithm will be the focus of this study.

This study will only be focusing on the respiratory status component in the box above.

<u>Pediatric Ventilator Associated Events (PedVAE):</u>

- Patient intubated for >2 calendar days (earliest day of event is calendar day 3)
  - Baseline stability
    - Stable or improving baseline period.
    - The 2 calendar days immediately preceding the first day of increased oxygen requirement, defined as an increased daily minimum mean airway pressure (MAP) or FiO_2.

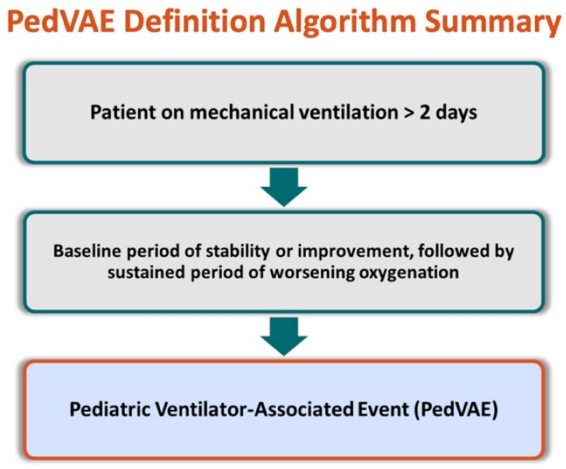


Figure 4 - CDC PedVAE algorithm

- After period of stability or improvement on the ventilator, the patient exhibits at least one of these indicators of worsening oxygenation:

- Daily minimum MAP values increase ≥ 4 cm H_2O over daily minimum for the preceding 2 calendar days.
- Daily minimum FiO_2 values increase ≥ 0.25 over daily minimum for preceding 2 calendar days.

Alarm policy compliance

Alarm analytics will be programmed based on the UTMB Mechanical Ventilation Alarms policies, national practice standards, and with the approval of the Respiratory Therapy Director. Variations will be recorded as the baseline.



Figure 5 - Example of an individual patient alerts

Ventilator weaning analytics

Ventilator weaning analytics will be programmed based on the UTMB standard spontaneous breathing trials (SBTs) and other indices of weaning determined by the medical directors.

Lung protective analytics

Lung protective analytics will be programmed based on the UTMB standard of care for tidal volumes (4-8 mL/Kg IBW), peak inspiratory pressure (< 35 cmH_2O), plateau pressures (< 30 cmH_2O), delta pressure (< 15 cmH_2O) as determined by the medical directors.

Phase 2: Use of RKP Messenger

Following the baseline data collection period, the ICU respiratory therapists (RT) will be educated on the use of RKP Messenger on their assigned UTMB Zebra phones.

RKP Messenger Protocol

The RTs will be asked to do the following:

1. Start the shift with seeing first the patients they are assigned to with the highest alerts. Color and number of alerts will indicate patient severity. Emergencies will always trump seeing the highest alert patients first.

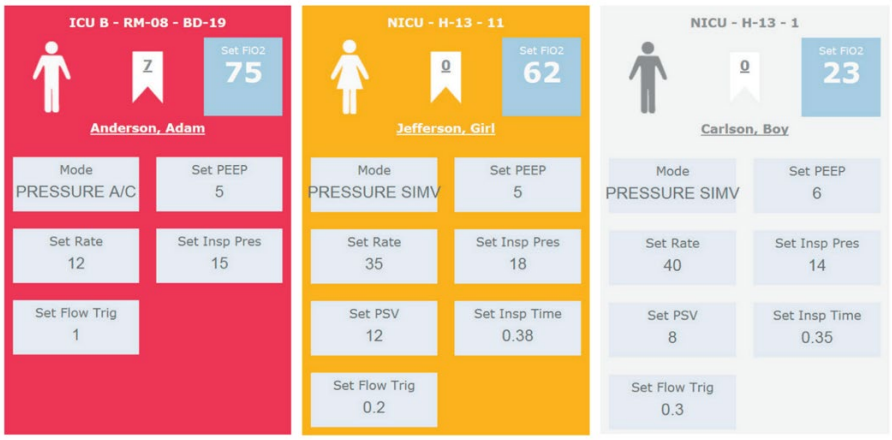


Figure 6 – Example of ranking of alerts for the RT to see first.

2. During their shift they check the RKP Messenger app twice a shift for alerts.

3. The RT will take all alerts under advisement and attempt to resolve the alerts within policy or practice.
4. Once a shift, the RT will notify the rounding team of all alerts they are unable to resolve.

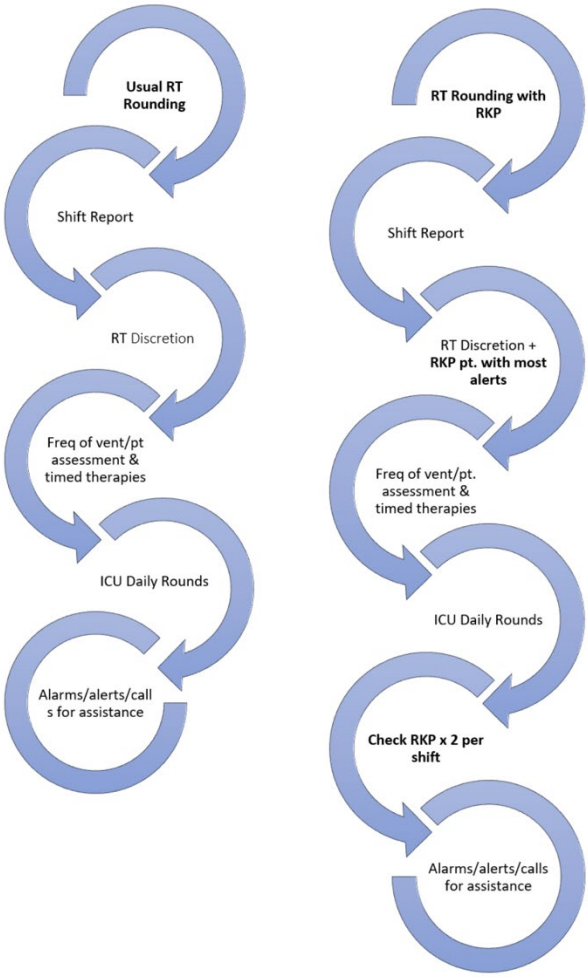


Figure 7 – Demonstrates the difference in standard of care with RKP use.

Below is an anticipated timeline from start of study.

Phase	3 months	6 months	9 months	12 months	16 months
Install RKP					
Phase 1 Obs					
Education					
Phase 2					
Analysis & Quality Reports to key stakeholders					
Peer Review Publication					

6.0 Potential Risks

Since this is an electronic system that does touch the subject and only summarizes data and compares it to the standard of care (via policy, or practice), there is no chance of physical harm. There is a potential for the loss of confidentiality in the electronic transfer of information. The estimated probability of this occurring will be very low as secure transfer protocols will be utilized. If a breach occurs it will only be name, MRN, analysis of mechanical ventilation numerical data. Additional outcomes data such as length of stay, mortality, diagnosis and duration of mechanical ventilation will be gathered from Epic and kept in the PI UTMB OneDrive outside of the RKP system. No social or economic data will be collected. The current standard of care does not include this RKP system or summaries of information, therefore there is no increase breech of information.

7.0 Potential Benefits

Respiratory Knowledge Portal (RKP) is an electronic system that gathers crucial physiologic and non-physiologic data that it transfers it into meaningful summaries of mechanically ventilated patients and presents it across multiple medical teams to assist in their clinical management and recognition of adverse events. The use of this tool has been associated with a decrease in ventilator associated events.[14] Additionally, RKP will make clinicians aware of alarm compliance and lung protective variances to policy or current practice. Therefore, RKP has the potential to improve safety.

8.0 Subject Safety and Data Monitoring

Subjects' safety is the forefront of this research. Due to medical errors being the 3rd leading cause of death in the US,[17] decision support systems like RKP have come on the market to assist in the cognitive vulnerabilities of ICU clinicians. Several steps have been taken to ensure the subject safety.

1. RKP and RKP Messenger securely manages the summary and transfer of data.
2. RKP leverages current and trustworthy UTMB infrastructure such as the Capsule and Zebra phone systems.
3. Limited identifiable data will be gathered to protect the identity of subjects recorded.

Data monitoring will begin with weekly summaries provided by the RKP administrative module. All data received by the clinicians will be verified prior to any interventions. RKP does not provide recommendations, only summaries of past events. RKP exports files (csv files) of outcomes data will be controlled by RKP database administrators and tracked by the PI through the administration function.

9.0 Study Product Description

RKP is a decision support system used to track and target the timeliness and execution of care therapies that may help shorten ventilator length of stay. Data from the ventilator pairs with mathematical models to see both current and historical information. RKP then produces proprietary management dashboards and reports to display the data over time but does not make clinical recommendations. When used daily, RKP provides tools that may help improve

patient management and process management strategies. Report views provide intelligence and insight for the user, opening the door to help make more efficient operational decisions:

- Assessment and trends of weaning protocols
- Identify staff efficiency of care delivery
- Identify patient outcome response
- Reduce time and labor of manual data entry

10.0 Unanticipated Problems involving Risk to Participants or Others

The study team will conduct the study in compliance with GCP, ICH E6. Since all alerts will be filtered through the RT for accuracy, little risk of change to the standard of care exists. All unanticipated problems involving risk to subjects or others (UPIRSO) will be reported to the PI for further investigation. The PI will submit all UPIRSOs to the IRB within 10 days as stated in the UTMB IRB Policy. Information to be collected on all UPIRSOs includes event description, time of onset, clinician's assessment of severity, relationship to study product, and time of resolution.

All inaccurate information or alerts improperly firing and not meeting the criteria for "UPIRSO" will be captured on the appropriate CRF.

Severity of Event: All UPIRSOs will be assessed by the PI and ICU Attending responsible for the care of the subject using a protocol defined grading system. For events not included in the protocol defined grading system, then the following guidelines will be used to quantify intensity.

- Mild: events require minimal or no treatment and do not interfere with the patient's daily activities.
- Moderate: events result in a low level of inconvenience or concern with the therapeutic measures. Moderate events may cause some interference with functioning.
- Severe: events interrupt a patient's usual daily activity and may require systemic drug therapy or other treatment. Severe events are usually incapacitating.
- Life-threatening: any adverse drug experience that places the patient or subject, in the view of the investigator, at immediate risk of death from the reaction as it occurred, i.e., it does not include a reaction that had it occurred in a more severe form, might have caused death.

Changes in the severity of an UPIRSO should be documented to allow an assessment of the duration of the event at each level of intensity to be performed. Adverse events characterized as intermittent require documentation of onset and duration of each episode.

Reporting Procedures

The research team will round daily for the first 5 days and weekly after to collect any concerns or issues that may occur from the use of the RKP Messenger app. Weekly administrative reports will be generated to evaluate the use and alerts for the week. The PI's contact information will be placed in all RT touchdown spaces and department. Monthly summary reports of alerts as well as any UPIRSOs will be reported to medical directors and RT manager and director.

11.0 Study Withdrawal/Discontinuation

Reasons for Withdrawal

A study subject will be discontinued from participation in the study if any of the following occur:

- Unforeseen and unacceptable actions taken by the RT or ICU team
- Unacceptable toxicity or adverse event (AE)
- Development of any exclusion criteria

Handling of Withdrawals

For any withdrawal of individual subject or ICUs, a detailed report will be gathered of reasons for withdrawal. Prior to withdrawal there will be an agreed upon consensus from the PI, co-PI, medical director, and director of respiratory care.

Termination of Study

Termination of the study will occur if the following occurs:

1. UPIRSOs that change the benefit risk ratio

12.0 Statistical Considerations

The following data will be collected for each patient: age, sex, primary diagnosis, comorbidities, outcome, hospital admission and discharge date and time, and ventilator start and termination date and time. VAEs will be automatically identified and recorded by RKP software according to the CDC definitions.

Sample Size

Sample size was calculated based on the ability to show a difference in VAE incidence between the control and intervention groups. An assumed 10% VAE incidence in the control group and a 3% VAE incidence in the RKP group (intervention). Based on the sample size calculations for two independent samples with dichotomous outputs, power of 80% and alpha of 0.05, a minimum of 388 total patients (194 in each group) are needed.

The incidence of VAEs will be quantified as the number of patients in each group (baseline & intervention) who had each category of event divided by the total number of patients in each group. Ventilator duration is defined as the number of days between ventilator start and termination and hospital length of stay is defined as the number of days between hospital admission and discharge. For patients who experience at least one VAE, we identify the number of days between ventilator start and the occurrence of the first VAE. Estimated cost are based on changes in VAE incidences were estimated to be $40,144 per VAE avoided based on previous research by Zimlichman et al.[18]

Unpaired t test will be used to compare the subjects ages between groups. Fisher exact test will be used to compare the proportion of males to females, VAE, VACs, IVACs, and PVAPs between the two groups. Wilcoxon rank-sum tests will be used to compare the median ventilation duration and hospital length of stay between the two groups. All analysis will be performed using JMP (SAS, Cary, NC). Adult and pediatric populations will be analyzed separately.

13.0 Ethics and the Protection of Human Subjects

The investigator will ensure that this study is conducted in full conformity with the principles set forth in The Belmont Report: Ethical Principles and Guidelines for the Protection of Human Subjects of Research of the US National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research (April 18, 1979) and codified in 45 CFR Part 46 and/or the ICH E6; 62 Federal Regulations 25691 (1997).

The investigator must provide for the review and approval of this protocol and recruitment material by an appropriate independent ethics committee (IEC) or IRB registered with the OHRP. Any amendments to the protocol must also be approved before they are placed into use. In the United States and in other countries, only institutions holding a current US Federal wide Assurance issued by OHRP may participate.

The Zoll Respiratory Knowledge Portal has validated the software and is fully HIPAA compliant. Zoll is providing support for this research project. Additionally, this system is leveraging our current Capsule technology used for EPIC charting and Zebra phones to run the application. This helps ensures easy access to the information through already established systems used today as the standard of care.

Privacy/Confidentiality Issues
Subject confidentiality is strictly held in trust by the participating investigators, their staff, and the sponsor(s), and their agents. This confidentiality is extended to cover testing of biological samples and genetic tests in addition to the clinical information relating to participating subjects.

The study protocol, documentation, data, and all other information generated will be held in strict confidence. No information concerning the study, or the data will be released to any unauthorized third party without prior written approval of the Principal investigator.

Individuals authorized to view study records will be identified to the study subject on the informed consent but may include a study monitor or other authorized representatives of the sponsor or funding agency or federal or local agencies that regulate research, including representatives from the Food and Drug Administration, Office of Human Research Protections, or the Institutional Review Board. Study records may also be made available for internal compliance reviews and quality assurance representatives.
These individuals may inspect all documents and records required to be maintained by the investigator, including but not limited to, medical records (office, clinic, or hospital) and pharmacy records for the subjects in this study. The clinical study site will permit access to such records.

In accordance with the Food and Drug Administration Amendment Act of 2007 (FDAAA) and The International Committee of Medical Journal Editors (ICMJE) member journals trials-registration policy as a condition for publication, this study will be registered in the public trials registry ClinicalTrials.gov, which is sponsored by the National Library of Medicine. Results will be published to clinicalTrial.gov when available but will not identify individual subjects.

14.0 Record Retention

Research records will be maintained in accordance with the current version of the UTMB Record Retention Schedule in accordance with 13 TAC 6.2.

15.0 References

1. Wunsch H, Linde-Zwirble WT, Angus DC, Hartman ME, Milbrandt EB, Kahn JM. The epidemiology of mechanical ventilation use in the United States. Crit Care Med 2010;38(10):1947-1953.
2. Kahn JM, Goss CH, Heagerty PJ, Kramer AA, O'Brien CR, Rubenfeld GD. Hospital volume and the outcomes of mechanical ventilation. N Engl J Med 2006;355(1):41-50.
3. Esteban A, Anzueto A, Frutos F, Alia I, Brochard L, Stewart TE, et al. Characteristics and outcomes in adult patients receiving mechanical ventilation: a 28-day international study. JAMA 2002;287(3):345-355.
4. Rubenfeld GD, Caldwell E, Peabody E, Weaver J, Martin DP, Neff M, et al. Incidence and outcomes of acute lung injury. N Engl J Med 2005;353(16):1685-1693.
5. Institute E. 2019 Top 10 Health Technology Hards
6. Walsh BK, Waugh JB. Alarm Strategies and Surveillance for Mechanical Ventilation. Respir Care 2020;65(6):820-831.
7. Network AAfRCaUHCsURC. Safe Initiation and Management of Mechanical Ventilation
8. Fan E, Villar J, Slutsky AS. Novel approaches to minimize ventilator-induced lung injury. BMC Med 2013;11:85.
9. Slutsky AS, Ranieri VM. Ventilator-induced lung injury. N Engl J Med 2013;369(22):2126-2136.
10. Marra A, Ely EW, Pandharipande PP, Patel MB. The ABCDEF Bundle in Critical Care. Crit Care Clin 2017;33(2):225-243.
11. Girard TD, Alhazzani W, Kress JP, Ouellette DR, Schmidt GA, Truwit JD, et al. 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(1):120-133.
12. Klompas M. Potential Strategies to Prevent Ventilator-associated Events. Am J Respir Crit Care Med 2015;192(12):1420-1430.
13. Ouellette DR, Patel S, Girard TD, Morris PE, Schmidt GA, Truwit JD, et al. Liberation From Mechanical Ventilation in Critically Ill Adults: An Official American College of Chest Physicians/American Thoracic Society Clinical Practice Guideline: Inspiratory Pressure Augmentation During Spontaneous Breathing Trials, Protocols Minimizing Sedation, and Noninvasive Ventilation Immediately After Extubation. Chest 2017;151(1):166-180.
14. Augustus Oglesby HJ, Cataldo SH, Pedro MJ. Automated Near Real-Time Ventilator Data Feedback Reduces Incidence of Ventilator-Associated Events: A Retrospective Observational Study. Crit Care Explor 2021;3(4):e0379.
15. Michaels K, Walsh BK, Rojas J. The Impact of Respiratory Mechanics on Mortality Among COVID-19 Subjects Requiring Mechanical Ventilation. Respiratory Care 2022;67(10).
16. Prevention CfDCa. Ventilator-Associated Event (VAE)
17. Makary MA, Daniel M. Medical error-the third leading cause of death in the US. BMJ 2016;353:i2139.

18. Zimlichman E, Henderson D, Tamir O, Franz C, Song P, Yamin CK, et al. Health care-associated infections: a meta-analysis of costs and financial impact on the US health care system. JAMA Intern Med 2013;173(22):2039-2046.