Title: "Awakening and breathing coordination: A mixed-methods analysis of determinants of implementation"

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Abstract

Rationale: Routine spontaneous awakening and breathing trial coordination (SAT/SBT) improves outcomes for mechanically ventilated patients, but adherence varies. Understanding barriers and facilitators to consistent daily use of SAT/SBT (implementation determinants) can guide the development of implementation strategies to increase adherence to these evidence-based interventions.

Objective(s): We conducted an explanatory, sequential mixed-methods study to measure variation in the routine daily use of SAT/SBT and to identify implementation determinants that might explain variation in SAT/SBT use across 15 intensive care units (ICUs) in urban and rural locations within an integrated, community-based health system.

Methods: We described the patient population and measured adherence to daily use of coordinated SAT/SBT from January-June 2021, selecting 4 sites with varied adherence levels for semi-structured field interviews. We conducted key informant interviews with critical care nurses, respiratory therapists, and physicians/advanced practice clinicians (n=55) from these four sites between October – December 2021 and performed content analysis to identify implementation determinants to SAT/SBT use.

Results: The 15 sites had 1901 ICU admissions receiving invasive mechanical ventilation (IMV) ≥24 hours during the measurement period. Mean IMV patient age was 58 years with median IMV duration of 5.3 days [IQR: 2.5-11.9] Coordinated SAT/SBT adherence (within two hours) was estimated at 21% systemwide (site range: 9-68%). ICU clinicians were generally familiar with SAT/SBT but varied in their knowledge and beliefs about what constituted an evidence-based SAT/SBT. Clinicians reported SAT/SBT coordination was difficult in the context of existing ICU workflows, and existing protocols did not explicitly define how coordination should be performed. The lack of an agreed upon system-level measure for tracking daily use of SAT/SBT led to uncertainty regarding what constituted adherence. The effects of the COVID-19 pandemic increased clinician workloads, impacting performance.

Conclusion: Coordinated SAT/SBT adherence varied substantially across 15 ICUs within an integrated, community-based health system. Implementation strategies that address barriers identified by this study, including knowledge deficits, challenges around workflow coordination, and the lack of performance measurement, should be tested in future hybrid implementation-effectiveness trials to increase adherence to daily use of coordinated SAT/SBT and minimize harm related to the prolonged use of mechanical ventilation and sedation.

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INTRODUCTION

Invasive mechanical ventilation (IMV) with sedation is a life-saving measure for patients in respiratory failure.[1] However, the prolonged use of IMV and continuous sedation can also cause harm, including lung injury, pneumonia, and delirium, contributing to lasting impairment known as post-intensive care syndrome.[2–11] Daily interruptions in sedation [spontaneous awakening trials (SAT)] and daily spontaneous breathing trials (SBT) separately decrease duration of IMV and intensive care unit (ICU) length of stay (LOS) without compromising patient comfort or safety.[12-13] Coordinating SAT and SBT (SAT/SBT) further increases ventilator free days, decreases ICU LOS, improves mortality and reduces ventilator associated events.[14-15] SAT and SBT are included in the ICU Liberation Bundle (ABCDEF Bundle), a collection of evidence-based interventions designed to hasten liberation from the ICU.[16-17]

Although Girard and colleagues demonstrated the efficacy of a paired SAT/SBT protocol in the Awakening and Breathing Controlled trial in 2008, attempts to implement the protocol in real-world settings have yielded variable results.[15,18–22] Recent surveys of SAT/SBT implementation in the context of the ABCDEF Bundle suggest widespread uptake remains suboptimal.[23,24] A recent systematic literature review highlighted the need to examine the barriers and facilitators (implementation determinants) for ABCDEF bundle components separately.[25] The purpose of this study was to measure variation in adherence to consistent daily coordinated SAT/SBT use across 15 ICUs in an integrated, community-based health system and to identify implementation determinants through key informant interviews with ICU clinicians that might explain site-level differences in adherence.

METHODS

Study Design and Setting

In preparation for a type II hybrid implementation-effectiveness trial (TEACH, NCT05141396), we conducted a sequential, explanatory mixed-methods investigation of implementation context from

January 2021-March 2022 at 15 ICUs in Utah and Idaho that are part of Intermountain Health (Intermountain), a not-for-profit, integrated, community-based health system in the western United States. The study coincided with periods of strained ICU capacity during the COVID-19 pandemic with approximately 4700 adult patients receiving IMV in 2021.[26] This study was approved by Intermountain's Institutional Review Board (IRB #1051681).

Critical care operations at Intermountain rely on an interprofessional team-based care model. In-scope ICUs were staffed by approximately 150 employed physicians and advanced practice providers (APPs); 750 critical care nurses; and 350 respiratory therapists (RTs). Larger ICUs were staffed by intensivists and smaller ICUs were staffed by hospitalists. A remote telemedicine team of critical care physicians, nurses, and RTs supported bedside patient care by reviewing patient data, clarifying policies and procedures, and guiding bedside teams in developing evidence-based treatment plans with an emphasis on supporting smaller ICUs staffed by hospitalists. Critical care teams used a computerized ventilator protocol within the systemwide electronic health record (EHR) (Cerner Corporation, Kansas City, MO) to support care for IMV patients.[27]

In 2018, Intermountain implemented the ABCDEF Bundle, including an SAT/SBT protocol adopted at all facilities **(Figure 1).**[17] The ABCDEF Bundle implementation strategies included didactic education, communications, and executive leadership emphasis. A workflow diagram job aid link was embedded with the EHR orders. Automated performance tracking was in place for other ventilator initiatives but not for SAT/SBT.

Measuring SAT/SBT Adherence

Site and patient-level characteristics were summarized from January 1, 2021 – June 30, 2021. The patient study population included patients ≥16 years old excluding solid organ donors and patients receiving IMV<24 hours. To measure site variation in adherence to coordinated SAT/SBT, we calculated

the proportion of eligible patient ventilator-days associated with this population with an SAT, SBT, and SAT/SBT performed. SAT was considered performed if the nurse documented performance or the patient was extubated. SBT was considered performed if the RT documented performance or the patient was extubated. Successful SAT/SBT coordination required SAT eligibility and performance of an SAT followed by an SBT within two hours (described at **Table E1 and Figure E1**). Proportions were calculated for the measurement period and sites were stratified by relative adherence level in tertiles: high, medium, and low. Sites were selected based on tertile, geography, facility size and site operational readiness as determined through conversations with local site ICU leaders.

Key Informant Interviews and Qualitative Data Analysis

To conduct key informant interviews, we developed tailored interview guides **(Figure E2)** for each professional role (nurse, RT, and physician/APP) using a published methodology.[28–33] We validated the interview guides through cognitive testing with content experts, and questions were refined based on participant feedback.[34] A field team of trained, experienced qualitative researchers (GO, PG, and AK) conducted semi-structured interviews from October-December 2021 using a purposive sample of 10-20 key informants per site and a role-based criterion to ensure interprofessional representation. Individuals within each role varied in terms of years of experience and attitudes and beliefs regarding SAT/SBT. Local leaders recruited participants through e-mail or direct conversation. Participation was voluntary. Informed consent was obtained for interview participation and recording. Interviews were conducted in person and lasted 30 minutes and were recorded for deidentified transcription. Interviews were continued at each site until thematic saturation was reached.[35]

The field team analyzed the interview content using a hybrid deductive-inductive approach, incorporating both conventional and directed content analysis.[36–38] Three experienced researchers trained in qualitative coding (GO, PG, and AK) independently coded interview content using open coding

at the question level. Discrepancies were then discussed between coders until consensus was reached. Identified implementation determinants were summarized by domain, site, and clinical role using the Consolidated Framework for Implementation Research (CFIR).[39] The CFIR framework consists of five domains used to categorize determinants to implementation effectiveness, including individual (clinical characteristics), intervention (SAT/SBT protocol characteristics), inner setting (organization context), external setting and implementation (prior implementation process).

RESULTS

From January 1-June 30, 2021, the 15 ICUs had 9305 patients ≥16 years old excluding solid organ donors with 1901 patients on IMV≥24 hours (20%) **(Figure E1)**. The patient population receiving IMV≥24 hours was 63% male. Mean IMV patient age was 58 years with median IMV duration of 5.3 [IQR: 2.5-11.9] days. The median patient Acute Physiology and Chronic Health Evaluation score was 18 [IQR: 13-24] with a median Charlson comorbidity count per patient of 3 [IQR:1-6] **(Table 2).** SAT/SBT adherence for the 15 sites was 21% [site range: 9%-68%] **(Table 1).**

Fifty-five ICU professionals participated in semi-structured interviews at four sites **(Table 3),** representing 40% of ICU beds and over half of eligible SAT/SBT patient ventilator-days. The four geographically distributed sites (average distance between sites: 200 miles [range: 38 – 382 miles]) included a Level 1 trauma and tertiary referral center, two Level 2 trauma and regional referral centers, and a small rural Level 3 trauma center. We did not observe meaningful differences in implementation determinants across interview sites based on adherence, apart from the small rural site, where low mechanical ventilation volumes and staff experience working together appeared to enable coordination. The implementation determinants are organized below according to the five CFIR domains.

1. SAT/SBT protocol characteristics (Table E2)

Clinicians at all sites acknowledged that SAT/SBT minimized the duration of IMV and continuous sedation.

> *"If we can wake them up and get them extubated… then the less the chance for them to end up with some kind of a hospital acquired infection." - Nurse (Site B)*

> *"The goal pretty much all the time is to get a patient off the ventilator. The longer they're on the ventilator, the more complications arise."– RT (Site B)*

Routine assessments were superior to clinical judgment alone for identifying readiness for extubation and SAT/SBT was generally beneficial.

> *"If we don't purposely do these tests, we can sometimes miss people who actually are able to breathe enough on their own [and are ready] to be extubated." – Physician (Site B)*

> *"When it's coordinated, it takes less time… If there's an issue at any point, we're both going to see it, and we're both going to do what we need to…to adjust." – Nurse (Site L)*

However, conducting an SAT or SBT often required remaining with the patient for an extended, unpredictable timeframe, which limited clinician ability to complete other required tasks.

> *"You can't turn it off or half it and then leave. You have to stay in the room. You've got to keep your eyes on it..." – Nurse (Site G)*

> *"You can't really put a timeframe on [an SBT] … realistically, timeframe wise…I would say everything's at least a half hour, and if they do bad, then it takes more time." – RT (Site G)*

Some clinicians did not believe coordination was always necessary to achieve the clinical benefits and the interdependence it fostered was disruptive to routine care.

> *"…In my experience, sometimes it doesn't matter if a patient's sedated or not. They can do just fine on a breathing trial." – RT (Site G)*

> *"[Coordination] could slow down the process...if you're not ready, or the nurse isn't ready, then somebody is waiting, and… patient care is getting delayed." – RT (Site G)*

Absent a systemwide standard for how to coordinate SAT/SBT, approaches varied by site.

> *"I make sure I know who my RTs are for the specific rooms…if they just so happen to be rounding at the same time as I am, then I'll go in and tell them…" – Nurse (Site B)*

"There's often times when the nurses don't communicate or the doctor comes by and turns off the sedation, and I'm busy doing something else and don't have time to get there immediately." – RT (Site G)

The current design of SAT and SBT documentation within the EHR slowed data entry and made information retrieval cumbersome.

"It's just really confusing on the documentation because it says,' Was a sedation vacation performed?' It's a 'yes' or 'no.' And when the patient's not on any sedation or a paralytic, there should be like a 'not applicable.'" – Nurse (Site B)

"Are SATs and SBTs documented in [the EHR]? Yes, I've seen them… Now, do I go in to check it? No, it's still too much of a hassle." – Physician (Site G)

2. ICU clinician characteristics (Table E3)

Nurses and RTs were generally familiar with the concept of waking patients and allowing them to breathe on their own and the process for accomplishing that. However, nurses varied in how they defined an SAT.

"I usually will turn off that sedation cold turkey." – Nurse (Site B)

"I will usually just halve their sedation… I'll keep an eye on them for half hour, 45 minutes… Then, I'll go down more." – Nurse (Site B)

Many RTs conflated an SBT with other spontaneous breathing modes, including weaning.

"So, we'll push a couple buttons on the ventilator, and we'll switch them to spontaneous mode and give them pressure support to start with….As long as they're breathing fine [and]…all their numbers on the ventilator are good, we're kind of set for a couple hours until we need to make another change." – RT (Site G)

Many nurses and RTs demonstrated limited understanding of the other's professional role knowledge domain potentially impeding development of a shared mental model for SAT/SBT performance.

"That I don't know because RT's come in to do their magical adjustments...." – Nurse (Site G)

Awake and spontaneously breathing patients required more attention than sedated patients on IMV, which influenced motivations.

"Obviously, a sedated patient is easier to take care of than a non-sedated patient….I mean it's a dream to have a vented sedated patient that doesn't have any family, right?" – Nurse (Site D)

"It's easier to care for the patient when they're snowed… And I hate to even say it that way. It's not good for their mental state. It's not good for anything after the ICU or their home life afterwards. But it's much easier to care for them here for your 12 hours." – RT (Site G)

3. External environment characteristics (Table E4)

The COVID-19 pandemic was the dominant external characteristic and influenced patient acuity at all sites, requiring more intensive care and added activities, such as prone positioning. Workforce constraints resulted in increased patient-to-clinician ratios. These capacity strains resulted in de-prioritization of SAT/SBT for some patients. In addition, many COVID-19 patients with severe acute respiratory distress syndrome remained ineligible for SAT/SBT for extended periods, limiting clinician experience with SAT/SBT and extubation.

"Pre-COVID, I feel like we were really big into our ABCDEF bundle, which included SAT and SBT to help produce the best outcomes for our patients." – Nurse (Site B)

"Especially in these COVID times where I have sometimes quite a few ventilators at one time, sometimes it's hard to get to every single one because some [patients] are maybe more critical than others… you kind of have to triage at that point." – RT (Site B)

4. Organizational context (Table E5)

Clinicians indicated that consistent daily SAT/SBT performance was challenging given existing workflows. Patient assignments did not always overlap across roles, leaving nurses and RTs to coordinate with multiple counterparts, with each additional individual's schedule increasing logistical complexity. Nurses cared for 1-3 patients in close proximity, while RTs cared for up to 12 patients, sometimes spread across multiple inpatient settings. Nurses structured their days around ICU rounds and medication administration. RTs structured their days around scheduled patient-ventilator assessments required by the computerized ventilator protocol.

"It's hard. In my world, there's three or four different nurses, three different doctors…" – RT (Site G)

"It's so hard that we all have different schedules... it's just a lot of moving parts... we don't just have a set schedule that we can just follow to a book, that's not real world." – RT (Site G)

Clinicians described many competing priorities that could take precedence over SAT/SBT and disrupt coordination plans.

"We're flipping people over, back and forth, morning and night. And between those hours we're doing physical therapy and occupational therapy and we're helping them out with that. And if we have any transfers in the middle of the day, it's very difficult to get in and do SBTs." – RT (Site B)

Telecommunication devices, including cellular phones and wireless communication badges, facilitated informal communication. Clinicians working in hospitalist-staffed units described how the remote telemedicine team facilitated care for mechanically ventilated patients.

"It's a good thing… to have some extra eyes in critical care… they help prompt us to do things for the care of patient… they do help identify if we're falling out of protocol, and they'll call and communicate that with us." – RT (Site G)

Staffing and workload issues impacted routine performance of SAT/SBT, fueled in part by the pandemic. As a result of staffing shortages, Intermountain began employing traveling nurses during the pandemic, impacting knowledge and buy in to institutional protocols.

"One thing recently that's been an issue is acuity and how thin we are staffing wise. So, it's very dangerous to be tripled and try and do a sedation vacation on a patient. Because you can't have eyes on them as often as you would need to." – Nurse (Site B)

"Our workloads prohibit us from doing some of those things that we want to be doing… if you have three or four really, really sick patients, you're having to triage." – RT (Site G)

5. Prior implementation process characteristics (Table E6)

The previous implementation of the ICU Liberation Bundle (ABCDEF Bundle) raised awareness of SAT/SBT through education efforts but the success or failure of past implementation experiences influenced their engagement.

"I didn't really understand it [SAT/SBT] fully until we did an ABCDE bundle [training], and that was maybe two or three years ago... I feel like our team does really well when there's a good, thorough roll out." – RT (Site G)

"Five years ago, the roll out [of the computerized ventilator protocol] was just a little bit weak…we had to do a little damage control...and roll everything out again." – RT (Site G)

DISCUSSION

This mixed-methods study, including quantitative data on 1901 patients invasively mechanically ventilated ≥24 hours at 15 ICU sites and 55 key informant interviews across 4 sites, details implementation determinants to consistent daily SAT/SBT use, filling an identified gap in the literature.[25] The results generally corroborate the findings of previous research regarding implementation of the ABCDEF Bundle, extends our knowledge of the specific determinants that influence consistent performance of SAT/SBT, and provides actionable insights for tailoring implementation strategies to increase SAT/SBT adherence, as part of a larger implementation trial we are conducting.[25,40,41]

Participants were generally familiar with routinely using SAT and SBT but differed in their detailed understanding of the protocol. Consistent with other studies, we found some nurses preferred to gradually reduce the rate of sedative infusion rather than pause it completely due to perceived safety concerns.[18,40,42] Some RTs conflated SBT with spontaneous breathing modes and weaning ventilatory support generally. This was due, at least in part, to the use of ventilator weaning protocols within our system that transition patients from a volume control mode to a pressure support mode, where the patient may continue for several days before extubation.[43] Implementation strategies that evaluate existing field practices and provide education and training for frontline teams may be required to address this variation and clarify expectations.

Routinized interprofessional coordination was inherently difficult, even when the tasks requiring coordination were understood by the clinical team. The lack of overlapping patient assignments resulted in clinicians having to coordinate with multiple counterparts. Differences in daily work routines across roles resulted in scheduling conflicts. Unpredictable events frequently disrupted plans. This supports previous research linking the ability to anticipate team members' behaviors with the ABCDEF Bundle implementation.[44] Other institutions have proposed standard times for conducting SAT/SBT.[21] Although this may enhance routinization, this approach may require frequent adaptation given the unpredictability of patient needs, impacting staff availability.

Organizations can strengthen existing protocols by establishing clear definitions of SAT/SBT consistent with clinical standards, providing explicit instructions regarding coordination communication, and designating process ownership.[45,46] Limiting the number of SAT/SBT required per day to the minimally necessary required to achieve the clinical benefit can minimize workflow disruption. Previous descriptions of SAT/SBT protocol implementation have noted the importance of tracking performance to achieve high adherence.[15,19] Most delivery systems rely upon their existing EHR for data capture, where documentation of SAT/SBT can vary meaningfully in both form and content. Implementation strategies may require redesigning specific EHR fields to capture clinical activities in a format useful for performance measurement. A task force with clinical, technological, and implementation expertise may be required to develop feasible metrics that have systemwide agreement for measuring performance. Creation of an automated electronic dashboard offers advantages.[22]

The effects of the COVID-19 pandemic impacted routine daily execution of SAT/SBT at all facilities, consistent with reports from other systems.[47,48] Sustained heavy workloads were associated with significant staff turnover, constraining nurse and RT labor supply, which led to the introduction of rotating travelers. Clinicians described adapting to these circumstances by making deliberate decisions regarding prioritization of daily work and clinical initiatives, shedding light on the practical limitations of

routine daily SAT/SBT relative to other evidence-based practices. SAT/SBT can be labor-intensive to implement routinely. Efforts to implement may not acknowledge and address practical resource limitations in sustained daily use across all eligible patients. Appropriate adaptations may exist at times given clinical circumstances and should be considered in setting performance standards.[49,50] Virtual teaming through telemedicine is one additional approach for expanding workforce capacity. Telemedicine approaches have been shown effective for implementation of evidence-based practice initiatives.[51]

This study has limitations. While useful for implementation purposes, this study design cannot establish causal relationships. Our measurements of site-level adherence may have mis-estimated actual adherence behavior given the reliance on clinical documentation within the EHR and the fact that measurements were taken during the COVID-19 pandemic when patient volumes were at capacity systemwide. We did not examine implementation determinants at all sites, nor did we interview all frontline clinicians within selected units. However, site selection based on differences in size and location represented more than 50% of eligible SAT/SBT patient ventilator-days during the study period. Although we compiled a large sample of key informants, participants were selected by local site leaders based on availability. We provided local leaders with specific instructions for identifying participants and allowed for additional interviews following the single-day site visit to ensure thematic saturation. While responses appeared frank, we cannot rule out the fact that participant statements were influenced by the researchers' institutional alignment as health system employees. Generalizability of study results may be influenced by system and site level characteristics, including patient volume, geographic reach and the patient and clinician study population.

The study has several strengths, including the use of adherence data to evaluate performance and guide sampling; qualitative methodological rigor; a large sample size with diverse viewpoints across locations and roles; and a theory-informed instrument to facilitate questioning. This study follows an

unsuccessful effort in 2018 to implement SAT/SBT with high adherence as part of the ABCDEF Bundle. The results of this study suggest that future implementation strategies to achieve high adherence should (1) ensure common definitions for SAT, SBT, and coordination; (2) optimize workflows across professional roles prior to implementation with potential for local adaptation; (3) implement a reliable and visible measurement system; and (4) consider the use of enabling technologies like telemedicine to facilitate interprofessional coordination. These results are actionable and will inform a Type II hybrid implementation-effectiveness trial (NCT05141396) to measure the effect of these implementation strategies on adherence to SAT/SBT and clinical outcomes.

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FIGURE LEGENDS

Figure 1. Desired behaviors for a spontaneous awakening trial (SAT), a spontaneous breathing trial (SBT), and SAT/SBT coordination. Interprofessional collaboration between critical care nursing and respiratory therapy is needed to perform a coordinated SAT/SBT and includes (1) joint determination of eligibility; (2) logistical planning; (3) sequenced execution ; and (4) ongoing assessment of team performance.

Table 1. Characteristics of study sites (n=15) from January 1, 2021- June 30, 2021

Site	ICU Type	Hospital Designation	Staffed by	Beds	# ICU patients†	# patients on IMV ≥24h§	% ICU patients on IMV ≥24h	Estimated % patient ventilator-days with performance of:			Performance Tertile
								Coordinated SAT/SBT	SAT	SBT	
A	General	Community	I	16	428	128	30%	9%	42%	19%	1-Low
B*	Respiratory	Level 1 Trauma‡	I	16	345	97	28%	11%	43%	35%	1-Low
C	General	Level 2 Trauma	I	16	1047	260	25%	16%	24%	49%	1-Low
D*	General	Level 2 Trauma	I	36	1584	390	25%	17%	42%	37%	1-Low
E	Thoracic	Level 1 Trauma‡	I	23	619	189	31%	18%	50%	23%	1-Low
F	Coronary	Level 1 Trauma‡	I	16	711	94	13%	20%	43%	44%	2-Medium
G*	General	Level 2 Trauma	I	32	1443	258	18%	22%	44%	48%	2-Medium
H	General	Community	H-T	4	107	3	3%	25%	50%	25%	2-Medium
I	Neurologic	Level 1 Trauma‡	I	16	598	99	17%	32%	44%	74%	2-Medium
J	General	Community	H-T	6	181	11	6%	33%	50%	100%	2-Medium
K	Medical/ Surgical	Level 1 Trauma‡	I	25	1118	291	26%	39%	71%	70%	3-High
L*	General	Community, Level 3 Trauma	H-T	14	418	26	6%	61%	83%	65%	3-High
M	General	Community	H-T	8	367	15	4%	63%	75%	88%	3-High
N	General	Community	H-T	8	229	10	4%	67%	67%	67%	3-High
O	General	Community, Level 3 Trauma	H-T	6	110	15	14%	68%	100%	100%	3-High
			Totals	242	9305	1901	20%	21%	45%	46%	

*Interview site †Includes all ICU patients ≥16yo excluding solid organ donors ‡Single hospital with 5 separate ICUs §Includes all patients on IMV ≥24 hours regardless of individual ventilator-day eligibility.

Abbreviations: SAT/SBT-coordinated spontaneous awakening and breathing trials; ICU – intensive care unit; IMV-invasive mechanically ventilated; I – Intensivist; H-T – Hospitalist/Telehealth; h – hours

Table 2. Characteristics of patients on invasive mechanical ventilation ≥24 hours at study sites from January 1, 2021 – June 30, 2021.

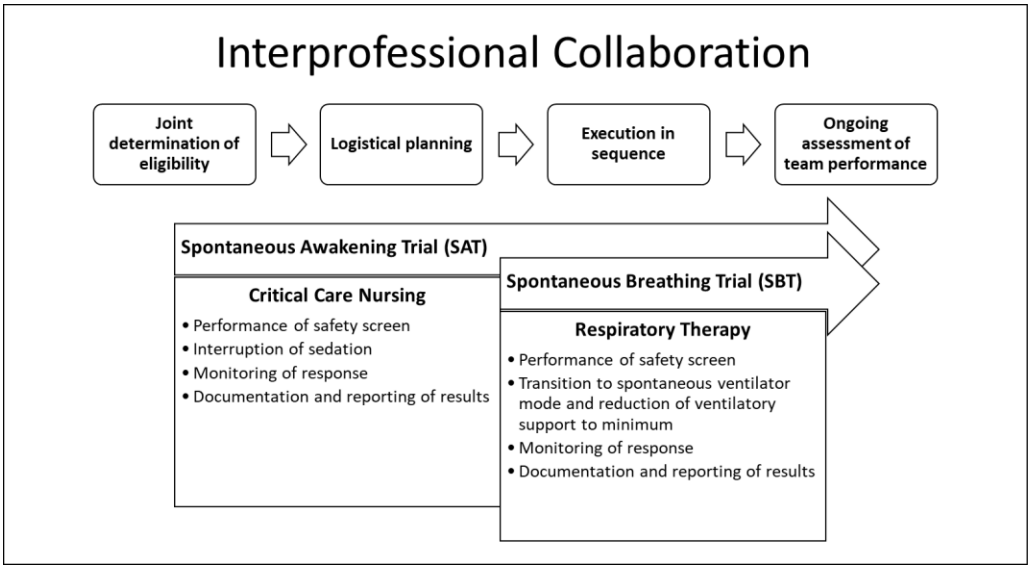
Characteristics	Patients (n=1901)
Age, mean, y (sd)	58 (17)
Age groups, n (%)	
16-17	6 (<1)
18-54	704 (37)
55-80	1063 (56)
80+	128 (7)
Male, n (%)	1206 (63)
Ethnicity, n (%)	
Hispanic	254 (13)
Not Hispanic	1516 (80)
Unknown	131 (7)
Race, n (%)	
Black	32 (2)
White	1592 (84)
Other	159 (8)
Unknown	118 (6)
Duration of invasive mechanical ventilation	
Mean, d (range)	9.6 (1-157)
Median, d (IQR)	5.3 (2.5-11.9)
Charlson comorbidities, median (IQR)	3 (1-6)
Acute Physiology Score, median (IQR)	18 (13-24)

Abbreviations: sd-standard deviation; IQR-interquartile range;

Table 3. Characteristics of clinician participants in key informant interviews (n=55) from October 1-December 31, 2021

Characteristics n (%)	Clinician Participants (n=55)
Male	30 (55)
Hispanic	5 (9)
Race:	
White	51 (93)
Asian	3 (5)
Native Hawaiian/Other Pacific Islander	1 (2)
Role:	
Critical Care Nurse	24 (44)
Respiratory Therapist	20 (36)
Physicians/Advanced Practice Clinicians	11 (20)
ICU Site:	
Site B – Level 1 Trauma Center	16 (29)
Site D – Level 2 Trauma Center	17 (31)
Site G – Level 2 Trauma Center	15 (27)
Site L – Level 3 Trauma Center	7 (13)

Figure 1. Desired behaviors for spontaneous awakening trials (SAT), spontaneous breathing trials (SBT), and SAT/SBT coordination. Interprofessional collaboration between critical care nursing and respiratory therapy is needed to perform a coordinated SAT/SBT and includes (1) joint determination of eligibility; (2) logistical planning; (3) sequenced execution ; and (4) ongoing assessment of team performance.



Online Supplement

"Awakening and breathing coordination: A mixed-methods analysis of determinants of implementation"

Griffin H. Olsen, MD; Perry M. Gee, PhD, RN, FAAN; Doug Wolfe, MBA; Carrie Winberg, RRT; Lori Carpenter, RRT; Chris Jones, MHA, BSN; Jason R. Jacobs, PhD; Lindsay Leither, DO; Ithan D. Peltan, MD, MSc; Sara J. Singer, PhD, MBA; Steven M. Asch, MD, MPH; Colin K. Grissom, MD; Rajendu Srivastava, MD, FRCP(C), MPH; and Andrew J. Knighton, PhD, CPA

Figure E1. Cohort selection diagram

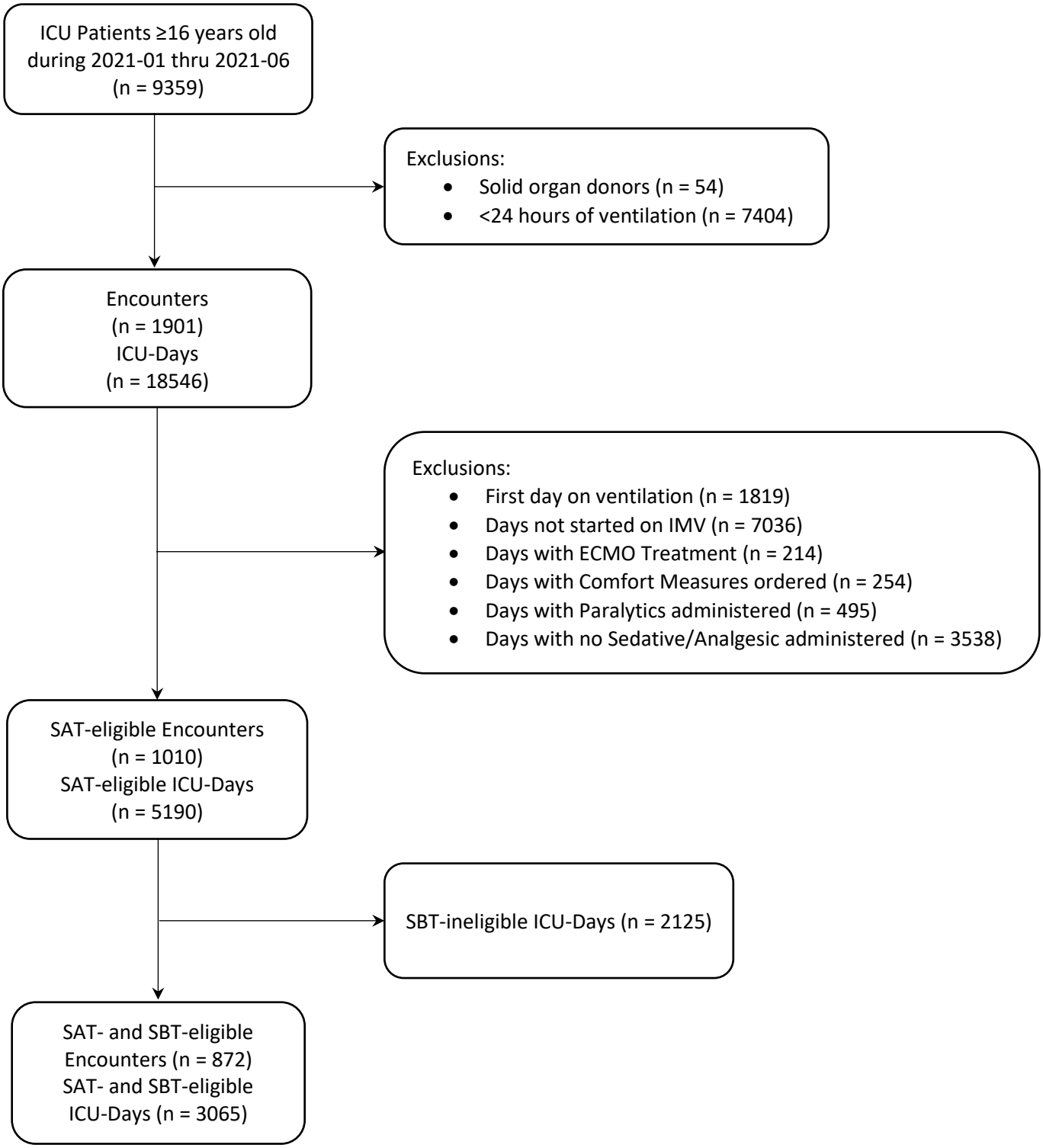


Table E1. Detailed description of adherence measurement for SAT, SBT and SAT/SBT

To measure site variation in adherence to SAT/SBT for this study, we calculated the proportion of eligible patient ventilator-days for which SAT, SBT, and coordinated SAT/SBT were performed for adults age 16 years or older between January 1, 2021 and June 30, 2021. We excluded solid organ donors encounters and patients who received invasive mechanical ventilation (IMV) <24 hours. In addition, we excluded the first day of IMV, days started not on IMV, and days where the patient received pre-specified treatments (extracorporeal membrane oxygenation, paralytics, or comfort measures). A patient day was considered eligible for SAT if the patient received a sedative infusion for ≥90 minutes. Patients were considered eligible for SBT if the computerized ventilator protocol generated an instruction to perform a weaning assessment based on oxygenation parameters or if the maximum setting for the fraction of inspired oxygen was ≤50% and for positive end expiratory pressure was ≤10 centimeters of water. SAT was considered performed if the nurse documented performance or the patient was extubated. SBT was considered performed if the RT documented an SBT safety screen or performance, or the patient was extubated. Successful SAT/SBT coordination required SAT eligibility and performance of an SAT followed by an SBT within two hours.

Table E2. Characteristics of the intervention (paired SAT/SBT protocol)

Determinant	CFIR Construct
Belief that evidence supports the effectiveness of SAT, SBT, and coordination for improving clinical outcomes	Evidence Strength & Quality
Perception that SAT/SBT are not appropriate for certain patient populations (e.g., patients with COVID-19)	Evidence Strength & Quality
Belief that routine assessment of readiness for extubation identifies eligible patients more reliably than clinical judgment alone	Relative Advantage
Belief that coordination is not always necessary to deliver the clinical benefits of SAT/SBT	Relative advantage
Perception that eligibility and failure criteria are too numerous to remember	Complexity
Perception that duration of SAT or SBT is unpredictable	Complexity
Intricacy of interprofessional coordination increases difficulty of acting in concert by complicating daily routines	Complexity
Perception that coordination creates interdependence that limits autonomy	Complexity
Timing of SAT/SBT performance and reporting are unpredictable for care team.	Complexity
Protocol's lack of role clarity and explicit instructions around interprofessional coordination limited shared understanding and reliance on informal means of communication and serendipity	Design Quality & Packaging
Belief that automated screening for SBT simplified determination of patient eligibility	Design Quality & Packaging
Belief that task in the electronic medical record prompted SBT and served as a reminder	Design Quality & Packaging
Belief that design of the electronic medical record made documentation and information retrieval cumbersome	Design Quality & Packaging

Table E3. Characteristics of the individuals

Determinant	CFIR Construct
Clinicians were familiar with the concepts of SAT, SBT, and coordination and the steps.	Knowledge & Beliefs
Lack of shared terminology within and across roles for "SAT" and "SBT" (e.g., "sedation vacation" or “weaning”) hinders development of a shared mental model	Knowledge & Beliefs
Lack of understanding of nuances of determining eligibility, performing assessments, and evaluating results leads to variation in performance	Knowledge & Beliefs
Lack of familiarity with other professional roles knowledge domain and activities hinders ability to develop a shared mental model	Knowledge & Beliefs
Belief that pausing sedation is unsafe, particularly when nurse-to-patient ratios are high and nurses are unable to actively monitor the patient, and preference for gradually reducing the infusion	Knowledge & Beliefs
Belief that patients are unique and protocolization of care in the ICU is inappropriate and effects the quality of care delivered	Knowledge & Beliefs
Perception across clinician roles that interprofessional communication facilitates coordination	Knowledge & Beliefs
Individual confidence in ability to perform SAT/SBT as they understand it, schedules/workload permitting	Self-Efficacy
Experience and routinization increased confidence in ability to perform SAT/SBT	Self-Efficacy
Use of an existing job aid increased confidence in ability to perform an SAT/SBT at the small site	Self-Efficacy
The presence of the interprofessional counterpart increased confidence in performing SAT/SBT and coordination	Self-Efficacy
Belief that awake and spontaneously breathing patients require more intensive care than sedated, ventilated patients	Other Personal Attributes (Motivation)

Table E4. Characteristics of the environment (outer setting)

Determinant	CFIR Construct
Increased numbers of ventilated patients during COVID-19 increased clinician workloads given the constraints on timing and availability.	Needs & Resources of Those Served by the Organization
Increased disease severity among COVID-19 patients limited patient eligibility for SAT/SBT for extended periods, which limited clinician experience	Needs & Resources of Those Served by the Organization

Table E5. Characteristics of the organization (inner setting)

Determinant	CFIR Construct
Smaller unit size increases familiarity among interprofessional colleagues and feasibility of coordinating SAT/SBT given the limited number of patients	Structural Characteristics
Lack of overlapping patient assignments between professional roles increases the complexity of logistical planning.	Compatibility
Dyssynchronous schedules and routines across professional roles increases the complexity of logistical planning.	Compatibility
Unpredictability of schedules due to constant disruptions increases the complexity of logistical planning.	Compatibility
Clinicians have many competing responsibilities that vie for priority over SAT/SBT	Relative Priority
Participation in interprofessional rounds and care coordination meeting enables team members to develop a shared mental model for individual patient care and unit operations. Many RTs do not participate in rounds, where discussions occur (need another forum to discuss that they have to seek out on their own).	Networks & Communications
Telecommunication devices (e.g., cellular phones, badges, and pagers) facilitate informal discussions between team members regarding patient care and facilitate completion of coordinated SAT/SBT absent a more formal process	Networks & Communications
The remote TeleCritical Care team helps facilitate SAT/SBT by providing front-line staff with determining eligibility, coaching, and patient monitoring	Networks & Communications
Most communication in the ICU is viewed as verbal and not electronic	Networks & Communications
Culture of continuous improvement and alignment of implementation with organizational values of standardization to reduce variation to improve clinical outcomes	Culture
Task-oriented culture/protocolization culture that focuses on checklist completion rather than adapting to patients needs as circumstances change	Culture
Access to job aid with either a physical copy or a link in the electronic medical record helped clinicians carry out the processes of SAT/SBT	Access to Knowledge & Information
Concern that staffing was inadequate, and workload increased as a result limited time for conducting coordinated SAT/SBT	Available Resources
Coordination of SAT/SBT was not viewed as a priority on some units (relative to additional COVID-19 interventions like prone positioning)	Relative Priority
Few leaders routinely ask front-line physicians, nurses and RTs about their success in coordination of SAT/SBT	Goals & Feedback
Lack of an agreed upon enterprise standard for measuring adherence to SAT/SBT and coordination (no goals or feedback)	Goals & Feedback

Table E6. Characteristics of the previous implementation process

Determinant	CFIR Construct
Frustration with the top-down approach that mandated the use of the computerized ventilator protocol created negative attitudes among RTs	Executing
Previous implementation of SAT/SBT coordination raised awareness	Reflecting & Evaluating
Overlap between SAT/SBT coordination and general ICU Liberation Bundle and computerized ventilator implementations reinforces each other and creates synergy	Reflecting & Evaluating
Physical distance and cultural differences across sites have limited the success of past implementation initiatives between hospital sites limits the success of implementation initiatives	Reflecting & Evaluating