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Factors associated with ABCDE bundle adherence in critically ill adults requiring mechanical ventilation: An observational design

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Abstract

Objective: To identify factors associated with the ABCDEF bundle (**A**ssess, prevent, and manage pain, **B**oth, spontaneous awakening and breathing trials, **C**hoice of sedation/analgesia, **D**elirium assess, prevent and manage, **E**arly mobility/exercise and **F**amily engagement/empowerment) adherence, in critically ill patients during the first 96 hours of mechanical ventilation.

Design: Observational study using electronic health record data.

Setting: 15 intensive care units located in seven community hospitals in a western United States health system.

Patients: 977 adult patients who were on mechanical ventilation for greater than 24 hours and admitted to an intensive care unit over six months.

Measurements and main results: Multiple regression analysis was used to examine factors contributing to bundle adherence while adjusting for severity of illness, days on mechanical ventilation, hospital site and time elapsed. ABCDEF bundle adherence was higher in patients on mechanical ventilation for less than 48 hours ($p = 0.01$), who received continuous sedation for less than 24 hours ($p < 0.001$), admitted from skilled nursing facilities ($p < 0.05$), and over the course of the six-month study period ($p < 0.01$). Bundle adherence was significantly lower for Hispanic patients ($p < 0.01$).

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.iccn.2020.102873.

Conclusions: Our study identified potentially modifiable factors that could improve the team's performance of the ABCDEF bundle in patients requiring mechanical ventilation.

Keywords

ABCDE bundle; Intensive care; Mechanical ventilation; Sedation; Adherence; Performance monitoring

Introduction

Patients who require mechanical ventilation (MV) during an intensive care unit (ICU) stay are at risk for developing a variety of health care associated infections and post intensive care syndrome (Girard et al., 2007; Harvey and Davidson, 2016). Previous investigations report adherence of the ABCDEF bundle (**A**ssess, prevent, and manage pain, **B**oth, spontaneous awakening and breathing trials, **C**hoice of sedation/analgesia, **D**elirium assess, prevent and manage, **E**arly mobility/exercise and **F**amily engagement/empowerment) is associated with significant and clinically meaningful improvements in patient-centered outcomes including survival, MV days, coma and delirium occurrence, restraint-free care, ICU readmission rates and post-ICU discharge disposition (Balas et al., 2014, 2018; Barnes-Daly et al., 2017; Pun et al., 2018). While believed beneficial, global adoption of the ABCDEF bundle remains suboptimal (Miller et al., 2015; Morandi et al., 2017).

A number of complex and interrelated factors are believed to effect ICU providers' ability to successfully deliver the ABCDEF bundle (Costa et al., 2017; Miller et al., 2015; Vasilevskis et al., 2010). These barriers include the presence of an endotracheal tube, clinical instability, body weight, and communication barriers associated with sedation and/or delirium (Barber et al., 2014; Hodgson et al., 2014). In addition to patient level factors, contextual elements including lack of resources, increased workload, burden of documentation and competing initiatives have been identified as barriers to ABCDEF bundle adherence (Costa et al., 2017; Jordan et al., 2016).

Prior ABCDEF bundle studies and quality improvement (QI) initiatives have excluded certain groups of ICU patients based on medical diagnoses or common ICU treatments/conditions, such as respiratory or haemodynamic instability, active alcohol withdrawal or patients receiving neuromuscular blockade (Barnes-Daly et al., 2017; Boehm et al., 2017; Carrothers et al., 2013; Kram et al., 2015). Furthermore, little research has been conducted exclusively on patients who require MV in whom sedation and intubation increase complexity in delivering the ABCDEF bundle. We hypothesised that patient and clinical factors could influence the ICU team's ability to deliver the ABCDEF bundle. Determining these factors could help identify types of patients in whom heightened attention to bundle adherence might help prioritise resources and increase benefits from the intervention. Our study aimed to identify factors associated with overall and individual elements of ABCDEF bundle adherence in critically ill patients during the first 96 hours of MV.

Materials and methods

Study design

This observational study utilised existing electronic health record (EHR) data collected from 15 ICUs in seven community hospitals. Approval from the institutional review boards was obtained from the health system and University of California, Davis (BAY-2017-083, 1005628-1).

Setting

The study hospitals were part of a large western United States health system using the Cerner® EHR platform. The ABCDEF bundle was phased in system-wide (ABC components first followed by D and E), from 2013 to 2016, along with education/training of clinicians and performance measures benchmarking against hospitals in the system. Due to limitations with the EHR, the F element of the bundle was not measured. This initiative was launched at a system-wide annual interprofessional critical care conference where clinical experts in the field presented various topics on the bundle, including sedation, delirium, early mobility, and family engagement. Care team education and training occurred at system-wide annual conferences and at the individual hospital level with educational resources, such as webinars, implementation tools and training materials. Seven of 29 hospitals were purposefully selected based on wide variations in their performance monitoring and feedback practices for the ABCDEF bundle. Each study site presented unique characteristics in location, bed size, type of ICU, number of ICUs and availability of an on-site educator (Supplemental Table 1).

Sample

We included adult patients who were: (a) age 18 or older, (b) had MV for 24 hours or longer during their ICU stay, and (c) admitted to one of 15 ICUs selected from the seven hospitals between August 1, 2016 and January 31, 2017. Patients on MV were identified using initiation of the MV order set and ventilator start/stop times documented by clinicians in the EHR. Patients with chronic ventilator/tracheostomy were excluded from this study since they were not expected to be liberated from the ventilator. Furthermore, we excluded patients with an order for comfort care within the first 48 hours of ICU admission and patients who were in a coma, based on sedation scores in the first 96 hours.

Study measures

Independent variables—These included patient factors (age, gender, race, ethnicity, type of insurance, Body Mass Index [BMI], admission source) and clinical factors (duration of sedation and sedation level). To adjust for severity of illness and confounding, we included age, acute physiologic assessment and chronic health evaluation (APACHE) III scores, days on MV, and days in ICU before MV. Hospital was used as a fixed effect. Duration of sedation was calculated from the start date/time of the first continuous sedation infusion to the stop date/time of the continuous sedation infusion. Medications used for sedation infusions were Propofol, Dexmedetomidine, Benzodiazepines or combinations of these. When there were combinations of infusions that overlapped, the stop date/time of the last

infusion was recorded. When all sedation infusions were discontinued for greater than 24 hours, sedation was recorded as stopped. If any of the sedation infusions were restarted within a 24-hour time period, they were counted as continuous. For sedation level, we used the Richmond Agitation-Sedation Scale (RASS) scores that were documented in the EHR during the first 96 hours of ICU admission. All RASS scores were categorised into three levels: deep sedation (−3, −4, −5), agitation (+2, +3, +4), and light sedation (+1, −1, −2) (Sessler et al., 2002, Shehabi et al., 2013). The percentage of total scores documented with the light sedation level (or goal sedation) was then categorised into high (100%), moderate (80–99%) and low (<80%) for each patient per day.

Outcome variables—Daily adherence for each eligible patient was measured for the first 96 hours using the EHR data (Table 1). If a bundle element was documented as being contraindicated, we considered it compliant with that particular element. In contrast, if there was no documentation of a bundle component, we considered it not delivered. We computed overall and individual adherence scores for each eligible patient by calculating a proportion of the total number of assessments/interventions documented each day on MV against the total number of assessments/interventions recommended. Individual adherence scores were discretised into a binary variable, complete (100%) and partial (other than 100%) adherence.

Data management and analysis—All data collected in this study were stored in a secured data repository at the health system. Patient-level data was retrieved from both a data warehouse for administrative data and the Cerner® EHR system for the bundle documentation and order entry for the first four days of MV. We performed manual chart review for some data fields in order to correct missing or erroneous values of the study variables.

Statistical analysis—We conducted all the statistical analyses using the SAS ® University Edition 9 platform software (“SAS ® University Edition 9”, 2018). A p value of ≤0.05 was considered significant in this study. Frequency tables were obtained for categorical variables means (M), medians (Mdn) and standard deviations (±) were calculated for continuous variables depending on whether the data were normally distributed or skewed. Independent variables were examined for multicollinearity and residual analysis was conducted to assess assumptions of normality, linearity, and constant variance (Cohen, 1999). Multiple linear regression analysis was used to examine associations between continuous outcome variables and independent variables. Logistic regression analysis was used for individual bundle element adherence scores which were categorised into complete (100%) vs partial. APACHE III scores and age were used as covariates in all models for risk adjustment regardless of whether or not they were significant in multiple regression models. Site was included in all models to account for differences between hospital sites. When examining missing values, only three variables had missing observations (≤7.7%). Complete case analysis was then conducted, resulting in no treatment of missing values.

Results

Patient and clinical characteristics

There were 977 patients in the study. Patient and clinical characteristics are summarised in Tables 2 and 3. The most common admitting medical diagnosis was sepsis (28.7%), and the majority (91.1%) of the patients were on sedation infusions during the first 96 hours of ICU admission. Of the patients on sedation infusions (n = 890), 73% of RASS scores ranged from +1 to −2 (i.e., “light” sedation level).

ABCDEF bundle adherence scores

Fig. 1 illustrates ABCDEF bundle adherence scores. The mean overall adherence score (as a proportion) for the first 96 hours was 66 ± 14% (range 25–100%); see Fig. 2 for distribution of adherence over the seven hospitals. Mean individual element adherence by the care teams was higher for sedation and pain (93 ± 16%), awakening (81 ± 35%), and breathing trials (73 ± 36%), and lower for delirium (44 ± 35%) and mobility (44 ± 35%). The adherence score increased significantly ($F = 13.73$, $p = .0002$) over the 6-month study period and there was considerable variability in adherence scores among the seven sites ($F = 7.64$, $p =$ <.0001).

Factors associated with overall ABCDEF bundle adherence

Multiple linear regression showed that six variables explained 26.9% of the variance in overall adherence scores (adjusted $R^2 = 0.245$, $F = 11.36$, $p < .0001$). Adherence scores were higher in patients on MV for less than 48 h ($F = 16.39$, $p < .001$) and with no continuous sedation or continuous sedation for less than 24 h ($F = 23.72$, $p < .001$), and admitted from skilled nursing facilities or nursing homes ($F = 3.89$, $p = .045$). Adherence scores were significantly lower for Hispanic patients ($F = 10.93$, $p = .001$). (Supplemental Table 2).

Factors associated with individual ABCDEF bundle element adherence

Logistic regression analysis revealed that adherence of individual elements of the bundle (except spontaneous breathing trials and delirium) were associated with days on MV ($p < .0001$). Pain assessments were more likely to be completed in African Americans (OR 3.24; 95% CI [1.26, 8.35]; $p = .015$) and White Americans (OR 2.49; 95% CI [1.32, 4.71]; $p = .005$) compared to Asians, and in patients on MV within two days of ICU admission (OR 2.24; 95% CI [1.53, 3.28]; $p < .0001$). Hispanic patients had half the odds of having delirium assessments performed twice daily by the care teams compared to non-Hispanics (OR .44; 95% CI [.22, .88]; $p = .0206$). Patients with no continuous sedation or shorter continuous sedation duration had over two times the odds of having pain, delirium and mobility assessments performed than those on two or more days of sedation (OR 2.327; 95% CI [1.457,3.718] $p = .0004$). Spontaneous awakening trials were more likely in patients with higher APACHE III scores (OR .98; 95% CI [.98, .99]; $p = .0006$), breathing trials more likely in female patients (OR 1.39; 95% CI [.99,1.95]; $p = .0534$). and less likely with increased age (OR .984; 95% CI [.972, .997]; $p = .0140$). As time elapsed over the six-month period of the study, pain and mobility assessments were more likely and breathing

trials less likely to be completed in MV patients ($p = .005$). There was significant variability in practice among the sites. Supplemental Tables 3–8 show the full regression model results.

Discussion

To our knowledge, this observational study involving secondary analysis of EHR data is the first to objectively assess factors associated with overall and individual element ABCDEF bundle adherence in ICU patients during the first 96 hours of MV, while adjusting for severity of illness. We examined adherence of the ABCDEF bundle for all MV patients during the first 96 hours of their stay, as recommended by the guidelines and did not exclude patients that were considered unstable or contraindicated for the interventions such as haemodynamic instability, use of neuromuscular blocking agents or alcohol withdrawal (Society of Critical Care Medicine, 2016). Furthermore, the observational design included both large and medium size community hospitals, resulting in a large sample size in a real-world setting.

Overall adherence of the bundle was at modest levels across the sites, with the median overall adherence rate of 67% ([56, 75]). Mean adherence scores ranged from 73 to 93% for pain and sedation assessments, spontaneous awakening and breathing trials, with lower mean rates of delirium and mobility assessment (44%) across all the sites. The overall bundle adherence rate of 67% found in our study is consistent with a previous study that examined bundle adherence of patients requiring MV using clinicians' self-report (Boehm et al., 2017). The lower rates of delirium and mobility element adherence are consistent with recent survey studies of the ABCDEF bundle that show lagging adoption of these bundle components (Miller et al., 2015).

Use of continuous sedation, Hispanic ethnicity, number of days on MV and hospital site were identified as critical factors influencing the care teams' overall adherence to the bundle.

Patients with no sedation infusions or shorter duration of continuous sedation had higher adherence scores in risk adjusted models, suggesting that longer sedation periods may hinder the execution of both, the overall ABCDEF bundle and individual elements of pain, delirium and mobility by the care team. Consistent with other studies, sedation has been shown to be a barrier to early mobility and contributes to the development of ICU delirium (Boehm et al., 2017; Hodgson et al., 2015). Spontaneous awakening trials can play a critical role in minimising duration of sedation, MV and hospital lengths of stay (Balas et al., 2014; Dale et al., 2014; Skrobik et al., 2010). Discontinuation of sedation is the first step to progressing the patient towards extubation and mobilisation out of bed, and should be a critical priority of the interprofessional team in ICUs (Pun and Devlin, 2013). Importantly, mobility and delirium assessments may be inextricably linked to decreased sedation use in ICU patients since adherence of mobility and delirium assessments are enhanced when the patient is awake.

Lower adherence of the overall bundle was seen in patents with Hispanic ethnicity yet individually, only the delirium assessment was significant. Although ethnicity may not be a reliable indicator for English language fluency (Fiscella et al., 2002), it could indicate the

presence of a communication barrier. Verbally communicating the questions in the Confusion Assessment Method (CAM)-ICU could pose a challenge for clinicians due to language barriers, the use of colloquial terms or the interpretive qualities of awake and alert patients from different backgrounds (Vélez-Uribe and Rosselli, 2019). In patients on sedation and MV these challenges can be heightened (Bakullari et al., 2014) impacting implementation of evidence based practice (Jordan et al., 2016). If family is not readily available, using translation services could be more challenging in patients that are on sedation and MV. While the CAM-ICU has been translated into a variety of languages (Wei et al., 2008), little is known about the application of this assessment tool in an ethnically diverse ICU. Further study is needed to evaluate the role of primary language as a barrier to clinicians' adherence to this bundle as a whole.

Race was a significant factor in the care team's adherence of pain assessments. Pain assessments (at least every 4 hours) were less likely to be done in Asians and most likely to be performed in African-Americans possibly reflecting differing expression of pain in these patients. A previous study reported lower pain thresholds and tolerance, and higher sensitivity to pain in African-Americans compared to non-Hispanic whites (Campbell and Edwards, 2012). However, little is known about cultural beliefs and preferences around pain management especially in the Asian community (Green et al., 2003; Shavers et al., 2010). Disparities in pain assessment and management in diverse ethnic and racial groups are a complex issue, which should be addressed with future study.

Overall bundle adherence was highest in the first 48 hours of MV. Patients on MV for longer duration were less likely to have individual elements performed 100% of the time in the first 96 hours of MV, suggesting that bundle adherence by the care team may have been a low priority in these sicker patients. This could be in part, due to increased demands of direct patient care or the team forgoing the screening/documentation with the knowledge that the patient would not be progressing or extubated that day. Yet, it is important to stress that real-time documentation of screening results could identify the earliest instance the patient may be ready for discontinuation of sedation, liberation from MV, and mobility out of bed.

While the overall bundle adherence scores increased significantly over the six-month study period, suggesting the effect of increased experience with the interventions by the ICU teams, there were variations in both overall and individual scores across the sites. Hospitals are dynamic entities with turnover of staff, changes in leadership and other initiatives that compete for priority, potentially influencing care teams' adherence and impact system-wide change at the unit level (Carrothers et al., 2013).

Limitations

There are several limitations associated with the nature of an observational study. We were restricted to the clinical data available in the EHR. Thus, while we measured the actual interventions for spontaneous awakening and breathing trials, we were only able to evaluate assessments for the pain, sedation, delirium and mobility elements. We were unable to account for the "family engagement" element in the bundle as it was documented in free text notes by a variety of providers in the EHR. While EHR documentation does not measure the

work activity of the clinicians, it measures compliance with documentation of assessments and interventions. This requires entering specific scores and numerical data when screening patients, as well as the documentation of specific levels of sedation or activity, making it less likely to simply check a box. If there was no documentation by the care team, it was considered not completed, potentially underestimating bundle adherence.

Our study also did not include analgesic infusions as sedation to determine duration of sedation and adherence of awakening trials. Intermittent use of sedation was also not studied due to inherent limitations with EHR data. Depth of sedation is an important factor, not necessarily the drug combinations used for sedation (Shehabi et al., 2013, 2018). Accordingly, this study used the percentage of light sedation level per patient as a proxy of measuring the depth of sedation. It is also important to note that APACHE III scores can only quantify severity of illness based on physiological values and diagnosis on ICU admission and do not capture changes in patient status during ICU stay.

Importantly, our study was limited to the examination of the early (first 96 hours on MV) adherence to the bundle by the care team. Future studies should explore the pattern of care team's adherence over the entire duration of MV and its effect on patient outcomes. Furthermore, it would be valuable to examine the effect of technology-enabled monitoring and feedback systems designed to improve clinicians' adherence to the recommended care (Borgert et al., 2015; DeMellow and Kim, 2018).

Conclusions

Our study identified potentially modifiable factors that could improve the ICU team's adherence to the ABCDEF bundle in patients on MV. Hospitals should invest in prioritising consistent delivery of pain, delirium and mobility assessments and interventions even in patients on sedation, and minimising use of unnecessary sedation, in order to improve bundle adherence. Barriers to the care team's ability to deliver the delirium assessment should be further studied in ethnically and culturally diverse ICU patients.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Conflict of interest

Dr. Balas currently receives grant support from *the National Heart, Lung, and Blood Institute* of the National Institutes of Health, United States, under award number R01HL14678-01. She was a steering committee member of the Society of Critical Care Medicine's ICU Liberation Collaborative. The remaining authors have no potential conflicts of interest to declare.

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Implication for clinical practice

- The ABCDEF bundle is associated with beneficial patient outcomes including survival, decreased occurrence of delirium and decreased number of days on mechanical ventilation.
- Decreased sedation levels in patients on Mechanical Ventilation are linked to higher adherence to the bundle components by the care team.
- Sedation may be a barrier to the performance of the bundle components, particularly mobility and delirium.
- Performing the delirium assessment may present a challenge in patients with Hispanic ethnicity possibly due to the presence of a communication barrier.

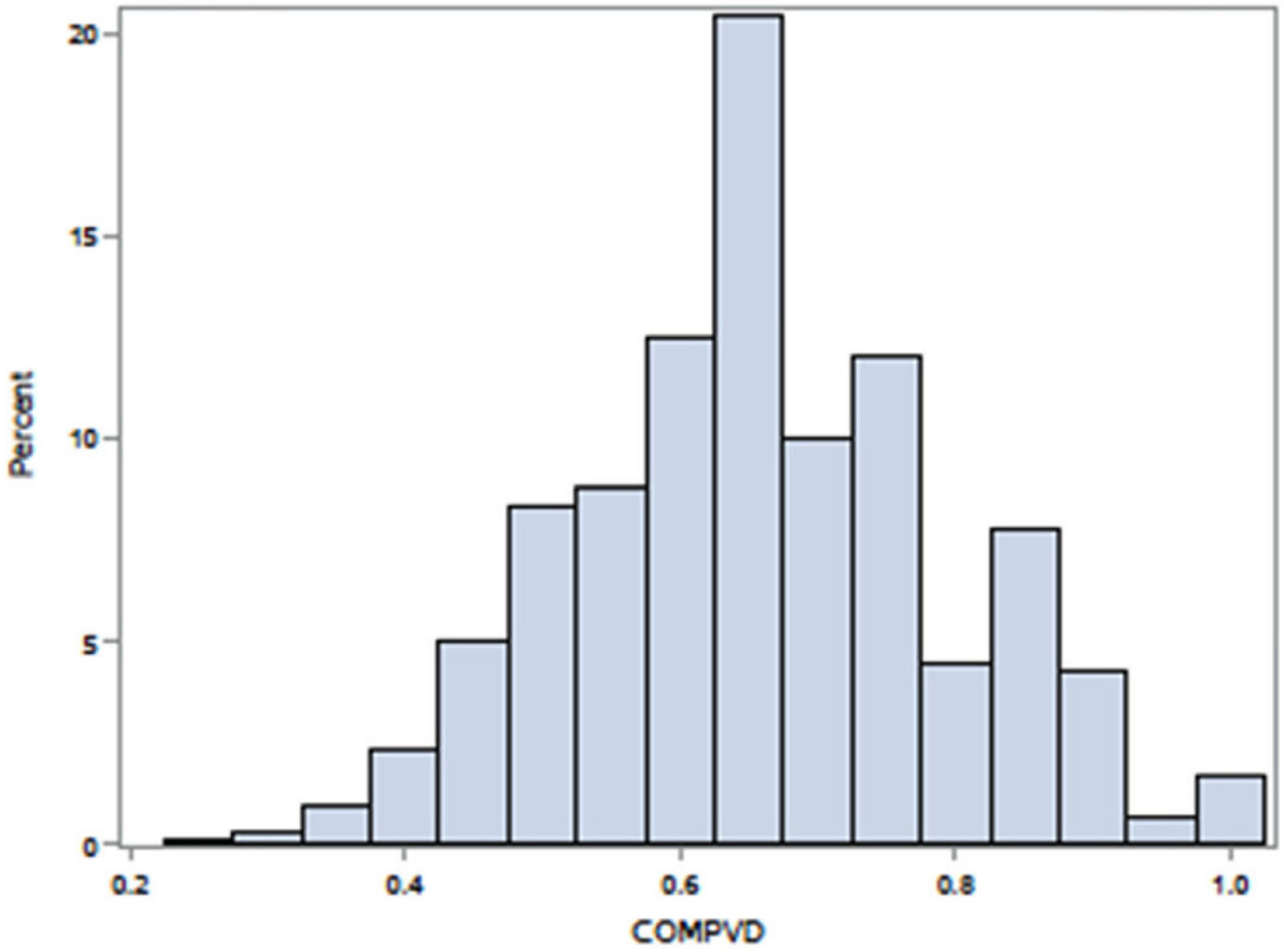

Fig. 1.
COMPVD refers to overall distribution of adherence scores across all sites combined, for the first four days on MV.

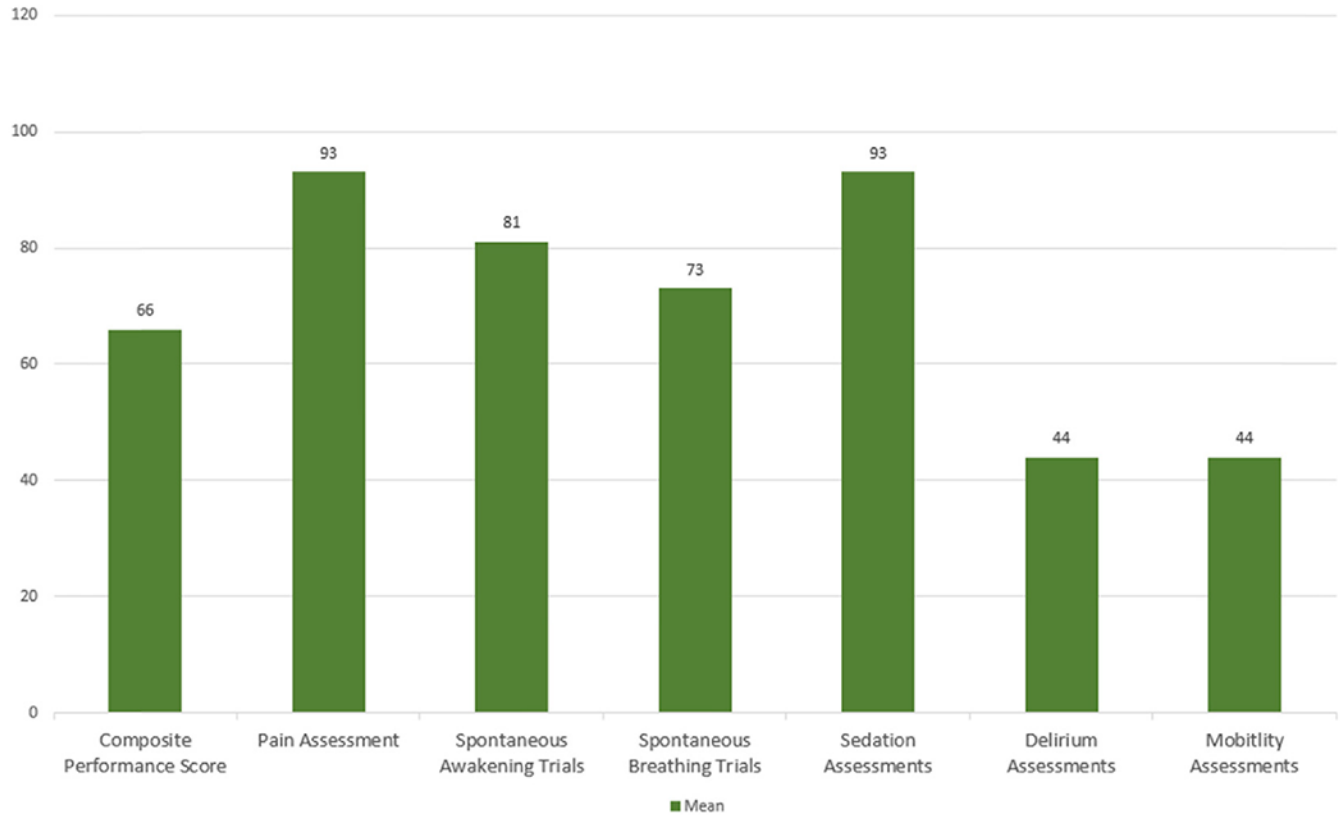

Fig. 2.
Composite and individual bundle element adherence scores (%) during the first 96 hours of MV.

Table 1

Methods of Computing the care team's Adherence to the ABCDEF Bundle.

Measure	Definition	Frequency	Adherence (%)
1. Assessment for pain	CPOT/NRS used for assessment of pain	6 times in 24 hours	Proportion of assessments actually performed of those that the patient was eligible for.
2. Both spontaneous awakening trials and spontaneous breathing trials	Documentation of spontaneous awakening trials or a contraindication while on sedation drip	Daily	Proportion of spontaneous awakening trials actually performed of those that the patient was eligible for.
	Documentation of spontaneous breathing trials or contraindication while on MV	Daily	Proportion of spontaneous breathing trials actually performed of those that the patient was eligible for.
3. Choice of sedation	RASS score every 4 h while on sedation infusion	6 times in 24 hours	Proportion of RASS per day actually performed of those that the patient was eligible for.
4. Delirium assessment	Patient screened for delirium with CAM ICU	Twice in 24 hours	Proportion of CAM assessments actually performed of those that the patient was eligible for.
5. Early mobility assessment	Documentation of mobility screen with activity level or contraindication	Twice in 24 hours	Proportion of mobility assessments actually performed of those the patient was eligible for.

Note. RASS refers to the Richmond Agitation Sedation Scale. NRS = numerical rating scale.

Table 2

Patient Characteristics.

Characteristic	Statistic
Number of patients in study	977
Age in years, mean (±)	63.3 (15.7)
Gender, n (%)	
Male	541 (53.4)
Female	436 (44.6)
Race, n (%)	
White Americans	716 (73.3)
Asian	72 (7.4)
African Americans	87 (8.9)
Other	56 (5.7)
Unknown	46 (4.7)
Ethnicity, n (%)	
Hispanic	122 (12.5)
Non-Hispanic	780 (79.8)
Unknown	75 (7.7)
BMI, mean (±)	29.3 (8.6)
Insurance, n (%)	
Commercial	639 (65.4)
Medicare only	164 (16.8)
Medicaid or Medical	174 (17.8)
Admission source, n (%)	
Home	880(90.1)
SNF	88 (9.0)
Acute care	9 (0.9)
Discharge disposition, n (%)	
Home	371 (38.0)
SNF	260 (26.6)
Died	224 (22.9)
Acute care	75 (7.7)
LTACH	47 (4.8)

Note. SD ± refers to standard deviation. BMI refers to body mass index. SNF refers to skilled nursing facility/nursing home. LTACH refers to long term acute care hospital.

Table 3

Clinical Characteristics of Patients in Study.

Characteristic	Statistic
APACHE III, mean (±)	65.2 (22.1)
Primary Diagnosis, n (%)	
Cardiovascular	169 (17.3)
Gastro Intestinal	50 (5.1)
Neurological	134 (13.7)
Respiratory	148 (15.1)
Sepsis	280 (28.7)
Alcohol/Poisoning	42 (4.3)
Trauma	75 (7.7)
Other	79 (8.1)
Days on MV category, n (%)	
<2 days on MV	304 (31.1)
2–<3 days on MV	186 (19.0)
3–<4 days on MV	127 (13.0)
≥4 days on MV	360 (36.9)
Days in ICU before MV n (%)	
<2 days	898 (92.0)
≥2 days	79 (8.0)
Sedation Category, n (%)	
No sedation	87 (8.9)
<24 hours	189 (19.3)
24–<48 hours	236 (24.2)
48–<96 hours	140 (14.3)
>96 hours	325 (33.3)
Proportion of “light sedation”, mean (±)	73 (26)

Note. APACHE III refers to acute physiological assessment and chronic health evaluation. MV refers to Mechanical Ventilation.