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Organizational Characteristics Associated With ICU Liberation (ABCDEF) Bundle Implementation by Adult ICUs in Michigan

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Objectives: The ICU Liberation (ABCDEF) Bundle can help to improve care and outcomes for ICU patients, but bundle implementation is far from universal. Understanding how ICU organizational characteristics influence bundle implementation could inform quality improvement efforts. We surveyed all hospitals in Michigan with adult ICUs to determine whether organizational characteristics were associated with bundle implementation and to determine the level of agreement between ICU physician and nurse leaders around ICU organizational characteristics and bundle implementation.

Design: We surveyed ICU physician and nurse leaders, assessing their safety culture, ICU team collaboration, and work environment. Using logistic and linear regression models, we compared these organizational characteristics to bundle element implementation, and also compared physician and nurse leaders' perceptions about organizational characteristics and bundle implementation.

Setting: All ($n = 72$) acute care hospitals with adult ICUs in Michigan.

Subjects: ICU physician and nurse leader pairs from each hospital's main ICU.

Interventions: We developed, pilot-tested, and deployed an electronic survey to all subjects over a 3 month period in 2016.

Results: Results from 73 surveys (28 physicians, 45 nurses, 60% hospital response rate) demonstrated significant variation in hospital and ICU size and type, organizational characteristics, and physician/nurse perceptions of ICU organization and bundle implementation. We found that a robust safety culture and collaborative work environment that uses checklists to facilitate team communication are strongly associated with bundle implementation. There is also a significant dose-response effect between safety culture, a collaborative work environment, and overall bundle implementation.

Conclusions: We identified several specific ICU practices that can facilitate ABCDEF Bundle implementation. Our results can be used to develop effective bundle implementation strategies that leverage safety culture, interprofessional collaboration, and routine checklist use in ICUs to improve bundle implementation and performance.

Key Words: ICU Liberation (ABCDEF) Bundle; checklists; critical care; intensive care units; patient safety; quality improvement

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Pain, agitation, and delirium (PAD) occur frequently in ICU patients, and managing these symptoms can be difficult, leading to poorer outcomes and higher costs of care for these patients (1). Using the ICU Liberation (ABCDEF) Bundle (**Fig. 1**) to implement the Pain, Agitation, Delirium, Immobility, and Sleep guidelines (2) can significantly improve ICU patient outcomes

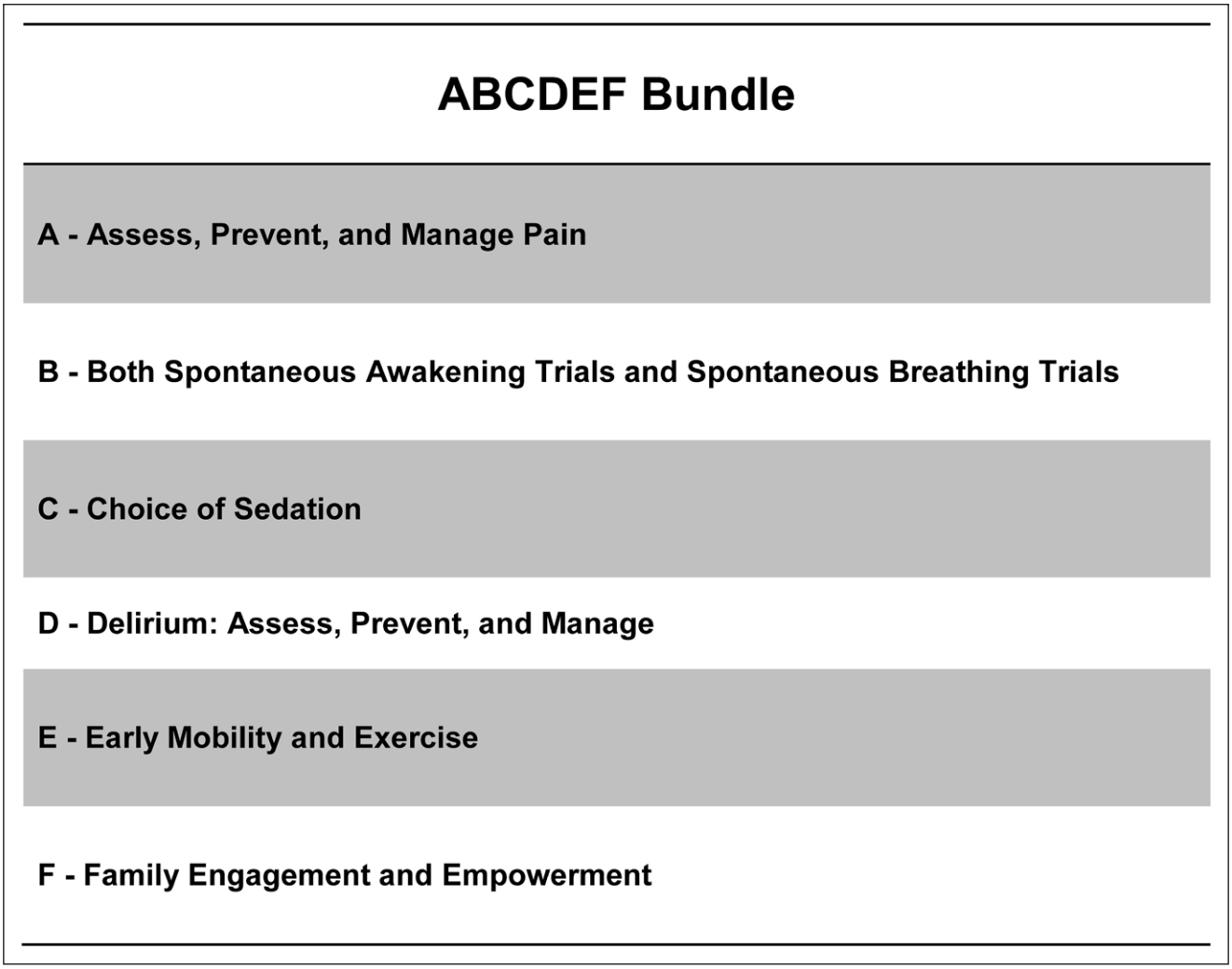

Figure 1. The ICU Liberation (ABCDEF) Bundle.

and reduce healthcare costs (3–6). But translating the bundle into clinical practice is challenging, requiring effective team communication, collaboration, and care coordination (7, 8), partnering with patients and families to prioritize care goals, and the use of real-time bundle data (9–11). Barriers to bundle implementation include poor team communication and care coordination, insufficient resources, lack of performance measurement, and poor leadership (12–17). Common characteristics of high-performing ICUs include high-intensity critical care physician staffing (18–21), low patient-to-nurse ratios (22–24), daily interprofessional team (IPT) rounds (25–27), use of both goals-of-care checklists (22, 28, 29) and electronic health records (EHRs) (30), a collaborative work environment (CWE) and a culture of safety (15, 25, 31, 32). To date, the role of these ICU organizational characteristics in terms of their influence on bundle implementation have not been examined.

We surveyed physician and nurse leaders from all Michigan hospitals with adult ICUs (33). Michigan ICUs have a successful history of translating evidence into clinical practice through statewide quality improvement (QI) initiatives organized by the Michigan Hospital Association (MHA) Keystone Center (34, 35). Since 2009, 51 adult ICUs in Michigan have voluntarily participated in an ABCDEF Bundle collaborative, yet bundle implementation remains low (15). Previous work also demonstrates significant differences in physician and nursing leadership perceptions about organizational characteristics and evidence-based practices in their ICUs (36). Statewide access to adult ICU data in Michigan provides a unique opportunity to better understand the relationships between these organizational characteristics and bundle implementation. The diversity of adult ICUs in Michigan also mirrors patterns of critical care delivery systems nationally, potentially making these results generalizable (37). We hypothesized that ICU organizational characteristics correlate with bundle implementation across ICUs and that physician and nurse leaders' perceptions of organizational characteristics and bundle implementation differ.

MATERIALS AND METHODS

Study Design and Sample

The Stanford University School of Medicine Institutional Review Board and the Michigan Health & Hospital Association-Keystone

Center approved this study and waived the need for informed consent. Between July and September 2016, we conducted an electronic census survey of all Michigan hospitals with adult ICUs (n = 72). The survey population of hospitals was identified and verified using the MHA Keystone Center (34) and Michigan Inpatient Databases (38). Investigators were blinded to the identities of hospitals and respondents.

Survey Development and Pilot Testing

We developed and tested our survey (39–41) based on the Consolidated Framework for Implementation Research, the Agency for Healthcare Research and Quality's National Quality Strategy and Comprehensive Unit and Safety Program (CUSP), and a review of knowledge translation strategies that improve patient care and safety (25, 42–47). Survey domains included: 1) respondent, ICU, and hospital characteristics; 2) organizational characteristics; 3) work environment (collaboration, safety culture); and 4) bundle implementation phases.

Respondents listed their ICU professional role (physician or nurse leader) and years of ICU experience. ICU characteristics included type (cardiovascular, neuro, medical or surgical only, medical/surgical combined), and number of beds. Hospital characteristics included type (community, public, or university medical center) and size (< 125 beds, 125–250 beds, > 250 beds).

Intensivist involvement was defined as either "high-intensity" (i.e., intensivists exclusively care for or have a mandatory consultation for all ICU patients, and are present in the ICU throughout the day) or "low-intensity" (i.e., an open ICU with elective consultation or no intensivist involvement) (20). Low patient-to-nurse ratios were defined as 1–2 patients per nurse versus greater than two patients per nurse. Routine IPT rounds were defined as occurring at least once daily versus less frequently or never, including (at least) a physician, nurse, pharmacist, and respiratory therapist. Daily use of a goals-of-care checklist to facilitate team communication and patient care was defined as either routine or not. EHR use as the primary repository for ICU patient information was also identified.

We used the previously validated Safety Organizing Scale (SOS) to assess five ICU safety culture domains: preoccupation with failure, reluctance to simplify interpretations, sensitivity to operations, commitment to resilience, and deference to expertise (48, 49). A 7-point Likert scale was used to score responses (i.e., "not at all," "to a very limited extent," "to a limited extent," "to a moderate extent," "to a considerable extent," "to a great extent," and "to a very great extent"). Answers were converted to a score of 1 to 7 and averaged, giving a composite SOS score ranging from 1 to 7. Higher scores reflected a more robust safety culture. The same 7-point Likert scale was used to assess CWE. Four cultural domains of interprofessional collaboration in the ICU were evaluated: staff accessibility, trust, value, and leadership (7, 8, 15, 25, 50). Similar to SOS, the higher the score, the better the CWE.

Respondents were asked about the implementation of PAD management, spontaneous awakening trial (SAT) and spontaneous breathing trial (SBT), and early mobility protocols (i.e., A–E bundle elements) within their ICUs, using a 5-point Likert scale (i.e., "not currently planning," "in the planning phase," "in the piloting phase," "implemented with remaining challenges," or "fully implemented for all eligible patients"), with protocols classified as being either fully implemented for all eligible patients or not. Patient and family engagement (i.e., the 'F' bundle element) was defined by how often in general that ICU patients and/or their families were invited to participate in bedside IPT rounds, using a 5-point Likert scale (i.e., "never," "rarely," "sometimes," "often," or "always"). Perceptions about patient and family participation in IPT rounds were classified as either always invited to participate or not. Bundle element implementation was assessed both individually and collectively.

Survey item responses included dichotomous, interval, multiple choice, Likert scale, and matrix formats. Investigators pretested and pilot-tested the entire survey using 23 ICU physicians and nurses to validate the survey instrument (39–41). The Delphi process was used to achieve final consensus on all 53 survey items and response formats.

Survey Administration

In July 2016, surveys were emailed to ICU physician and nurse leaders of the main ICU at each hospital (51). Hospitals were given a unique identifier that allowed investigators to remain blinded while also enabling a hospital's responses to be benchmarked against other Michigan ICUs. Respondents were required to answer each question before proceeding to the next question. The survey administrator sent monthly email reminders to all nonrespondents for 3 months. De-identified survey results were (52) reviewed to ensure data quality and completeness and identify missing data patterns. The investigators coded open-ended responses.

Statistical Analyses

We summarized self-reported clinician, ICU, and hospital characteristics from all hospitals, from hospitals with paired physician/nurse responses, and from hospitals with only a single response. Categorical responses were summarized as counts and percentages; continuous responses were summarized as medians and interquartile ranges (IQRs). The absolute standardized difference (53), expressed in units of SDs, was reported for all characteristics and interpreted using Cohen's guidelines (d: 0.2 = small difference; 0.5 = medium difference; 0.8 = large difference; d < 0.2 = trivial difference) (54). Providers' perceptions of the work environment, as measured by the composite SOS scores and the average CWE domain scores, were summarized as medians and IQRs.

To characterize associations between ICU organizational features and bundle element implementation, we first described ICU features by implementation status and then fit univariable logistic regression models under the generalized estimating equation (GEE) framework, relating each ICU feature to individual bundle element implementation (55, 56). Similarly, we used GEE to fit a univariable linear regression model to estimate the association of each ICU organizational characteristic with overall bundle implementation (composite bundle implementation score equal to the number of implemented bundle elements). The GEE framework was also used to account for within-ICU correlation and obtain model estimates (57). Estimated odds ratios or linear effects were reported with 95% CIs.

To compare physician/nurse perceptions of ICU organizational characteristics and bundle element implementation, we determined the percentage indicating full implementation of each bundle element. We then performed statistical tests for marginal homogeneity between respondent groups using the exact McNemar test for paired nominal data to assess marginal homogeneity of categorical characteristics by provider status; we used the Wilcoxon signed-rank test to assess marginal homogeneity of continuous characteristics.

Because this was a statewide census survey of all Michigan hospitals with adult ICUs, we did not a perform a pre-survey power analysis. Statistical significance for all tests was assessed at the 0.05 level. We used Cohen's guidelines to assess the magnitude of between-group differences (54, 57). We described all missing data and performed complete case analyses.

RESULTS

Cohort Identification

We obtained 73 survey responses (28 from physician leaders [39%], 45 from nurse leaders [63%]), from 43 of the 72 hospitals surveyed (60%) (**Fig. 1S**, Supplemental Digital Content 1, http://links.lww.com/CCX/A236). Paired physician/nurse responses were available from 24 hospitals (33%). Two hospitals contributed greater than one nurse response (three responses total) which were excluded from the paired physician/nurse analyses (clinical nurse specialists or nurse managers were retained). One nurse partially completed the survey; these results were included in the demographic and organizational pooled analyses but were excluded from both pooled and paired response analyses pertaining to bundle element implementation.

Baseline Demographics, ICU, and Hospital Characteristics

There was moderate heterogeneity across respondents' hospitals and ICUs (**Table 1**). Most respondents worked at community hospitals of varying size in combined medical-surgical ICUs averaging 14 beds (IQR, 8–20 beds). The median duration of ICU experience for all respondents was 15 years (IQR, 7–25 yr); nurses had slightly more years of ICU experience than physicians. Over 60% of respondents reported high-intensity intensivist staffing (**Table 2**). Nearly 80% indicated a low patient-to-nurse ratio of 1–2 patients per nurse.

TABLE 1. Respondent and ICU Demographics for All Hospitals and Hospitals With Paired Responses

		All Hospitals			Hospitals With Paired Responses[a]		
Items Surveyed	Overall	MDs	RNs	d[b]	MDs	RNs	d[b]
Respondents (*n*)	73	28	45		24	24	
Years of ICU experience, median (Q1–Q3)	15.0 (7.0–25.0)	14.5 (7.8–22.8)	16.0 (6.0–27.0)	0.147	14.5 (7.8–20.5)	16.5 (7.8–27.8)	0.276
Hospital type, *n* (%)				0.552			0.312
Community hospital	59 (80.8)	22 (78.6)	37 (82.2)		20 (83.3)	20 (83.3)	
Public hospital	4 (5.5)	0 (0)	4 (8.9)		0 (0)	1 (4.2)	
University affiliated	10 (13.7)	6 (21.4)	4 (8.9)		4 (16.7)	3 (12.5)	
Hospital size, beds, *n* (%)				0.128			< 0.001
< 125	20 (27.4)	7 (25.0)	13 (28.9)		7 (29.2)	7 (29.2)	
125–250	21 (28.8)	9 (32.1)	12 (26.7)		9 (37.5)	9 (37.5)	
> 250	32 (43.8)	12 (42.9)	20 (44.4)		8 (33.3)	8 (33.3)	
Number of ICU beds, median (Q1–Q3)	14.0 (8.0–20.0)	14.0 (9.8–20.5)	13.0 (8.0–20.0)	0.134	13.5 (8.2–0.5)	12.5 (7.5–20.5)	0.091
ICU type, *n* (%)				0.515			0.549
Medical/surgical	47 (64.4)	17 (60.7)	30 (66.7)		15 (62.5)	16 (66.7)	
Medical only	19 (26.0)	9 (32.1)	10 (22.2)		7 (29.2)	5 (20.8)	
Surgical only	3 (4.1)	0 (0)	3 (6.7)		0 (0)	2 (8.3)	
Neuro	3 (4.1)	1 (3.6)	2 (4.4)		1 (4.2)	1 (4.2)	
Cardiovascular	1 (1.4)	1 (3.6)	0 (0)		1 (4.2)	0 (0)	

MD = physician leader, RN = nurse leader.

[a]Three RN responses were excluded from two hospitals with > 1 RN response.

[b]Cohen's d, a larger d corresponds to a larger difference between the groups (i.e., 0.2 = small difference; 0.5 = medium difference; 0.8 = large difference; and d < 0.2 = trivial difference between two groups).

Nearly 90% of respondents reported that they conduct IPT rounds in their ICUs, but only 64% conducted rounds daily. Only 59% reported that IPT rounds included at least a physician (or advance practice provider), nurse, respiratory therapist, and pharmacist. Physician and nurse perceptions of the frequency and composition of IPT rounds varied significantly (Table 2). Seventy-nine percent of physicians said IPT rounds occurred at least once daily, versus only 56% of nurses. These differences were smaller but nevertheless persisted in the paired physician/nurse responses as well. Both the pooled (**Fig. 2S**, Supplemental Digital Content 1, http://links.lww.com/CCX/A236) and paired (**Fig. 3S**, Supplemental Digital Content 1, http://links.lww.com/CCX/A236) response groups found that more physicians reported broader participation in IPT rounds by most staff types than nurses. Only 52% used a daily ICU goals-of-care checklist. Physicians were somewhat more likely than nurses to report the routine use of a daily goals-of-care checklist. All hospitals had comprehensive EHRs in their ICUs.

In terms of work environment, the overall average SOS score was 5.7 (IQR, 4.8–6.1) (**Table 3**). Physician and nurse safety scores were similar, although nurses reported higher safety scores than physicians in the paired responses. Median CWE scores for each domain were accessibility = 6.0 (IQR, 5.0–6.2), trust = 6.0 (IQR, 6.0–7.0), value = 6.0 (IQR, 6.0–7.0), and leadership = 6.0 (IQR, 5.2–6.5). In the pooled responses, nurses reported significantly higher scores than physicians in the trust and value domains. In the paired responses, nurses reported significantly higher scores than physicians across all domains, with the greatest differences observed in the accessibility (CWE accessibility scores: nurse leaders = 6.0 [IQR, 6.0–7.0]; physician leaders = 6.0 [IQR, 5.0–6.0]; d = 0.418), and value (CWE value scores: nurse leaders = 7.0 [IQR, 6.0–7.0]; physician leaders = 6.0 [IQR, 5.0–7.0]; d = 0.581) domains.

ABCDEF Bundle Implementation

Bundle implementation varied significantly across ICUs (**Table 1S**, Supplemental Digital Content 1, http://links.lww.com/CCX/A236). Only 36% percent had fully implemented a comprehensive pain management protocol, only 60% had fully implemented SAT/SBT protocols, and only 57% had fully implemented sedation

TABLE 2. ICU Organizational Characteristics for All Hospitals and Hospitals With Paired Responses

		All Hospitals			Hospitals With Paired Responses[a]		
Items Surveyed	Overall	MDs	RNs	d[b]	MDs	RNs	d[b]
Level of involvement of intensivists, *n* (%)	73	28	45		24	24	
High-intensity intensivist staffing	43 (60.6)	17 (60.7)	26 (60.5)	0.005	13 (54.2)	15 (62.5)	0.170
Closed ICU care model	24 (33.3)	9 (32.1)	15 (34.1)	0.041	7 (29.2)	10 (43.5)	0.301
Mandatory ICU consultation model	19 (26.4)	8 (28.6)	11 (25.0)	0.081	6 (25.0)	5 (21.7)	0.077
Low-intensity intensivist staffing	28 (39.4)	11 (39.3)	17 (39.5)	0.005	11 (45.8)	9 (37.5)	0.170
Optional ICU consultation model	17 (23.6)	6 (21.4)	11 (25.0)	0.085	6 (25.0)	5 (21.7)	0.077
No intensivist involvement	10 (13.9)	5 (17.9)	5 (11.4)	0.185	5 (20.8)	3 (13.0)	0.209
Average ICU patient-to-nurse ratio, *n* (%)				0.317			0.304
1–2 patients per nurse	57 (79.2)	24 (85.7)	33 (75.0)		20 (83.3)	18 (78.3)	
2–3 patients per nurse	14 (19.4)	4 (14.3)	10 (22.7)		4 (16.7)	4 (17.4)	
Other	1 (1.4)	0 (0)	1 (2.3)		0 (0)	1 (4.3)	
Routinely conducts ICU IPT[c] team rounds, *n* (%)				0.669			0.461
Conducts IPT rounds at least once a day	47 (64.4)	22 (78.6)	25 (55.6)		21 (87.5)	17 (70.8)	
Conducts IPT rounds at least five times a week	12 (16.4)	2 (7.1)	10 (22.2)		1 (4.2)	3 (12.5)	
Conducts IPT rounds 1–4 times a week	6 (8.2)	3 (10.7)	3 (6.7)		1 (4.2)	1 (4.2)	
Does not conduct IPT rounds	8 (11.0)	1 (3.6)	7 (15.6)		1 (4.2)	3 (12.5)	
Has essential ICU IPT[c] rounds participants, *n* (%)	43 (58.9)	17 (60.7)	26 (57.8)	0.060	15 (62.5)	15 (62.5)	< 0.001
Use of daily ICU goals-of-care checklist, *n* (%)	36 (52.2)	16 (61.5)	20 (46.5)	0.305	13 (59.1)	12 (54.5)	0.092
ICU electronic health record use, *n* (%)	72 (100.0)	28 (100.0)	44 (100.0)	0	24 (100.0)	23 (100.0)	< 0.001

IPT = interprofessional team, MD = physician leader, RN = nurse leader.

[a]Three RN responses were excluded from two hospitals with > 1 RN response.

[b]Cohen's d, a larger d corresponds to a larger difference between the groups (i.e., 0.2 = small difference; 0.5 = medium difference; 0.8 = large difference; and d < 0.2 = trivial difference between two groups).

[c]Essential IPT rounds participants: MD, RN, respiratory therapist, and pharmacist.

TABLE 3. ICU Work Environment for All Hospitals and Hospitals With Paired Responses

Items Surveyed	Overall	All Hospitals			Hospitals With Paired Responses		
		MDs	RNs	d[a]	MDs	RNs	d[a]
Number of respondents	73	28	45		24	24	
Safety Organizing Scale score, median (Q1–Q3)	5.7 (4.8–6.1)	5.7 (5.1–5.9)	5.8 (4.6–6.2)	0.14	5.6 (4.8–5.9)	5.8 (5.1–6.3)	0.376
Collaborative Work Environment scores[b], median (Q1–Q3)							
Accessibility	6.0 (5.0–6.2)	6.0 (5.0–6.2)	6.0 (5.0–6.2)	0.045	6.0 (5.0–6.0)	6.0 (6.0–7.0)	0.418
Trust	6.0 (6.0–7.0)	6.0 (6.0–7.0)	6.5 (6.0–7.0)	0.338	6.0 (6.0–7.0)	6.0 (6.0–7.0)	0.230
Value	6.0 (6.0–7.0)	6.0 (5.0–7.0)	6.0 (6.0–7.0)	0.556	6.0 (5.0–7.0)	7.0 (6.0–7.0)	0.581
Leadership	6.0 (5.2–6.5)	6.0 (5.4–6.4)	6.0 (5.2–6.5)	0.187	6.0 (5.4–6.4)	6.0 (5.5–6.6)	0.245

MD = physician leader, RN = nurse leader.

[a]Cohen's d, a larger d corresponds to a larger difference between the groups (i.e., 0.2 = small difference; 0.5 = medium difference; 0.8 = large difference; and d < 0.2 = trivial difference between two groups).

[b]Collaborative Work Environment scores (median [interquartile range]), for the domains of Accessibility, Trust, Value, and Leadership (Note: Leadership domain scores were averaged across four leadership questions).

protocols. Only 42% of ICUs had fully implemented a delirium management protocol, and only 36% had fully implemented an early mobility protocol. More than half the ICUs did not routinely invite patients and families to participate in ICU rounds. There were no significant differences between perceptions of physicians and nurses around implementation of individual bundle elements or overall bundle implementation (**Table 4**).

ICU Organizational Characteristics and Work Environment Versus Bundle Implementation

Table 2S (Supplemental Digital Content 1, http://links.lww.com/CCX/A236) summarizes the frequency distribution of fully implemented bundle elements versus intensivist involvement, patient-to-nurse ratios, IPT rounding frequency, checklist use, SOS scores, and composite CWE scores. Table 4 summarizes the regression analyses comparing these ICU organizational characteristics to full implementation of individual bundle elements, as well as overall bundle implementation. The use of a daily goals-of-care checklist was significantly associated with full implementation of all individual bundle elements, except for combined SAT/SBT trials and patient/family engagement in IPT rounds (Table 4). Indications of a better work environment (i.e., a higher SOS mean score and/or a higher composite CWE domain score) were also significantly associated with full implementation of all individual bundle elements, except for patient/family engagement in IPT rounds.

Daily use of a goals-of-care checklist, a more robust safety culture, and a CWE were also significantly associated with a higher reported rate of overall bundle implementation (Table 4). Daily checklist users averaged 1.3 more fully implemented bundle elements than non-users. A 1-point increase in the SOS score was associated with 1.1 additional fully implemented bundle elements. A 4-point increase in the composite CWE domain score was associated with 1.0 additional fully implemented bundle elements.

Tables 3S and **4S** (Supplemental Digital Content 1, http://links.lww.com/CCX/A236) summarize the survey results from the 23 ICUs with complete paired physician/nurse responses. There were no significant differences between physicians and nurses in perceived intensivist involvement, patient-to-nurse ratios, frequency of rounds, daily use of a goals-of-care checklist, or SOS scores. However, their perceptions differed significantly for the CWE composite domain score ($p = 0.024$), with nurses having higher composite CWE scores than physicians. Perceptions of individual and overall bundle element implementation did not differ significantly between physicians and nurses.

DISCUSSION

Reducing PAD in ICU patients pose numerous challenges, but consistent application of the ABCDEF bundle can significantly improve PAD management and patient outcomes (3, 4, 58, 59). In this survey, bundle implementation varied widely across ICUs, and full implementation of all bundle elements remains an elusive goal for most ICUs surveyed. Notably, only 60% of ICUs have fully implemented an SAT/SBT protocol, which is surprising since Michigan ICUs have been working collaboratively statewide since 2004 to implement SAT/SBT protocols. The results of this survey demonstrate that ICU organizational characteristics, specifically ICUs with a strong safety culture and a CWE, and ICUs that use checklists to facilitate patient care, are more likely to have fully implemented the bundle. Furthermore, we observed a favorable dose-response effect between an ICU's safety culture, their CWE, and overall bundle implementation.

In 2003, all Michigan ICUs implemented a CUSP, which initially improved ICU safety scores (60). But SOS scores in our survey varied significantly, which may be explained by a high degree of staff turnover since that time, as ICU experience for physician and nurse respondents in our survey averaged only 14.5 and 16 years, respectively. Nurses also had higher SOS scores than physicians, perhaps reflecting a greater emphasis on patient safety inherent to nursing culture (61, 62). The Institute of Medicine has recommended that healthcare organizations develop safety cultures to align delivery system processes with the workforce requirements to improve patient outcomes (48, 63). As a reliable

TABLE 4. ICU Organizational Characteristics Versus ICU Liberation (ABCDEF) Bundle Element Implementation by Respondent (k = 72)[a]

	Logistic Regression[b]						Linear Regression
Covariates	Pain Management	Spontaneous Awakening Trial/ Spontaneous Breathing Trial	Sedation Management	Delirium Management	Early Mobility	Patient/Family Engagement in ICU Rounds	Overall Bundle Implementation[c]
Professional role							
Nurse leader	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Physician leader	1.54 (0.62–3.79)	1.27 (0.57–2.82)	1.65 (0.68–3.97)	1.64 (0.70–3.83)	0.71 (0.34–1.47)	0.80 (0.44–1.45)	0.22 (–0.58 to 1.02)
Intensivist Involvement							
Low-intensity staffing	Reference	Reference	Reference	Reference	Reference	Reference	Reference
High-intensity staffing	2.22 (0.65–7.55)	1.77 (0.62–5.07)	0.90 (0.29–2.74)	1.36 (0.50–3.70)	2.63 (0.72–9.67)	0.48 (0.18–1.29)	0.29 (–0.72 to 1.30)
ICU patient:nurse ratio							
> 2 patients/nurse	Reference	Reference	Reference	Reference	Reference	Reference	Reference
1–2 patients/nurse	1.56 (0.38–6.41)	0.79 (0.24–2.58)	0.43 (0.12–1.49)	0.66 (0.17–2.56)	0.87 (0.29–2.59)	1.23 (0.52–2.90)	–0.23 (–1.51 to 1.04)
ICU interprofessional team rounds							
< once a day	Reference	Reference	Reference	Reference	Reference	Reference	Reference
≥ once a day	1.84 (0.59–5.72)	1.12 (0.40–3.18)	2.45 (0.95–6.29)	2.35 (0.84–6.58)	0.87 (0.32–2.41)	0.75 (0.35–1.59)	0.62 (–0.38 to 1.61)
Use of ICU daily goals-of-care checklist							
No	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Yes	4.96 (1.51–16.25)	2.10 (0.80–5.50)	2.74 (1.12–6.72)	7.60 (2.65–21.81)	3.20 (1.21–8.45)	0.42 (0.13–1.33)	1.30 (0.49–2.12)
ICU work environment							
Safety Organizing Scale mean score (range 1–7)	4.93 (2.06–11.80)	3.21 (1.63–6.31)	2.69 (1.34–5.40)	2.88 (1.27–6.52)	3.55 (1.49–8.46)	1.20 (0.83–1.71)	1.10 (0.75–1.45)
Composite Collaborative Work Environment domain score[d]	1.30 (1.06–1.59)	1.30 (1.07–1.57)	1.24 (1.03–1.49)	1.28 (1.03–1.59)	1.34 (1.02–1.76)	1.07 (0.90–1.27)	0.26 (0.16–0.37)

[a]Excludes one incomplete nurse leader response; electronic health record (EHR) use was excluded from this analysis since EHR responses = 100%.

[b]Each bundle element is considered implemented if survey response is "fully implemented for all eligible patients."

[c]Overall bundle adoption corresponds to the number of bundle elements fully implemented.

[d]Composite Collaborative Work Environment domain score, i.e., the sum of Accessibility, Trust, Value, and Leadership (averaged) domain scores (range 7–28).

All estimates are presented with corresponding 95% CIs. CI's for estimates from logistic regression models that do not cover 1, and CI's for estimates from linear regression models that do not cover 0, indicate that covariate levels are significantly different with respect to bundle element implementation.

measure of safety culture, higher SOS scores correlate with greater trust in managers, fewer medication errors, lower fall rates, and lower mortality rates in patients (48). Low patient-to-nurse ratios also correlate with higher SOS scores. The primary objective of the ABCDEF bundle is to reduce the occurrence of preventable harms in ICU patients (e.g., delirium, muscle weakness, postintensive care syndrome, death). A strong safety culture may help to align bundle implementation efforts around the overarching goals of improving patient safety and reducing harms in the ICU.

CWE scores also varied widely in our survey, especially in paired responses, with nurses having higher CWE domain scores than physicians. This may reflect broader physician/nurse cultural differences in their perceptions of teamwork, with nurses tending to be more collaborative and physicians more hierarchical in their practices (36, 61, 64–68). Execution of bundle elements requires ongoing communication, collaboration, and care coordination between provider groups outside of IPT rounds. The use of goals-of-care checklists helps to standardize care practices and to improve ICU team communication and compliance with

evidence-based practices (22, 28, 29). ICU team members who value one another, who are accessible to each other, and who can predict each other's behavior are more likely to collaborate and perform bundle elements in a correct and timely fashion, suggesting that team member communication and care coordination around the bundle is critical (7). Teams are also more likely to successfully translate evidence into practice when their leaders are actively engaged in bundle QI efforts. Strong healthcare leaders create a shared team vision, encourage a high level of team performance, and promote concrete, desirable team behaviors which can translate to improved care and outcomes in patients (69–71).

Our findings that full bundle implementation is associated with a strong safety culture, a robust CWE, and the routine use of a daily goals-of-care checklist, are consistent with a recent review of protocol-related and ICU barriers to implementing bundle elements (17). Previous studies have shown that high-intensity intensive care physician staffing is associated with improved ICU patient outcomes (18–21), but intensivist involvement in patient care alone does not ensure better adherence to clinical practice guidelines or evidence-based bundles (25). A recent review stressed that both ICU structure and processes of care are important for achieving optimal ICU patient outcomes (72): 1) having intensivist-led, high-performing, multidisciplinary teams; 2) robust process improvement; 3) use of standardized ICU protocols; and 4) institutional support for performance measurement. Results from the recent ICU Liberation Collaborative involving over 15,000 adult ICU patients demonstrated that ICUs which are actively engaged in a comprehensive bundle QI initiative with strong leadership support can significantly increase bundle implementation and performance and improve ICU patient outcomes (4, 13).

To our knowledge, this is the first statewide census survey of ABCDEF Bundle implementation efforts by adult ICUs in the United States. Prior bundle surveys focused on convenience samples of ICU providers, which introduces selection bias and may not accurately reflect organizational characteristics or evidence-based practices (73–75). This is also the first survey directly comparing ICU organizational "best practices" with bundle implementation, filling an existing gap in implementation research, and helping inform future bundle QI efforts nationally.

Our survey has several limitations. Significantly, more nurses than physicians responded to our survey, and only one-third of hospitals provided paired physician and nurse responses. This potentially introduces a response bias to our paired physician/nurse analyses (i.e., ICUs with higher levels of bundle implementation were more likely to have both physician leader and a nurse leader respond), which could limit our ability to evaluate true differences between physician leaders' and nurse leaders' perceptions, and to evaluate differences in paired responses due to ICU organizational characteristics. Except for CWE scores, our paired physician/nurse responses about ICU organizational characteristics and bundle implementation were similar. This finding contrasts with previous survey results (36), suggesting that our observed differences between nurse and physician pooled responses reflect true differences in the ICUs they represent, since 60% more nurses responded ($n = 45$) than physicians ($n = 28$), most of which were unpaired. Generalizability to adult ICUs in other states may be limited to combined medical-surgical and medical ICUs since our survey included few surgical and subspecialty ICUs. Finally, we surveyed only physician and nurse leaders, whose perceptions may not accurately reflect day-to-day bedside practice and bundle performance.

CONCLUSIONS

A strong safety culture, CWE, and use of ICU goals-of-care checklists are associated with a higher degree of ABCDEF bundle implementation, but physician and nurse leaders may have different perceptions about these characteristics in their ICUs. Our results can be used to develop effective bundle implementation strategies that leverage safety culture, IPT collaboration, and checklist use in ICUs to improve bundle implementation and performance. Our survey findings may help clinicians, managers, and hospital administrators to better understand how ICU organizational characteristics can influence bundle implementation, how differing perspectives of physician and nurse leaders can influence bundle QI efforts, and how to use this information to improve bundle compliance and performance within their ICUs (76).

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