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On the CUSP: Stop BSI: Evaluating the relationship between central line–associated bloodstream infection rate and patient safety climate profile

Sallie J. Weaver, PhD[a,b,*], **Kristina Weeks, MHS**[a], and **Julius Cuong Pham, MD, PhD**[a,c]

[a]Armstrong Institute for Patient Safety and Quality and Department of Anesthesiology and Critical Care Medicine, Johns Hopkins University School of Medicine, Baltimore, MD

[b]Johns Hopkins Carey School of Business, Baltimore, MD

[c]Armstrong Institute for Patient Safety and Quality, and Department of Anesthesiology and Critical Care Medicine, Johns Hopkins University School of Medicine, Baltimore, MD

[d]Department of Health Policy and Management, Johns Hopkins University Bloomberg School of Public Health, Baltimore, MD

Abstract

Background—Central line–associated bloodstream infection (CLABSI) remains one of the most common and deadly hospital acquired infections in the United States. Creating a culture of safety is an important part of healthcare–associated infection improvement efforts; however, few studies have robustly examined the role of safety climate in patient safety outcomes. We applied a pattern-based approach to measuring safety climate to investigate the relationship between intensive care unit (ICU) patient safety climate profiles and CLABSI rates.

Methods—Secondary analyses of data collected from 237 adult ICUs participating in the On the CUSP: Stop BSI project. Unit-level baseline scores on the Hospital Survey on Patient Safety, a survey designed to assess patient safety climate, and CLABSI rates, were investigated. Three climate profile characteristics were examined: profile elevation, variability, and shape.

Results—Zero-inflated Poisson analyses suggested an association between the relative incidence of CLABSI and safety climate profile shape. K-means cluster analysis revealed 5 climate profile shapes. ICUs with conflicting climates and nonpunitive climates had a significantly higher CLABSI risk compared with ICUs with generative leadership climates.

Conclusions—Relative CLABSI risk was related to safety climate profile shape. None of the climate profile shapes was related to the odds of reporting zero CLABSI. Our findings support using pattern-based methods for examining safety climate rather than examining the relationships between each narrow dimension of safety climate and broader safety outcomes like CLABSI.

[*]Address correspondence to Sallie J. Weaver, PhD, Assistant Professor, Armstrong Institute for Patient Safety and Quality and Department of Anesthesiology and Critical Care Medicine, Johns Hopkins University School of Medicine, 750 E. Pratt St, 15th Fl, Rm 1544, Baltimore, MD 21202. sjweaver@jhu.edu (S.J. Weaver).

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Keywords

Patient safety; Organizational culture; Central line–associated bloodstream infection

Central line–associated bloodstream infection (CLABSI) remains one of the most common and deadly hospital acquired infections in the United States. The most recently available estimates from the Centers for Disease Control and Prevention (CDC) indicate that approximately 41,000 patients experienced a CLABSI in 2011, and that approximately 1 in 4 affected patients died as a result.[1] In addition, CLABSIs represent a significant cost burden, with an estimated $17,000 (range $7288–$29,156) in added care expenses associated with each such infections.[1,2] Widespread patient safety efforts to reduce CLABSI focus on both the technical aspects of care (eg, clinical care procedures) and adaptive aspects of care (eg, behavioral norms among unit clinicians and staff regarding patient safety, teamwork, and communication, as reflected in the unit's safety climate)[3,4]; however, few previous studies have meaningfully examined the relationship between adaptive aspects of care, such as patient safety climate, and patient outcomes in a meaningful way.

Patient safety climate can be defined as the collection of habits, policies, procedures, and behaviors observed in daily practice related to patient safety that are shared among members of a unit, team, or organization.[5,6] Specifically, safety climate is a multidimensional concept comprising several aspects, including teamwork and communication among care providers, peer and leadership responses to patient safety events or concerns, and management support for patient safety activities and those who act in the name of patient safety. In this way, the concept of safety climate is like a cake that is composed of multiple ingredients. It is not one single ingredient that makes a cake, but rather the cake emerges from complex interactions and patterns among the various ingredients that have gone into it. In much the same way, safety climate can be thought of as an overarching concept that emerges from all of the different dimensions that compose it.

Safety climate, and the closely related concept of safety culture, have been publicized as critical elements for reducing hospital-acquired infections[7–9]; however, studies examining the nature of the relationship between safety climate and unit-level CLABSI rates are needed. Previous studies have identified relationships between certain individual dimensions of safety climate and length of hospital stay,[10,11] in-hospital complications and adverse events,[12] risk-adjusted mortaility,[10] and clinician compliance with safe work practices.[13] Yet findings vary, and the magnitude of the observed relationships is inconsistent, making it difficult to determine how much patient safety climate matters when it comes to hospital-acquired infections.

A potential alternative explanation for these varied findings is related to the way in which previous studies elected to operationalize the analysis of patient safety climate. Most previous studies took what is termed a "reductionist" approach to examining the safety climate–outcome relationship, meaning that they tested the relationship between each individual dimension of safety climate (ie, each individual ingredient) and a targeted outcome, rather than studying the relationship between safety climate as an entire concept (ie, the cake) and the given outcome of interest. Examining the dimensions individually can be problematic from both a theoretical and an analytical perspective, and can lead to weak observed relationships and conflicting findings.[14–17] For example, when the dimensions of safety climate are investigated individually, there is an inherent mismatch between the bandwidth of the predictor (ie, a single dimension measured using a safety climate survey) and the bandwidth of the outcome (eg, infection rates) that makes it more difficult to detect true relationships between safety climate and patient safety outcomes.

To address this gap, the present study drew on configural (ie, pattern-based) theories of organizational culture and climate[18,19] to examine the association between the constellation of dimensions that comprise patient safety climate and CLABSI rates in a sample of adult intensive care units (ICUs) in the United States. Configural theories of organizational climate and culture suggest that the pattern of the different dimensions of safety climate can be described in terms of 3 profile characteristics: (1) profile elevation, the general positive or negative valence of the safety climate across all different dimensions; (2) profile variance, the degree of variation among different climate dimensions; and (3) profile shape, the specific pattern of peaks and valleys among the different climate dimensions. We adopted a pattern-based methodology to investigate the relationships among these 3 safety climate profile characteristics and our primary outcome of interest.

METHODS

Secondary analyses were conducted using a subset of data collected as part of the On the CUSP: Stop BSI project, a national improvement collaborative funded by the Agency for Healthcare Research and Quality (AHRQ). The Stop BSI program used a multiple time series design to evaluate the effectiveness a multifaceted intervention that included the Comprehensive Unit-Based Safety Program(CUSP),[3,20,21] a model for translating research into practice that includes using a checklist of best practices to prevent infection and providing feedback on infection rates as a strategy to reduce CLABSI rates in ICU settings. Baseline safety climate survey data and baseline bloodstream infection data from the first 4 cohorts of participating adult ICUs (n = 238) were included for secondary analysis. The majority of units (78%) were located in nonrural areas, and 50% of these units were part of a teaching hospital.

Measures

Safety climate

Safety climate was measured using the Hospital Survey on Patient Safety (HSOPS),[22] which measures 10 distinct dimensions of safety climate (see Table 1) and has demonstrated sound psychometric properties across a variety of acute care settings.[23] Each dimension comprises 3 or 4 questions that are aggregated to form a dimension score for each unit. In line with scoring recommendations from the survey developer, a unit-level score on each of the 10 dimensions is calculated as the average percentage of positive responses (score of 4 or 5 on a 5-point Likert response scale) across all respondents in a given unit. Thus, the “percent positive score” can range from 0% to 100% on each of the 10 dimensions for each unit, with higher scores indicating more positive or desirable climate characteristics.

Participating ICUs had the option to administer the survey to clinicians and staff working in participating ICUs using a Web-based survey platform at the onset of the project or to submit HSOPS data that their unit had already collected during annual safety climate measurement activities within their hospital if collected recently. Project leaders for the ICUs worked in partnership with the national project team to distribute surveys using an online survey platform and to provide background data regarding their unit, including bed size and type. Baseline HSOPS data were collected during the first 30–60 days of each cohort's participation in the project. Cohort 1 collected baseline HSOPS data between September and November 2009. Cohort 2 and a portion of cohort 1 collected baseline HSOPS data between October and December 2009. Cohort 3 collected baseline HSOPS data between May and June 2010, and cohort 4 collected survey data between September and October 2010.

Operationalizing the climate profile characteristics for each unit—The 3 safety climate profile characteristics (profile elevation, variability, and shape) were operationalized for each unit based on the 10 dimension scores. Profile elevation was computed as a single score for each ICU representing the mean percent positive score across all 10 safety climate dimensions. Profile variability was similarly computed for each ICU as the variance of the 10 dimension scores around their respective mean. In line with previous studies examining organizational climate profiles,[19] profile shape was operationalized using *k*-means cluster analysis, which uses algorithmic iterations to group individual ICUs into relatively homogeneous groups based on a battery of selected characteristics, such as scores on each of the 10 safety climate dimensions. Within health care, similar clustering methods have been used to examine the relationship between health care personnel attitudes about risk and influenza vaccination uptake and absenteeism.[24] The method used to derive the 5 different profile shapes that emerged from this cluster analysis are fully described in the next section.

Operationalizing climate shape—During exploratory data analysis, potential *k*-means cluster solutions for 2–6 clusters were examined. The best-fitting cluster solution was selected based on the Calinski and Harabasz[30] criterion, as well as on examination of cluster interclass correlations (ICCs) and theoretical interpretation of resulting clusters. Our results suggested a 5-cluster solution as the best-fitting, most theoretically sound solution. The 5 climate profile shapes are displayed in Figure 1. We drew on other configuration-based theories of organizational climate and culture as theoretical grounding for the 5 shapes that emerged, including the competing values framework.[19,31,32] Profile shape 1, generative leadership climate, describes units in which high levels of hospital leadership support for patient safety and collaboration across units and services is perceived as a priority, even relative to teamwork among ICU team members. In these climates, organizational leadership plays a significant role in motivating and reinforcing patient safety as the top organizational priority. Conversely, a nonpunitive climate shape is one in which the peers and unit leaders demonstrate a blame-free response to error and unit members perceive that speaking up with concerns or ideas to improve safety is valued and reinforced. The foregoing climates might not be as strong in acting on these suggestions, however, and clear structures that support accountability for patient harm may be lacking.

The third climate shape, a comprehensive climate shape, represents climates that are uniformly high across all dimensions. The team-oriented shape describes climates in which teamwork within the unit and across units is uniformly perceived as more positive than other dimensions. In these climates, team members rally among themselves in support of safety, but may not sense that they have significant support from local or organizational level leadership. Finally, conflicting climate shapes refer to those in which local leadership and frontline staff demonstrate and perceive a local commitment to patient safety, but might not perceive similar support from organizational level leaders or other units with which they work. Table 1 displays raw mean scores on each climate dimension by climate shape, as well as ICC and other descriptive information.

CLABSI

CLABSI data were collected during a 12-month baseline period before the start of the intervention for each cohort (2008 for cohort 1, 2009 for cohort 2 and a portion of cohort 1, 2008–2009 for cohort 3, and 2009–2010 for cohort 4). Specifically, the number of infections and the number of line-days (ie, number of days in which a central line is in place for all patients in a given ICU) for each unit were collected according to definitions provided by the CDC. Individual patient level data were not collected. The total number of CLABSIs was summed over the 12-month period to create a numerator for analysis, and line-days were summed over the same 12-month period for each unit to create a denominator for analysis. Details of infection rate data collection are reported elsewhere.[25–27]

Other covariates

Other covariates of interest included unit size (number of beds) and unit type (ie, specialty ICU, medical ICU, surgical ICU, or combined medical-surgical ICU). Unit bed size ranged from 4 beds to 50 beds (mean, 14.27; standard deviation [SD], 7.48). Specialty ICUs (n = 39) included burn, trauma, coronary, and specialized surgical ICUs that focused solely on cardiothoracic patients. In addition, traditional medical ICUs (n = 24) caring for adult and geriatric patients with complex medical needs, surgical ICUs (n = 13) caring for critically ill patients who have undergone complex surgical procedures, and combined medical-surgical ICUs (n = 161) that care for a wide range of patients with complex care needs were also included in the analyses.

Analyses

Descriptive summary statistics and descriptive graphs were created to explore variations in CLABSI rates, as well as the unadjusted relationships between the 3 safety climate profile characteristics and CLABSI rates. One ICU was dropped during data management processing for not reporting a valid denominator for their infection data (reported as 0); thus, analyses were conducted on 237 ICUs.

Exploratory data analyses including unadjusted histograms and stem-and-leaf plots revealed a large number of units reporting zero infections during the baseline period, suggesting that zero-inflated Poisson regression analyses should be used to fit observed data. Zero-inflated Poisson (ZIP) models assume that the series of zero outcomes may be predicted by different process than nonzero outcomes and thus include 2 separate models, 1 model examining the predictors of nonzero outcomes (ie, noninflated model) and 1 model examining zero outcomes (ie, inflated model).[28,29] First, a series of unadjusted ZIP models were examined to investigate the crude relationship between the 3 safety climate profile characteristics and baseline CLABSI infection risks. These models were then extended to adjust for both unit size and type. All analyses were conducted with Stata/IC 12.1 for Windows (StataCorp, College Station, TX).

RESULTS

Relationships between the 3 safety climate profile characteristics and CLABSI

Overall, the mean CLABSI rate was 1.78 infections per 1000 central line-days (SD, 2.09) across all ICUs during the baseline period. Boxplots examining infection rates by unit type suggested meaningful variation among unit types, and lowess plots examining unadjusted relationships between unit size and rate also implicated size as a potential confounder of the safety climate–infection relationship.

We used an initial series of ZIP regression models to examine the unadjusted relationship between the three climate profile characteristics and infection risk. These models indicated that none of the profile characteristics were significantly related to the odds of having a unit infection rate of zero (Table 2). The noninflated portion of the model indicated that climate profile shape was significantly related to infection rates for units with infection rates greater than zero (Wald $\chi^2 = 32.68$; $P < .0001$). Specifically, the relative risk of infection was significantly higher in units with a conflicting climate shape (incident risk ratio [IRR], 1.70; $P < .0001$) and in units demonstrating a nonpunitive climate shape (IRR, 1.79; $P < .0001$) compared with units with a generative leadership shape. Profile elevation and profile variation were not significantly related to infection risk (IRR, 1.00; $P = .19$ and IRR, 0.99; $P = .19$, respectively).

To adjust for potential confounding variables and examine other unit characteristics likely to influence the odds of a unit having zero infections, we next examined a second series of ZIP models that included unit size and type. Three different models were explored: a model that fit unit size as a covariate in both the Poisson and inflated models, a model that fit both unit size and unit type as covariates in both the Poisson and inflated models, and a model that fit unit type and unit size as covariates in the Poisson model, but fit only unit size in the inflated model. Indices of model fit, including the Akaike information criterion, and qualitative investigation of model residual plots suggested that the model fitting unit type and unit size as covariates in the Poisson model but including only unit size in the inflated model provided the best fit.

The results summarized in Table 2 indicate that unit size was significantly related to the odds of a unit having zero infections (odds ratio, 0.62; $P = .02$). This indicates that larger ICUs were less likely to have zero infections and, specifically, that for each additional bed added to a unit, the odds of reporting zero infections were reduced by 38%. Unit type was significantly related to the relative risk for CLABSI (Wald $\chi^2 = 22.86$; $P < .0001$). The risk of infection in specialty ICUs (eg, burn, trauma) was 22% higher compared with medical-surgical ICUs (IRR, 0.78; $P < .01$) and 68% higher compared with surgical ICUs (IRR, 0.32; $P < .001$).

After adjusting for unit type and unit size, climate profile shape remained a significant predictor of infection risk (Wald $\chi^2 = 36.63$; $P < .0001$); however, profile elevation and profile variability again were not significantly related to infection risk ($P = .74$ and .48, respectively). These results indicate that the incidence rate of infection was 77% higher in units with a nonpunitive climate shape (IRR, 1.77; $P < .001$) and 57% higher in units with a conflicting climate shape (IRR, 1.57; $P < .001$) compared with units with the generative leadership shape. Generative leadership climate served as the reference group given that theoretically and empirically, it is the most positive, and also most balanced, climate shape; that is, climate scores were high on both unit-referenced dimensions like unit leader actions and support for safety and hospital-referenced dimensions like teamwork across units.

DISCUSSION

Understanding the role that organizational factors, such as patient safety climate, play in shaping clinician behavior and patient outcomes is critical for improving the quality and safety of care provided to some of the most at-risk patients. Our findings indicate that patient safety climate, when operationalized in terms of climate profile characteristics, is significantly related to the CLABSI rate in ICUs after controlling for other unit factors, such as size and type. Although simple summary profile characteristics, such as profile elevation and profile variation, were not meaningfully related to incidence rates, climate profile shape was significantly related to incidence rates above zero. This finding suggests that the various aspects of safety climate are neither additive nor interchangeable, and that it is the constellation of factors that compose the safety climate, as well as the complex patterns and interactions among them, that must be studied to understand the relationship between patient safety climate and patient outcomes. Our findings also align with previous preliminary work across a range of acute care areas in which profile elevation and variation were related to patient ratings of their care experience, but only profile shape was related to the number of adverse events occurring in the unit.[33]

Our results indicate that ICUs with conflicting climates and nonpunitive climates demonstrated greater relative CLABSI risk compared with ICUs with a generative leadership climate, but that climate shape is not related to the odds of a unit reporting zero infections. Whereas climate profile shape was found to be related to infection rates only in those ICUs reporting rates above zero, these findings underscore the importance of safety climate in units that continue to struggle with sustaining a zero rate over time. Theoretically, these findings align with previous work highlighting that a climate of safety and sustainment of safe outcomes is the product of multiple interacting factors, including leadership actions that emphasize and reinforce safety, proactive identification of potential threats to safety, and continuous learning.[34] They also supplement previous findings indicating that individual climate domains that pertain to teamwork both within and across work areas, as well as leadership, are related to composite indices of the AHRQ patient safety indicators.[12] Conversely, units with a conflicting climate shape or a nonpunitive climate shape demonstrated significantly higher infection risks.

The theoretical pathways underlying these findings may differ in meaningful ways, however; for example, conflicting climates were characterized by discrepancies between hospital-level climate domains and unit-level climate domains. This suggests that in these units, team members may perceive that local leaders and direct colleagues support and value safety, but do not perceive the same level of support for safety from hospital level leaders or other areas of the organization. This theoretically could reflect conflicting or unclear goals that may tacitly reinforce unsafe behavior (eg, using workarounds or shortcuts to improve efficiency). For units characterized by nonpunitive climates, the pathway may look different. Documented reporting bias and underreporting[35–37] of hospital-acquired harm has led to efforts to create nonpunitive, psychologically safe climates in which clinicians and staff feel comfortable speaking up about potential or reals harms that they observe or encounter.[38] Team members working in units characterized by a nonpunitive climate may be more likely to identify and discuss real or potential hazards, as well as to more accurately document instances of hospital-acquired infection. This is an important step on the road to improvement and enhances the validity of their rate data, but may make it more difficult to detect true relationships between other climate shapes and rates, given that some underreporting may still occur in units characterized by other climate shapes.

Our findings must be considered in light of several study limitations. First, this study was secondary analysis of a subset of a larger intervention study. There is the potential that ICUs included in these analyses are not entirely representative of all ICUs, though they did represent both teaching and nonteaching hospitals, as well as rural and nonrural settings. In addition, their safety climate scores were in line with national benchmarks reported by the AHRQ based on their national HSOPS database, and the average infection rate across included ICUs was in line with national averages reported by the CDC. Second, infection incidence rates were reported at the unit level of analysis, and there was no direct way to adjust for patient case mix. Unit type was included as a proxy measure for patient acuity, and models were adjusted for this. Moreover, directionality or causality cannot be inferred from these analyses. Another important potential limitation includes other factors that we were not able to control for in these analyses that might have impacted or confounded findings. For example, units included in these analyses might have previously implemented interventions outside of this project to improve CLABSI rates, the safety culture, or both. Finally, we evaluated the relationship between safety climate and baseline CLABSI rate. The relationship between climate and CLABSI might have been different had we evaluated improvement in CLABSI or postintervention CLABSI rate.

Overall, our results suggest that the relative risk of CLABSI in US adult ICUs is related to patient safety climate profile shape. In addition, they underscore the value of understanding and operationalizing patient safety climate, in line with theoretical definitions that define climate as the pattern among dimensions, rather than examining the effects of individual dimensions of climate in a piecemeal manner. Finally, these findings suggest that hospital leaders, managers, clinicians, and staff should work to foster a safety climate characterized by high levels of both local unit leader and hospital leader commitment to supporting their clinicians and staff in their efforts to optimize patient safety, as well as high levels of teamwork both within and across units.

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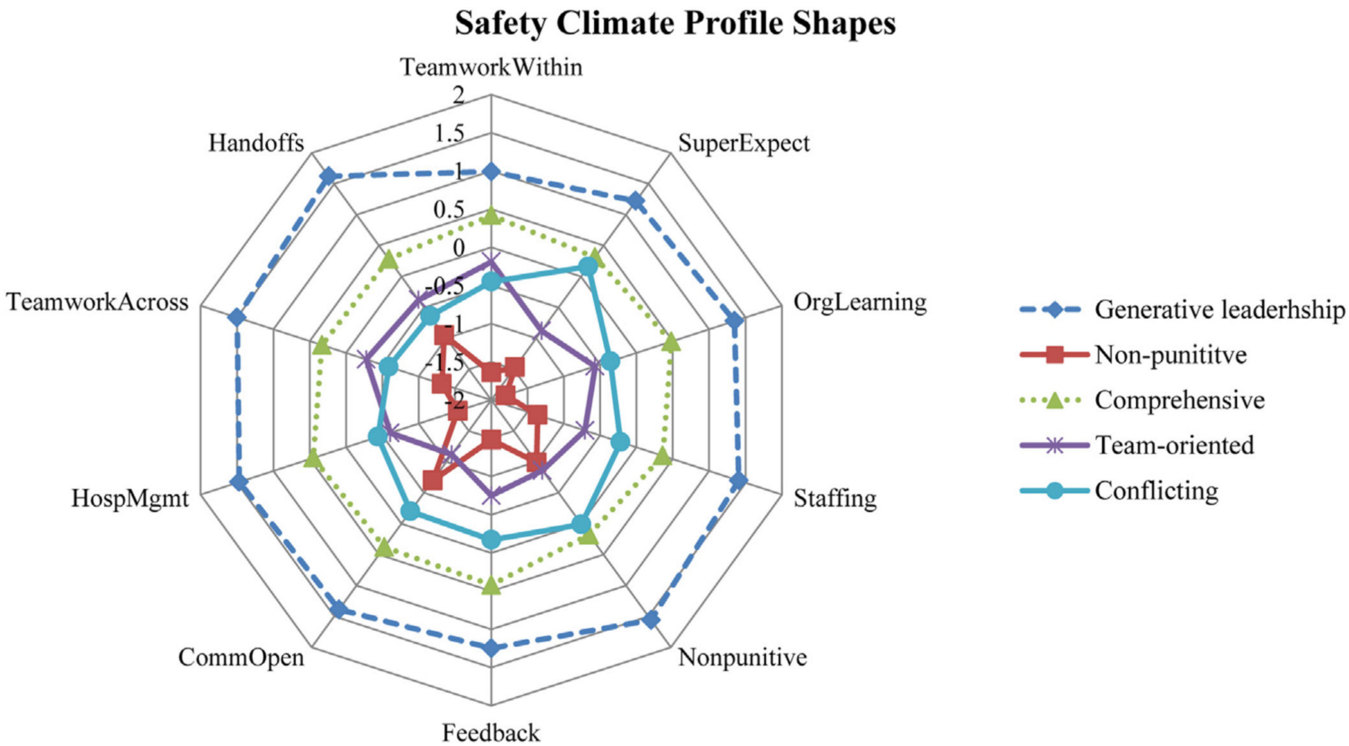

Fig 1.

The 5 safety climate profile shapes. Scores on each of the 10 dimensions have been standardized to demonstrate the relative relationships among these dimensions.

Table 1

Unit level climate shape descriptive statistics

Climate shape	Teamwork within ICU	Supervisor expectations	Continuous learning	Staffing and workload	Nonpunitive response	Feedback about error	Open communication	Hosptial management support	Teamwork across ICUs	Handoffs and care transitions
Generative leadership										
Mean	86.10	78.37	72.46	58.00	41.09	60.71	64.08	59.16	50.72	42.48
SD	7.29	7.38	6.37	10.10	10.73	9.81	9.27	9.26	7.55	6.87
Nonpunitive										
Mean	90.21	84.10	83.13	67.24	45.95	70.38	69.50	75.81	62.67	52.39
SD	5.11	6.21	4.90	9.22	7.93	9.43	6.46	7.22	8.62	8.47
Team-oriented										
Mean	76.76	63.47	61.43	46.32	25.40	45.71	52.11	47.77	45.58	37.53
SD	9.87	10.78	8.21	9.25	8.37	9.75	7.46	10.33	9.68	8.85
Comprehensive										
Mean	95.13	91.72	91.47	79.66	62.34	79.11	79.87	87.60	78.34	69.60
SD	3.60	5.79	5.17	8.65	14.37	7.20	8.78	6.62	9.90	10.21
Conflicting										
Mean	87.62	71.67	76.28	58.34	30.00	59.37	58.81	65.85	62.98	55.06
SD	6.49	7.98	6.37	9.41	8.37	9.87	8.52	8.56	6.96	7.47
F test statistic	38.48*	75.77*	127.47*	64.34*	78.61*	72.10*	63.68*	123.85*	81.64*	81.18*
$ICC_{cluster}$ (95% CI)	0.41 (0.16–0.72)	0.59 (0.29–0.84)	0.71 (0.41–0.90)	0.57 (0.27–0.83)	0.64 (0.33–0.86)	0.58 (0.28–0.83)	0.57 (0.27–0.83)	0.71 (0.41–0.90)	0.64 (0.33–0.86)	0.64 (0.33–0.86)

$ICC_{cluster}$: 1, 61 ICUs; 2, 61 ICUs; 3, 54 ICUs; 4, 24 ICUs; 5, 38 ICUs.

NOTE. To determine whether the 5 profile shapes differed meaningfully from one another in terms of safety climate scores, ANOVA was performed on each safety climate dimension. A significant F value indicates that the shapes demonstrated significantly different scores on the particular dimension. In addition, ICCs are reported to show meaningful similarities among respondents categorized with the same climate profile shape.

* $P < .0001$.

Table 2

Crude and adjusted zero-inflated Poisson regression coefficients

	Crude						Adjusted					
	Infections >0			Infections = 0			Infections >0			Infections = 0		
Variable	**IRR**	**95% CI**	***P* value**	**Coefficient**	**95% CI**	***P* value**	**Coefficient**	**95% CI**	***P* value**	**Coefficient**	**95% CI**	***P* value**
Unit patient safety profile												
Profile elevation	1.00	0.97–1.02	.76	0.22	−0.11 to 0.55	.19	1.00	0.97–1.02	.74			
Characteristics												
Profile variability	0.99	0.96–1.02	.51	0.22	−0.11 to 0.54	.19	0.99	0.96–1.02	.48			
Profile shape			<.001[w]			.26[w]			<.001[w]			
Nonpunitive	1.79	1.33–2.38	<.001	−0.75	−5.55 to 4.05	.76	1.77	1.33–2.36	<.001			
Comprehensive[s]	1.19	0.84–1.67	.33	2.93	−1.39 to 7.26	.18	1.19	0.85–1.69	.31			
Team-oriented	0.78	0.37–1.62	.51	0.7	−5.88 to 7.27	.84	0.61	0.30–1.23	.16			
Conflicting	1.7	1.35–2.13	<.001	1.3	−2.57 to 5.17	.51	1.57	1.25–1.98	<.001			
Other unit												
Unit size							1.00	0.99–1.00	.28	−0.48	−0.48	.02
Characteristic												
Unit type									<.001[w]			
Medical ICU							0.86	0.68–1.09	.22			
Medical-surgical ICU							0.78	0.66–0.93	<.01			
Surgical ICU							0.32	0.19–0.53	<.001			

w, wald test

s, generative leadership is the referent climate profile shape.

* Adjusted model includes unit size and unit type covariates, as well as an inflated factor for unit size.