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Structure, process and annual intensive care unit mortality across 69 centers: United States Critical Illness and Injury Trials Group Critical Illness Outcomes Study (USCIITG-CIOS)

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Abstract

Objective—Hospital-level variations in structure and process may affect clinical outcomes in intensive care units (ICUs). We sought to characterize the organizational structure, processes of care, use of protocols and standardized outcomes in a large sample of U.S. ICUs.

Design—We surveyed 69 ICUs about organization, size, volume, staffing, processes of care, use of protocols, and annual ICU mortality.

Setting—ICUs participating in the United States Critical Illness and Injury Trials Group Critical Illness Outcomes Study (USCIITG-CIOS).

Measurements and Main Results—We characterized structure and process variables across ICUs, investigated relationships between these variables and annual ICU mortality, and adjusted for illness severity using APACHE II. Ninety-four ICU directors were invited to participate in the study and 69 ICUs (73%) were enrolled, of which 25 (36%) were medical, 24 were surgical (35%) and 20 (29%) were of mixed type, and 64 (93%) were located in teaching hospitals with a median number of 5 trainees per ICU. Average annual ICU mortality was 10.8%, average APACHE II score was 19.3, 58% were closed units and 41% had a 24-hour in-house intensivist. In multivariable linear regression adjusted for APACHE II and multiple ICU structure and process factors, annual ICU mortality was lower in surgical ICUs than in medical ICUs (5.6% lower, 95% CI 2.4%–8.8%) or mixed ICUs (4.5% lower, 95% CI 0.4%–8.7%). We also found a lower annual ICU mortality among ICUs that had a daily plan of care review (5.8% lower, 95% CI 1.6%–10.0%) and a lower bed-to-nurse ratio (1.8% lower when the ratio decreased from 2:1 to 1.5:1; 95% CI 0.25%–3.4%). In contrast, 24-hour intensivist coverage ($p=0.89$) and closed ICU status ($p=0.16$) were not associated with a lower annual ICU mortality.

Conclusions—In a sample of 69 ICUs, a daily plan of care review and a lower bed-to-nurse ratio were both associated with a lower annual ICU mortality. In contrast to 24-hour intensivist staffing, improvement in team communication is a low-cost, process-targeted intervention strategy that may improve clinical outcomes in ICU patients.

Keywords

protocols; structure; process; ICU management; intensivist; ICU administration

INTRODUCTION

Caring for the critically ill is a resource intensive process that requires a specialized clinical team and real-time monitoring to provide life-sustaining interventions. In the United States, each day of intensive care costs on average 3500 US dollars and intensive care units (ICUs) account for 13% of hospital costs, 4% of the national health expenditures and approximately 1% of the GDP (1, 2). Clinical outcomes vary substantially between ICUs (5–8), which can be attributed to heterogeneous patient case-mix and differences in organizational structure and processes of care within an ICU. With the increasing demand and cost of critical care worldwide, it is important to understand the organizational characteristics and process of care variables associated with optimal outcomes and costs.

Recently it has been recognized that both organizational structure (i.e., the conditions under which patient care is provided) and processes of care (i.e., activities that constitute patient care) in an ICU directly influence clinical outcomes and are an important platform for care improvements. Structure-driven factors previously shown to be associated with clinical outcomes include the type of ICU (3, 4), hospital and ICU case volume (5–7), open or closed ICU format (8–10), 24-hour presence of an intensivist (11–13), nurse staffing (14–17) and staff workload (18). Several of these characteristics, are resource-intensive (e.g., 24-hour intensivist staffing or higher ratio nurse staffing) or immutable (e.g., case volume or type of ICU). Processes of care frequently involve disease-driven interventions, such as lung protective ventilation and conservative fluid management strategies for Acute Respiratory Distress Syndrome (19, 20), and early goal-directed therapy for sepsis (21). Process-driven interventions offer a potentially cost-effective alternative to reduce practice variation and improve clinical outcomes across ICUs. Previous investigations in single-center studies have demonstrated that the use of a standardized protocol vs. physician-directed assessment (i.e., usual care) of spontaneous breathing trials alone (22) or in combination with a spontaneous awakening trial (23) resulted in better patient outcomes. Similarly, another investigation in a single center-study found that use of a daily plan of care checklist was associated with 50% decrease in length of stay (24).

In this study, we sought to characterize the heterogeneity in organizational characteristics in a sample of 69 ICUs in the United States, to identify variations in processes of care and use of protocols; and, describe the ecological association between these variables and annual ICU mortality.

MATERIALS AND METHODS

Study design

The United States Critical Illness and Injury Trials Group Critical Illness Outcomes Study (USCIITG-CIOS) has been described in detail elsewhere (25). Briefly, CIOS is a large, prospective, observational study of ICU patients. Participating investigators were selected from a range of institutions participating in USCIITG. CIOS was conducted in two stages. In the first stage, participating investigators were asked to complete a standardized questionnaire about physician and nurse staffing, number of beds and case volume of the hospital and study ICU, processes of care including rounding practices and use of protocols,

and the most recent annual reported ICU mortality for the study ICU. After recruitment into the study but before enrollment of individual patient data, investigators were asked to first complete this standardized questionnaire regarding ICU structure and process. All investigators were given a manual of operations that provided definitions for each potential answer (See Online Supplement). This standardized questionnaire was also pilot tested at a couple of our facilities and independently validated by our study staff prior to use. Moreover, once completed, each standardized questionnaire was individually reviewed by the Principal Investigator and the responses were discussed with individual investigators over the telephone. We chose to use annual ICU mortality for this study because it is a highly reliable, standardized metric used at most hospitals. With the exception of APACHE II data, which is not a commonly available quality metric collected by hospitals or ICUs, we limited our analyses to data collected in the first stage of CIOS (i.e., structural questionnaire). We obtained the average Acute Physiology and Chronic Health Evaluation II (APACHE II) score for each ICU from individual patient data collected prospectively in approximately 100 patients per ICU. We instructed investigators to enroll all newly admitted patients on randomly chosen days, with 5 to 10 days between enrollments to allow for patient turnover (25). CIOS was approved by the ethics review boards of all participating institutions.

Definitions

We defined an intensivist as a physician who is board-eligible or board-certified in Critical Care Medicine, board-certified in Emergency Medicine and completed a Critical Care fellowship in an accredited program, or board-certified in Medicine, Anesthesiology, Pediatrics or Surgery who completed training prior to the availability of Critical Care Medicine certification and who provides at least six weeks of full-time ICU care annually since 1987. We defined an ICU as: open if any credentialed physician could admit and manage a patient in the unit, and semi-open if any credentialed physician could admit to the unit, but an automatic critical care consult occurred if certain parameters such as expected length of stay are exceeded. The type of ICU was: medical if it managed exclusively medical or cardiac patients; surgical if it managed only surgical, cardiothoracic, trauma, burn or neurosurgical patients; and, mixed if it managed both medical and surgical or neurology patients. We defined a trainee as either a resident or fellow. We categorized case volume as high or low according to the median number of annual ICU admissions, and bed capacity as high or low according to the median number of ICU beds. We considered an ICU as having a daily plan of care review if it either had a checklist for daily goals of care or if the attending physician reviewed the plan of care with the charge nurse. We defined rounds as multidisciplinary if it included at least two other clinical specialties beyond the ICU physician and nurse.

We defined a protocol as a precise and detailed plan for a regimen of therapy, which included a set of guiding rules initiated by a physician order or included as part of standing orders during admission. We grouped protocols into the following categories: pulmonary and ventilator management bundle (lung protective ventilation, weaning and ventilator-associated pneumonia prevention), infection control bundle (sepsis treatment, rapid antibiotic use, stress ulcer prevention, catheter placement, oral hygiene and ventilator-

associated pneumonia prevention), nutrition bundle (nutrition and glucose control), thromboembolism management bundle (deep vein thrombosis prevention and venous thromboembolism), delirium management bundle (delirium assessment and delirium treatment), sedation management bundle (daily discontinuation of sedation or other sedation protocol), neuroprotective bundle (stroke treatment, acute brain injury, intracerebral hemorrhage and hypothermia after acute cardiac arrest) and transfusion management bundle (massive transfusion or transfusion restriction). We defined a protocol with a high requirement for a physician order if >75% of the ICUs in the study required a physician order to initiate a protocol.

Biostatistical methods

We summarized structure and process variables stratified by type of ICU. In unadjusted analysis, we compared proportions across types of ICU using Fisher exact tests, and compared continuous variables across types of ICU using one-way analysis of variance as appropriate. We used multivariable linear regression adjusted to determine structure and process factors associated with annual ICU mortality adjusted for the APACHE II at each center. Specifically, the multivariable linear regression model included the following variables: average APACHE II score, ICU type, case volume, bed capacity, 24-hour intensivist coverage, bed-to-nurse ratio, trainee-to-bed ratio, ICU organization (open vs. closed), computerized order entry, daily plan of care review, multidisciplinary rounding, and use of protocols guiding management of electrolytes, mobility, codes, neuroprotection, delirium, and transfusions. We selected these variables *a priori* based on biological plausibility and previous research. We did not include protocol bundles that were ubiquitously used across ICUs (>97%) such as pulmonary and ventilator management, infection control, nutrition and thromboembolism management protocols. For example, 68 centers (99%) had either the lung protective ventilation, weaning or ventilator-associated pneumonia prevention protocols, i.e., the pulmonary and ventilator management bundle. Due to the high number of covariates included, which can increase the risk of overfitting, we also conducted sensitivity analyses examining the association between each of the structure and process variables and annual ICU mortality, adjusted only for average APACHE II score and ICU type. Although all structure and process data were complete, 11 ICUs were missing average APACHE II scores. We therefore used multiple imputation analysis to perform multivariable linear regression, to a total of 20 imputations. In sensitivity analyses, the use of 50 and 100 imputations did not affect the results (See Online Supplement). Additional exploratory analyses demonstrated reasonable ranges for the imputed values. As a further sensitivity analysis, we conducted a multivariable linear regression in which we excluded the 11 ICUs without average APACHE II scores and found that the point estimates were similar (See Online Supplement). Finally, since a large percentage of centers only contributed data for 1 or 2 ICUs of a different type (the median number of ICUs per hospital center was 1), we assume that ICUs are independent and identically distributed units in our analyses. We conducted all statistical analyses in R (www.r-project.org) and STATA 12 (Stata Corp., College Station, USA).

RESULTS

Hospital characteristics and utilization

We approached 94 ICU directors in the United States and 69 (73%) agreed to participate in the study. All 69 participating investigators completed the structure and process form for their ICUs without any missing data. A total of 25 hospital centers contributed data for 1 ICU only, 10 centers contributed data for 2 ICUs, 5 centers contributed data of 3 ICUs, 1 center contributed data of 4 ICUs and 1 center contributed data of 5 ICUs. The median number of ICUs per hospital center was 1. We summarized hospital characteristics and demographics in Table 1. Briefly, 25 (36%) ICUs were medical, 24 (35%) were surgical and 20 (29%) were of mixed type. Average annual ICU mortality was 10.8% (median 9%); average APACHE II score was 19.3 (median 19.1); 64% of hospitals were private non-profit and 18% were non-federal public. 80% were located in urban centers; 93% had a resident training program and 83% had a critical care training program; 90% had electronic patient records and 81% had computerized patient order entry.

Staffing, organization and rounding practices

We summarize staffing, organization and rounding practices in Table 2. Overall, 100% of participating ICUs had attending intensivists; 100% had a medical director and 99% had a nurse manager; 58% were closed units; 41% had 24-hour intensivist coverage. Mean bed-to-nurse ratio was 1.8:1 (median 1.7:1), mean number of critical care trainees was 5.9 (median 5, range 0 to 29), 4% had electronic ICU coverage. Multidisciplinary rounds were performed in 41% of units, but included palliative care in only 7% of ICUs. Nurses performed delirium assessment while charting in 67% of ICUs, and 87% conducted a daily plan of care review.

Protocols

The median number of protocols was 19 for all ICUs (Table 2) and 93% of the ICUs had 10 or more protocols in place. We summarized the availability of protocols and need for a physician order to initiate the protocol rules in Table 3. Pulmonary and ventilator management, infection control, nutrition and thromboembolism management protocols were ubiquitous with 97% to 99% coverage across ICUs. Neuroprotective and sedation management protocols were also very common with 84% and 86% coverage, respectively. In contrast, only 36% of ICUs had early mobility protocols, 55% had transfusion management protocols, 57% had acute coronary syndrome protocols, 62% had delirium management protocols and 81% had electrolyte protocols in place. When we examined individual protocols, only 48% used a rapid antibiotic protocol and 48% had a palliative care protocol, and these were consistently low across all types of ICUs. Most protocols had a high requirement (i.e., >75%) for a physician order (Table 3). Examples of specific protocols with a lower requirement for a physician order included such as catheter placement, ventilator associated pneumonia prevention, oral hygiene, daily interruption of sedation, both delirium assessment and treatment and Advanced Cardiovascular Life Support/Critical care code.

Structure and process factors associated with ICU mortality

In single variable analyses, both APACHE II score and type of ICU were associated with annual ICU mortality as were several structure and process variables (first column of Table 4). Several of these relationships, however, were likely confounded by either severity of illness, type of ICU or other factors, and most of the associations found in single variable analyses became non-significant in multivariable analyses (second and third columns of Table 4). In multivariable linear regression adjusted for average APACHE II score among other organizational characteristics, annual ICU mortality was lower in surgical ICUs than in medical and mixed ICUs (third column of Table 4). In addition, we found that the adjusted annual ICU mortality was lower among ICUs that had a daily plan of care review (5.8% lower than having no daily review, 95% CI 1.6%–10.0%) and a lower bed-to-nurse ratio (1.8% lower when the ratio decreased from 2:1 to 1.5:1; 95% CI 0.25%–3.4%). In contrast, 24-hour intensivist coverage and closed ICU status were not associated with a lower annual ICU mortality. In sensitivity analyses examining structure and process factors in models adjusting only for severity of illness and ICU type, results were similar to those found in the full multivariable model with a few exceptions: the association between bed-to-nurse ratio and mortality was less robust, and associations between electrolyte and mobility protocols and mortality became significant when adjusting only for average APACHE II and ICU type.

DISCUSSION

Our study identified substantial heterogeneity in both ICU organizational structure and processes of care across 69 centers in the United States, most of which were located in teaching hospitals. While annual ICU mortality varied by type of ICU, the primary factors that were strongly associated with a lower ICU mortality were improved daily team communication strategies and a lower bed-to-nurse ratio. We did not find that 24-hour attending intensivist staffing (vs. fewer attending hours) or a closed ICU format (vs. open) was associated with a lower annual ICU mortality in the USCIITG-CIOS cohort.

We identified that daily team communication strategies was a process-driven factor associated with a lower ICU mortality in the 69 participating centers, after adjusting for case volume, utilization, severity of illness, type of ICU and other organizational factors. In our study, more than 25% of ICUs reported either not having a checklist for daily goals of care or not having a daily meeting between the attending intensivist and charge nurse to discuss the plan of care. This proportion may be higher in community hospitals; however, we do not have data to substantiate this statement as >92% of participating ICUs were in teaching hospitals. Improved team communication via a daily meeting or checklist is a modifiable process-driven factor that is simple, cost-effective and is associated with improved clinical outcomes (11, 26, 27).

The ratio of beds to nurses was a structure-driven factor that was associated with a lower ICU mortality in multivariable analysis. Our study is in agreement with findings of previous studies and systematic reviews, which identified that a higher number of nursing care hours or a higher relative number of nurses to patients (or beds) was related to improved clinical outcomes (14–17, 28). An increase in nursing staff is costly and may be challenging for

some centers, especially those with limited resources (e.g., safety net and critical access hospitals). Moreover,, intensive care nursing requires a high level of qualifications and competencies (29) and is associated with a high rate of burnout, each of which contribute to nursing shortages to adequately cover the growing demand for critical care. Thus, while nurse staffing may be important to achieve optimal clinical outcomes, it is constrained by both financial and workforce limitations.

Our study did not confirm previous findings that the presence of a 24-hour intensivist was associated with improved clinical outcomes (11–13, 30). A large number of the previous studies, however, were single-center based, whereas our study summarizes information across 69 ICUs using a standardized survey. It seems likely that, since the majority of our ICUs were located in teaching hospitals with critical care trainees, this may obscure the impact of 24-hour intensivist staffing. Our findings were consistent with a recent cross-over trial of two intensivist staffing models in Manitoba which found no difference in hospital mortality with greater intensivist staffing (31) and with a recent retrospective study which found that addition of night-time intensivist coverage was not associated with a reduction in mortality in ICUs with high-intensity daytime staffing (32). A closed ICU format was also not associated with a lower annual ICU mortality, and counters previous studies (8–10, 33). One potential explanation for this difference is this ICU cohort was highly managed (100% of ICUs were covered by a medical director and 99% had a nurse manager) and included a large number of protocols, both likely decreasing practice variation across admitting, non-intensivist trained physicians.

Limitations of our study include a modest sample of participating ICUs in the United States, limited representation of community hospitals, use of standardized annual ICU mortality as the outcome, and voluntary participation by ICU directors. We did not collect any information in non-participating ICUs to evaluate the potential risk of a self-selection bias in our sample. Another potential shortcoming is that our findings may not be generalizable to all hospital ICUs, especially to those found in community hospitals. Our findings are based on a sample of hospitals participating in USCITTG, which is primarily composed of leading academic institutions and university hospitals from around the country. Several structure and process variables may be different in our sample of ICUs vs. those in community hospitals: such as the median number of ICU beds (84 beds), hospital locations (80% found in urban settings), a large number of available protocols (median of 19 per ICU), the ubiquitous presence of electronic patient records (90%), and a high number of median number of ICU trainees (5 trainees per ICU). Similar process and structure relationships still need to be studied in community hospitals which are markedly different in terms of staffing characteristics, protocol utilization, patient case-mix and ICU resource availability. Several of these factors may limit the generalizability of our findings. Moreover, our sample size may also affect both the effect size and significance of our findings; however, the association between improved daily team communication or bed-to-nurse ratio and annual ICU mortality were relatively robust in both single variable and multivariable analyses. While we based our analysis on reported annual ICU mortality, we believe that this reported value is quite robust as this is a common statistic measured and utilized by hospital units and it summarizes mortality using a denominator of thousands of patients seen over a one-year period. Thus, the use of annual reported ICU mortality may provide a more precise estimate

of the actual mortality in any given ICU. Annual ICU mortality is a standardized metric, however, factors beyond ICU care such as hospital throughput and transfer practices can influence this metric. For example, the Critical Care Societies Collaborative has recommended that ICU mortality, even when risk-adjusted, not be used to evaluate ICU quality or performance. Instead measures such as 30-day mortality or duration on mechanical ventilation can more reliably indicate quality. There are other clinically-important endpoints such as ICU length-of-stay, ventilator-free days, case and severity adjusted cost of care that did not examine in this report but which could also be affected different structural and process of care variables. Although we had complete structure and process data for participating ICUs, we had to use multiple imputation analysis because 11 ICUs (16%) were missing average APACHE II scores. However, in sensitivity analyses, we found that the multiple imputation and case-deletion approaches yielded similar point estimates for the variables under study. We chose to report the results of multiple imputation analysis because it will result in less biased estimates under the assumption of missing at random than a case-deletion approach. The fact that APACHE II was not associated with ICU mortality in our multivariable analysis may be due to sample size, potential unmeasured confounders or lack of APACHE II calibration for contemporary ICU outcomes. It is also possible that the structural and process factors examined in this study were unaccounted in the original APACHE II derivation, and their inclusion in our study mitigated the predictive power of APACHE II. Finally, we did not collect the period of time in which APACHE II score were obtained at each center. Therefore, it is possible that variations in the data period collection may influence the average severity of illness measured across ICUs.

Our study also has significant strengths. We used a standardized questionnaire supported with a manual of operations that standardized the definitions of our structure and process variables, which were then individually checked for consistency by study staff. Second, our study directly obtained comprehensive structure and process information from multiple geographically and organizationally disparate ICUs, and it is one of the first aimed to investigate the effects of multiple process-driven factors on clinical outcomes independent of other organizational factors in the ICU and utilization such as case volume. Third, we also aimed to include a similar number of medical, surgical and mixed ICUs to capture the full spectrum of critical care services.

Increasing evidence points to the importance of organization, structure and process within an ICU in the management of critically ill patients (33, 34–40). Heterogeneity in structure and process can contribute to practice variation and, in turn, affect clinical outcomes across ICUs, and it provides a unique opportunity to implement structure-and-process driven interventions to test whether clinical outcomes can be improved. Our results suggest that heterogeneity in both structure-and-process and type of ICU (medical vs. surgical vs. mixed) may play an important confounding or effect-modifying role in the interpretation of multi-center observational studies in critical care. We recommend that future observational studies that involve multiple ICUs collect both organizational structure and process data for adjustment in multivariable analyses.

In summary, we found that better daily team communication and greater nurse staffing were associated with patient-related outcomes in ICUs; these ICU structure and process factors

are amenable to intervention. In particular, improvement in team communication is a low-cost process-targeted intervention that may improve clinical outcomes in ICU patients.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Hospital characteristics and utilization by Intensive Care Unit (ICU) type.

	All (n=69)	Medical (n=25)	Surgical (n=24)	Mixed (n=20)	P
Annual ICU mortality, median (range)	9.0 (1.5 – 38.6)	14.8 (6.2 – 38.6)	5.5 (1.5 – 22.0)	8.4 (3.3 – 22.0)	<0.001
Mean APACHE II, median (range)	19.1 (9.7 – 29.2)	20.2 (13.3 – 28.4)	17.7 (9.7 – 24.8)	20.6 (15.6 – 29.2)	0.02
Type of hospital, n (%)					
Private non-profit	44 (64)	18 (72)	16 (67)	10 (50)	0.14
Non-federal public	18 (26)	7 (28)	6 (25)	5 (25)	
Private for profit	4 (6)	0 (0)	2 (8)	2 (10)	
Federal	3 (4)	0 (0)	0 (0)	3 (15)	
Hospital location					
Urban (vs. Suburban)	55 (80)	22 (88)	19 (79)	14 (70)	0.29
Hospital characteristics, n (%)					
Teaching hospital	64 (93)	25 (100)	24 (100)	15 (75)	<0.01
Critical care training program	57 (83)	24 (96)	22 (92)	11 (55)	<0.001
Rapid response team	66 (96)	24 (96)	22 (92)	20 (100)	0.63
Electronic patient record	62 (90)	23 (92)	22 (92)	18 (90)	1
Computer physician order entry	56 (81)	21 (84)	21 (88)	14 (70)	0.37
Number of Beds, median (range)					
Adult beds at hospital	611 (10 – 1300)	618 (16 – 1300)	718.5 (10 – 1113)	364.5 (41 – 1113)	<0.01
Adult ICU beds at hospital	82 (4 – 184)	84 (35 – 184)	99.5 (35 – 180)	41 (4 – 158)	<0.001
Adult step down beds at hospital	31 (0 – 539)	36 (0 – 202)	48 (0 – 539)	15 (0 – 202)	0.04
Pediatric ICU beds at hospital	48 (0 – 214)	48 (0 – 122)	50 (0 – 107)	27 (0 – 214)	0.77
Beds in study ICU	16 (4 – 44)	16 (8 – 44)	17.5 (10 – 36)	19 (4 – 33)	0.55
Utilization, median (range)					
Annual ED visits	65660 (0– 156519)	75000 (29816 – 156519)	65660 (29816 – 106000)	54287.5 (0– 106000)	0.02
Annual hospital admissions	34856 (1170 – 56330)	35000 (19021 – 56330)	37580 (19021 – 56330)	23348 (1170 – 56330)	<0.001
Annual study ICU admissions	1299 (230 – 4556)	1200 (581 – 4556)	1119.5 (496 – 2500)	1313 (230 – 3816)	0.46

Abbreviations: Acute Physiology and Chronic Health Evaluation II (APACHE II), Emergency Department (ED).

Table 2

Staffing and organization by Intensive Care Unit (ICU) type.

	All (n=69)	Medical (n=25)	Surgical (n=24)	Mixed (n=20)	P
ICU staffing					
Intensivist in ICU (%)	69 (100%)	25 (100%)	24 (100%)	20 (100%)	1
24/7 intensivist (%)	28 (41%)	9 (36%)	11 (46%)	8 (40%)	0.78
Leapfrog compliant?	57 (83%)	19 (76%)	22 (92%)	16 (80%)	0.37
Median number of ICU fellows (range)	1 (0 – 10)	1 (0 – 4)	1 (0 – 5)	0.5 (0 – 10)	0.95
24/7 ICU fellow	18 (26%)	3 (12%)	11 (46%)	4 (20%)	0.03
Median number of ICU residents (range)	4 (0 – 16)	6 (0 – 16)	3.5 (0 – 9)	3 (0 – 14)	0.04
Median number of RTs in ICU (range)	2 (1 – 7)	2 (1 – 7)	1 (1 – 5)	2 (1 – 3)	0.38
Median number of ICU nurses (range)	10 (2 – 30)	8 (4 – 30)	9.5 (5 – 24)	10 (2 – 30)	0.92
Median ratio of beds to nurses (range)	1.7:1 (0.8:1 – 5.2:1)	1.7:1 (0.8:1 – 4.4:1)	1.7:1 (0.8:1 – 5.2:1)	1.9:1 (0.9:1 – 2.7:1)	0.70
Median number of PAs (range)	0 (0 – 4)	0 (0 – 4)	0 (0 – 4)	0 (0 – 1)	0.18
Median number of NPs (range)	0 (0 – 12)	0 (0 – 5)	0 (0 – 12)	0 (0 – 3)	0.38
Charge nurse provides patient care?	26 (38%)	9 (36%)	10 (42%)	7 (35%)	0.91
ICU Organization, n (%)					
Closed units	40 (58%)	20 (80%)	12 (50%)	8 (40%)	0.02
Mandatory critical care consult in open or semi open units	16 (55%)	1 (20%)	11 (92%)	4 (33%)	<0.01
Has medical director	69 (100%)	25 (100%)	24 (100%)	20 (100%)	1
Has nurse manager	68 (99%)	25 (100%)	24 (100%)	19 (95%)	0.29
Has clinical nurse specialist	57 (83%)	20 (80%)	20 (83%)	17 (85%)	0.92
Electronic ICU coverage	3 (4%)	2 (8%)	1 (4%)	0 (0%)	0.77
CRRT in ICU	59 (86%)	23 (92%)	22 (92%)	14 (70%)	0.09
Sustained Low Efficiency Dialysis	38 (55%)	11 (44%)	13 (54%)	14 (70%)	0.21
ICU rounding practices, n (%)					
Pharmacist on rounds	63 (91%)	25 (100%)	21 (88%)	17 (85%)	0.10
Respiratory therapist on rounds	41 (59%)	13 (52%)	13 (54%)	15 (75%)	0.24
Physical therapist on rounds	7 (10%)	1 (4%)	1 (4%)	5 (25%)	0.04
Social worker on rounds	18 (26%)	6 (24%)	1 (4%)	11 (55%)	<0.001
Nutritionist on rounds	28 (41%)	5 (20%)	9 (38%)	14 (70%)	<0.01

	All (n=69)	Medical (n=25)	Surgical (n=24)	Mixed (n=20)	P
Palliative care on rounds	5 (7%)	1 (4%)	1 (4%)	3 (15%)	0.43
Delirium assessment by nursing	45 (65%)	20 (80%)	14 (58%)	11 (55%)	0.14
Daily goals of care sheet	47 (68%)	17 (68%)	19 (79%)	11 (55%)	0.24
Daily meeting between physician and charge nurse	49 (71%)	17 (68%)	17 (71%)	15 (75%)	0.94
Median number of protocols (range)	19 (5 – 27)	18 (6 – 27)	19 (10 – 27)	18.5 (5 – 27)	0.26

Abbreviations: Respiratory Therapist (RT), Physician Assistant (PA), Nurse Practitioner (NP), Continuous renal replacement therapy (CRRT).

Table 3

Types of protocols available and requirement of physician order by Intensive Care unit (ICU) type, n (%).

Protocol	Available				Physician Order required					
	All (n=69)	Medical (n=25)	Surgical (n=24)	Mixed (n=20)	P	All (n=69)	Medical (n=25)	Surgical (n=24)	Mixed (n=20)	P
Ventilator Management										
Lung protective ventilation	55 (80)	18 (72)	19 (79)	18 (90)	0.34	52 (95)	18 (100)	19 (100)	15 (83)	0.06
Ventilator Weaning	61 (88)	23 (92)	21 (88)	17 (85)	0.81	43 (70)	15 (65)	16 (76)	12 (71)	0.73
Infection Control										
Sepsis treatment	46 (67)	18 (72)	16 (67)	12 (60)	0.73	42 (91)	17 (94)	14 (88)	11 (92)	0.82
Rapid antibiotics	33 (48)	12 (48)	12 (50)	9 (45)	0.95	30 (91)	11 (92)	10 (83)	9 (100)	0.76
Stress ulcer prevention	59 (86)	20 (80)	22 (92)	17 (85)	0.52	54 (92)	19 (95)	19 (86)	16 (94)	0.61
Catheter placement	53 (77)	22 (88)	21 (88)	10 (50)	<0.01	30 (57)	14 (64)	9 (43)	7 (70)	0.30
Oral hygiene	63 (91)	24 (96)	23 (96)	16 (80)	0.17	24 (38)	8 (33)	11 (48)	5 (31)	0.52
Ventilator associated pneumonia prevention	66 (96)	25 (100)	24 (100)	17 (85)	0.02	35 (53)	9 (36)	14 (58)	12 (71)	0.08
Nutrition										
Nutrition	46 (67)	15 (60)	18 (75)	13 (65)	0.53	41 (89)	15 (100)	16 (89)	10 (77)	0.17
Glucose control	66 (96)	24 (96)	24 (100)	18 (90)	0.28	61 (92)	23 (96)	21 (88)	17 (94)	0.62
Electrolyte replacement	56 (81)	18 (72)	23 (96)	15 (75)	0.06	54 (96)	17 (94)	22 (96)	15 (100)	1
Venous Thromboembolism										
Deep vein thrombosis prevention	62 (90)	22 (88)	23 (96)	17 (85)	0.48	58 (94)	21 (95)	21 (91)	16 (94)	1
Venous thromboembolism	55 (80)	17 (68)	21 (88)	17 (85)	0.24	55 (100)	17 (100)	21 (100)	17 (100)	1
Sedation Management										
Daily interruption of sedation	53 (77)	20 (80)	18 (75)	15 (75)	0.88	34 (76)	9 (45)	12 (67)	13 (87)	0.04
Other sedation	45 (65)	18 (72)	17 (71)	10 (50)	0.27	42 (93)	17 (94)	15 (88)	10 (100)	0.60
Delirium assessment	39 (57)	18 (72)	14 (58)	7 (35)	0.05	8 (21)	3 (17)	3 (21)	2 (29)	0.87
Delirium treatment	25 (36)	13 (52)	8 (33)	4 (20)	0.08	25 (36)	13 (100)	8 (100)	4 (100)	1
Neuroprotective										
Acute brain injury	22 (32)	5 (20)	13 (54)	4 (20)	0.02	21 (95)	4 (80)	13 (100)	4 (100)	0.41
Stroke treatment	46 (67)	15 (60)	18 (72)	13 (65)	0.53	46 (100)	15 (100)	18 (100)	13 (100)	1
Intracerebral hemorrhage	23 (33)	7 (28)	11 (46)	5 (25)	0.29	23 (100)	7 (100)	11	5 (100)	1
Hypothermia after cardiac arrest	55 (80)	23 (92)	18 (75)	14 (70)	0.13	55 (100)	23 (100)	18 (100)	14 (100)	1

Protocol	Available					Physician Order required				
	All (n=69)	Medical (n=25)	Surgical (n=24)	Mixed (n=20)	P	All (n=69)	Medical (n=25)	Surgical (n=24)	Mixed (n=20)	P
Early mobility	25 (36)	11 (44)	9 (38)	5 (25)	0.42	15 (60)	5 (45)	5 (56)	5 (100)	0.13
Transfusion										
Transfusion restriction	27 (39)	10 (40)	11 (46)	6 (30)	0.58	20 (75)	8 (80)	6 (55)	6 (100)	0.12
Massive transfusion	30 (43)	9 (36)	11 (46)	10 (50)	0.65	26 (87)	7 (78)	9 (82)	10 (100)	0.42
Other										
Palliative care	33 (48)	12 (48)	9 (38)	12 (60)	0.35	30 (91)	10 (83)	8 (89)	12 (100)	0.47
Acute Coronary Syndrome	39 (57)	13 (52)	13 (54)	13 (65)	0.68	39 (100)	13 (100)	13 (100)	13 (100)	1
Advanced Cardiovascular Life Support/Critical care code	48 (70)	16 (36)	18 (33)	14 (25)	0.72	26 (54)	7 (44)	10 (56)	9 (64)	0.51

Single variable and multivariable linear regression analysis of annual ICU hospital mortality as a function of organizational structure and process factors.

Table 4

	Single variable analysis		Adjusted for APACHE II score and type of ICU		Multivariable analysis	
	% difference in annual ICU mortality (95% CI)	P	% difference in annual ICU mortality (95% CI)	P	% difference in annual ICU mortality (95% CI)	P
Severity of illness						
APACHE II (per unit score)	0.5 (0.01 to 1.1)	0.05			0.3 (−0.3 to 0.8)	0.35
Type of ICU						
Medical ICU	3.0 (0.6 to 5.4)	0.01			5.6 (2.4 to 8.8)	<0.001
Mixed ICU	0.8 (−1.2 to 2.8)	0.44			4.6 (0.4 to 8.7)	0.03
Utilization						
High case volume	3.0 (1.5 to 4.6)	<0.001	−0.6 (−3.4 to 2.2)	0.65	−2.0 (−4.9 to 0.9)	0.17
High bed capacity	0.6 (−1.3 to 2.4)	0.54	−0.2 (−3.2 to 2.7)	0.88	2.0 (−1.6 to 5.6)	0.26
Staffing						
24-hour intensivist	5.6 (4.0 to 7.3)	<0.001	−1.5 (−4.2 to 1.3)	0.29	0.2 (−2.9 to 3.4)	0.89
Bed-to-nurse ratio (per 1:1 unit increase)	2.4 (1.8 to 3.1)	<0.001	2.1 (−0.3 to 4.6)	0.09	3.7 (0.5 to 6.8)	0.02
Trainee-to-bed ratio (per 1:1 unit increase)	2.5 (−1.7 to 6.8)	0.24	2.0 (−5.1 to 9.1)	0.58	2.7 (−3.8 to 9.1)	0.41
ICU organization						
Closed ICU	−2.0 (−3.6 to −0.4)	0.02	2.3 (−0.5 to 5.3)	0.11	2.0 (−0.8 to 4.8)	0.16
Computerized patient order entry	−4.7 (−6.5 to −2.9)	<0.001	−0.5 (−4.2 to 3.2)	0.80	0.5 (−3.1 to 4.1)	0.79
Rounding practices						
Daily plan of care review	−9.6 (−11.3 to −7.7)	<0.001	−6.2 (−10.0 to −2.5)	<0.01	−5.8 (−10.0 to −1.6)	<0.01
Multidisciplinary rounding	−3.6 (−5.2 to −2.0)	<0.001	−0.8 (−3.9 to 2.4)	0.93	0.4 (−2.8 to 3.6)	0.82
Protocols						
Electrolyte protocol	−1.5 (−3.6 to 0.6)	0.15	−4.8 (−8.2 to −1.3)	<0.01	−3.0 (−6.7 to 0.7)	0.11
Mobility protocol	4.6 (2.9 to 6.3)	<0.001	3.3 (0.6 to 6.1)	0.02	1.8 (−1.1 to 4.8)	0.22
Critical care code	−5.2 (−7.4 to −3.0)	<0.001	−0.5 (−3.5 to 2.5)	0.74	1.4 (−1.4 to 4.3)	0.32
Neuroprotective protocol	9.3 (7.5 to 11.2)	<0.001	2.9 (−1.2 to 6.9)	0.17	2.7 (−1.6 to 7.0)	0.21
Delirium management protocol	0.3 (−1.3 to 1.9)	0.35	1.2 (−1.8 to 4.2)	0.42	1.8 (−1.3 to 4.9)	0.26
Transfusion protocol	2.7 (1.2 to 4.3)	0.001	−0.4 (−3.2 to 2.4)	0.78	−1.2 (−4.7 to 2.2)	0.48