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The association of closed-collaborative SICU modeling on emergency general surgery patient outcomes

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A R T I C L E I N F O

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A B S T R A C T

Objective: Surgical intensive care unit (SICU) optimization is a critical factor impacting patient outcomes and resource utilization. SICUs operate using an open or closed model, where the surgeon or intensivist, respectively, manages critically-ill patients. In 2017, we adopted a closed-collaborative model. This study aimed to compare patient outcomes in the closed-collaborative model vs. the previous open model in a cohort of emergency general surgery (EGS) patients.
Methods: A retrospective review of EGS SICU patients from August 2015 to July 2019 was performed. Patients were divided into "Open" and "Closed" cohorts before or after closed-collaborative model implementation on August 1, 2017. Demographic variables and clinical outcomes were analyzed.
Results: We identified 434 patients (O:191; C:243). While no significant demographic differences were observed, there was a higher proportion of patients with qSOFA scores greater than 2 in the closed cohort. There were no differences regarding sepsis, cerebrovascular accident, myocardial infarction, venous thromboembolism, anemia, SICU length of stay (LOS), SICU costs, ventilation requirements, or ventilator duration; mortality rate was higher, but hospital LOS was shorter in the closed cohort.
Conclusion: Overall, outcomes were not statistically different between the two models, despite sicker patients in the closed group, which we suspect accounts for the higher mortality in this group. We expect the decreased hospital LOS observed in the closed cohort improved bed management, patient flow, and ultimately led to institutional cost savings. Further investigation is warranted to examine SICU modeling effects in other surgical specialties and to evaluate potential hospital-level administrative benefits.

Introduction

High quality surgical critical care has been observed as an important contributor to post-operative patient recovery and long-term health. Further, reduced intensive care unit (ICU) length of stay (LOS) has been correlated with improved patient outcomes [1–5,11]. Therefore, optimization of ICU care is a critical factor in maximizing patient health and resource utilization, as ICU management accounts for up to 34% of all hospital expenditures [1].

Depending on institutional preference, the surgical ICU (SICU) can operate using an open or closed model, where the operating surgeon or intensivist, respectively, primarily cares for patients during their ICU stay. Prior studies support improved outcomes in a closed SICU [3–5], yet there is no robust data on the effect of SICU modeling on patients who underwent emergency general surgical (EGS) procedures.

In-line with emerging data at the time, our academic hospital transitioned from an open to a closed-collaborative SICU model on August 1, 2017. In the closed-collaborative model, a dedicated intensivist team rounds on and provides primary care for the patients while they are in the SICU, with the surgical team providing recommendations and

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collaborative input on patient care. We sought to investigate if the transition to a closed-collaborative model corroborated improved outcomes seen in previous literature. In particular, this study focused on comparing patient outcomes and resource utilization in critically-ill EGS patients in the SICU.

Methods

We performed a retrospective cohort study with a pre- vs post- group comparison to analyze patient outcomes and resource utilization at a single academic institution. The primary outcomes for this study were mortality, in-hospital complications, LOS and SICU charges. The study was approved by the Institutional Review Board (IRB) of the University of Arkansas for Medical Sciences as non-human subjects research (IRB #261352) with a waiver of informed consent.

Data was collected using the Arkansas Clinical Data Repository (AR-CDR). Data points captured included the following: patient demographics (age, gender, race, sex, and comorbidities); mortality rates; quick sequential organ failure assessment (qSOFA) scores; sepsis rates; in-hospital complications, including events of anemia, sepsis, cerebrovascular accidents, myocardial infarctions, and venous thromboembolism; SICU LOS; hospital LOS; and SICU charges. qSOFA scores were continually calculated throughout each patients' SICU stay, and the highest recorded score was reported for each patient in the data set. The criteria used in the calculations were altered mental status, defined as GCS <15, tachypnea, defined as a respiratory rate ≥ 22, and hypotension, defined as a systolic blood pressure ≤ 100. For each of the criteria met, one point was added to the score. As comorbid conditions are also a significant predictor of mortality in surgical patients, we compared comorbidities between the open and closed group using the Elixhauser comorbidity index as existing literature has validated its use to predict in-hospital mortality, length of hospitalization, and hospital charges [17]. The Elixhauser comorbidity index for both cohorts were calculated using the standard 30 variables and were identified with ICD-10 coding algorithms.

Patients included in the study were those who underwent an emergency general surgical procedure and required admission to the SICU at the University of Arkansas for Medical Sciences (UAMS) Medical Center from August 1st, 2015 to July 31st, 2019. The surgical cases were numerous and included the full scope of acute care/emergency general surgical procedures. Examples of cases included diagnostic laparoscopy, exploratory laparotomy (including lysis of adhesions, drainage of intraabdominal abscesses, reduction of small bowel volvulus), cholecystectomy (open and closed), laparoscopic appendectomy, colonic and small bowel resection, colostomy and ileostomy, colonoscopy and upper endoscopy, video-assisted thoracoscopic surgery, tracheostomy (traditional open and percutaneous), feeding tube placement (percutaneous endoscopic gastrostomy, open gastrostomy, and jejunostomy tubes), debridement procedures, inguinal and abdominal hernia repairs with and without mesh, and skin grafting. The criteria for admission to the SICU did not change between the open and closed models. We excluded patients who were prisoners at the time of admission, pregnant, minors (under the age of 18), or were otherwise identified as being part of a vulnerable population. We also excluded patients whose stay in the SICU overlapped the transition period. In total, 434 patients met inclusion criteria. Patients were included in the "open" cohort if their SICU admission occurred between August 1, 2015 and July 31, 2017. The "closed" cohort included those patients whose SICU admission occurred between August 1, 2017 and July 31, 2019. We selected 2 years prior to and 2 years after the SICU model changed so that the sample sizes were comparable between the cohorts.

Data analysis included *t*-test and chi-square analyses to compare outcomes between the two cohorts. A separate logistic regression model was used to examine if higher qSOFA scores were predictive of mortality rates in the closed group. The variables included in the regression were age, Elixhauser score, male sex, sepsis, and a qSOFA score >2. The data analysis was done using Stata 15 and SAS 9.4. A p value of 0.05 was used for statistical significance.

Results

We identified 191 patients in the open group and 243 patients in the closed group. There was no significant difference between open and closed cohorts with regards to age, sex, race, or comorbid conditions (Table 1), however the closed group did have a significantly higher portion of patients with a qSOFA score higher than 2 ($p = 0.0167$) (Table 2).

A higher rate of mortality was observed in the closed group, with an increase of 8.05% compared to the open group ($p = 0.0401$). No significant differences were seen between the cohorts regarding in-hospital complications such as sepsis events, cerebrovascular accident, myocardial infarction, venous thromboembolism, pulmonary embolism events, or anemia. In regards to ventilatory requirements, there were no significant differences between the groups for ventilator use rates, ventilation length, or tracheostomy rates. There was no significant difference in SICU LOS, however the closed group did have a significantly decreased hospital LOS by 2 days on average ($p = 0.0473$). The closed group had a trend in reduction of ICU charges, with an average of $21,302.08 in the open group and $21,025.95 in the closed group, however it did not reach statistical significance ($p = 0.9143$). The closed group also showed a slight reduction in antibiotic duration with an average of 5.18 days in the open group and 4.54 days in the closed group, but it did not reach statistical significance. ($p = 0.3554$) (Table 2).

A multiple logistic regression was used to analyze the relationship between mortality and patient outcomes. The results indicate that age, Elixhauser, and being male were not significantly associated with mortality seen in the closed group. It did show that the increased incidence of qSOFA scores >2 was perfectly correlated with increased mortality (Table 3).

Discussion

The results of this study show that despite having a sicker group of patients in the closed cohort, measures of clinical outcomes and in-hospital complication rates were similar to the open cohort. The closed-collaborative model provided an equivalent level of care despite caring for a sicker patient population, as evidenced by a higher proportion of patients with qSOFA score > 2 in the closed cohort. Based on these results, we think the closed-collaborative model provides superior care to the open model and should be utilized when caring for EGS patients.

The SICU at our academic center adopted a "closed-collaborative" model in August 2017. The closed-collaborative model differs somewhat from a typical closed SICU model. In a traditional "closed" ICU care model, the intensivist team assumes full control over decision making and management of critically-ill patients in the ICU, even if the surgical team disagrees with management. In a "closed-collaborative" model, intensivists still function as the primary care providers for ICU patients, but rather co-manage these patients in conjunction and collaboration with the primary surgical teams. If there is a difference in the

Table 1
Population demographics.

Variable	Open ($n = 191$)	Closed ($n = 243$)	p-value
Age, mean ± SD	58.19 ± 16.40	57.47 ± 15.53	0.6380
Male	106 (55.50%)	119 (48.97%)	0.1768
Female	85 (44.50%)	124 (51.03%)	
White	133 (70.24%)	172 (71.02%)	0.2008
African American	53 (27.75%)	57 (23.46%)	
Other race	5 (2.62%)	14 (5.76%)	
Elixhauser score, mean	252.88	238.43	0.2641

Table 2
Patient outcomes.

Variable	Open (n = 191)	Closed (n = 243)	p-value
qSOFA > 2	135 (72.19%)	195 (81.93%)	0.0167
Mortality	31 (16.23%)	59 (24.28%)	0.0401
Sepsis events	94 (49.21%)	133 (54.73%)	0.2533
Cerebrovascular accidents	3 (1.57%)	9 (3.70%)	0.1785
Myocardial infarctions	5 (2.62%)	6 (2.47%)	0.9221
Venous thromboembolisms	2 (1.05%)	7 (2.88%)	0.1833
Pulmonary embolism events	1 (0.52%)	4 (1.65%)	0.2767
Anemia events	9 (4.71%)	10 (4.12%)	0.7629
SICU LOS (days), mean ± SD	5.82 ± 7.68	5.42 ± 5.99	0.5494
Hospital LOS (days), mean ± SD	14.62 ± 14.41	12.25 ± 10.35	0.0473
SICU charges, mean ± SD	$21,302.08 ± $27,959.45	$21,025.95 ± $24,157.04	0.9143
Ventilator required	152 (79.58%)	207 (85.19%)	0.1253
Ventilation length (days), mean ± SD	5.68 ± 8.37	5.65 ± 7.35	0.9707
Tracheostomy required	8 (4.19%)	4 (1.65%)	0.1088
Antibiotic duration (days), mean ± SD	5.18 ± 7.48	4.54 ± 5.44	0.3554

Table 3
Logistic regression analysis for mortality.

	OR	95% CI	p-value
Protocol	1.66	[0.99–2.78]	0.052
Age	1.02	[1.01–1.04]	0.006
Elixhauser mortality	1.02	[1.01–1.04]	0.008
Male	1.07	[0.64–1.77]	0.783
Sepsis	3.06	[1.78–5.26]	0.000

We controlled for SOFA score greater than 2, treated as a categorical variable divided into the closed group with the open group as the referent, but it was omitted and found to be a perfect predictor of mortality.

recommended treatment plans, the SICU attending and surgical attending discuss their plans with each other in an attempt to come up with a mutually agreeable option. If the opinions still differ, the SICU team has the final say in all critical care management decisions. This model provides for autonomy of the intensivist providers to manage patients according to their training and established ICU-specific protocols and guidelines, while still making accommodations for the surgical team's desired management. After discharge from the SICU but before transfer to the general floor, EGS patients were placed in a step down unit with heightened floor-level care. The organization of the step down unit did not change between the open and closed models, as the primary surgical team served as the primary provider in the step down unit throughout the study period.

Our closed-collaborative SICU model utilizes a team-based approach to patient care. With this model, a multidisciplinary SICU critical care team is solely dedicated to the management of SICU patients. The team comprises critical care pharmacists, respiratory therapists, critical care nutritionists, a consolidated group of ICU residents and critical care nurse practitioners, and a board-certified surgical intensivist (surgeons and anesthesiologists) leading the team. The historically open ICU did not have the benefits of a dedicated critical care support team so surgical teams rounded on and managed their patients independently. Also overlapping the transition from an open to a closed-collaborative model was the introduction of a surgical critical care fellowship in July of 2018, adding a fellow to the SICU rounding team. We believe that the dedicated multidisciplinary critical care team based approach of the closed-collaborative model was responsible for static in-hospital complication rates in the face of a sicker group of patients, as well as a 2 day reduction in hospital LOS and a non-significant trend toward decreased ICU charges (Table 2).

EGS patients represent a distinct subset of surgical patients that require ICU care, with upwards of 7%−17% of EGS patients requiring SICU admission following surgery [12,13]. Emergency general surgical patients have also been shown to require significantly longer SICU stays, lengthier periods of mechanical ventilation, and more frequent initiation of continuous renal replacement therapy (CRRT) when compared to other surgical subspecialties (oral-maxillofacial, transplant, neurosurgery, and non-emergent general surgical patients) [7]. Prior literature has also shown that a dedicated emergency general surgery service decreased mortality and LOS when compared to grouping these patients with an elective general surgery cohort [8,9,14], suggesting that the modeling of an EGS service as well as its subsequent SICU admission protocols are highly relevant to outcomes. While our study did not show a direct reduction in mortality, we were able to demonstrate a decreased hospital LOS by 2 days with the closed-collaborative model (p = 0.0473). Further, literature has established that critical care beds comprise up to four times higher cost per day than floor beds [10], making the management of SICU resources a critical factor in hospital-level administrative decisions and resource allocation. While it did not reach statistical significance (p = 0.9143), the SICU charges in the closed cohort had a downward trend of almost $300 per patient despite having sicker patients. Literature has also shown improved clinical outcomes, reduction in antibiotic resistance, and improved cost-control with greater antibiotic stewardship in the ICU [18,19]. The structure of our closed-collaborative multidisciplinary SICU team involves clinical pharmacists to help decide antibiotic duration. Our study showed a non-significant reduction (p = 0.3554) in antibiotic duration in the closed group by more than half a day on average, which could suggest improved choices on antibiotic duration (Table 2).

We believe the increased mortality seen in the closed group is explained by the group having higher qSOFA scores (qSOFA > 2) on average. According to Marik and Taeb, a qSOFA score greater than 2 correlates with high rates of organ failure and has predicted mortality rates greater than 10% [6]. Their study also found that qSOFA score is superior to SIRS criteria for predicting in-hospital mortality. Our regression analysis corroborated this hypothesis with its perfect prediction of mortality by qSOFA being greater than 2 (Table 3).

We believe that the lack of improvement in the in-hospital complication rates in the closed-collaborative model is driven by sicker patients as well as the fact that most of the attending surgeons who provided SICU care to patients in the open model (fellowship-trained acute care surgeons who are also board certified in surgical critical care) are the same physicians who assume the role of primary provider in our closed-collaborative model, with the addition of a few anesthesia intensivists. Upon the adoption of the closed-collaborative model, the EGS surgeons assumed their role as intensivists when they were not staffing the EGS service. Although the training path for a fellowship-trained anesthesia intensivist differs from that of a surgeon intensivist, a study by Matsushima et al. demonstrated that there were only minimal disparities in the care process and showed similar mortality and complication rates when care by anesthesia intensivists and surgeon intensivists were compared in trauma patients [16].

With the single-institution retrospective design, this study carries a limitation in its ability to apply results broadly. In addition, the introduction of standardized critical care protocols and guidelines happened concurrently with the introduction of the closed-collaborative model. Thirdly, overlapping the study period was the incorporation of a surgical critical care fellowship beginning in July 2018. All these factors could confound conclusions about the direct effect of the closed-collaborative model on the observed outcome measures. Additional studies examining the effect of the closed-collaborative model on outcomes in non-EGS patient populations are warranted to see if similar outcomes are seen under this care model.

This study was conducted as part of a larger initiative that evaluated the outcomes of different populations of surgical patients cared for in the SICU at our institution, including cardiac surgical, trauma surgical, and vascular surgical patients. In cardiac SICU patients, a decreased ICU LOS was seen, along with decreased readmission rate and a reduction in SICU charges for the closed-collaborative model [3]. In the trauma SICU patients, mortality and complication rates were similar in the closed-collaborative cohort despite the closed group having higher Injury Severity Scores (ISS ≥ 15), with a reduction in ICU LOS among the most injured patients and a trend towards lower SICU charges for the closed group [15]. The vascular surgery cohort is currently being studied with results soon to be published. Replication of these results outside our institution would also help affirm that a closed-collaborative model of ICU care provides at least equivalent care to the historical open model with respect to EGS patients.

Conclusion

Previous literature has highlighted that SICU modeling carries an effect on patient outcomes, with closed SICU models generally improving mortality. This study contributes to a growing body of research that suggests a closed model provides similar outcomes despite caring for a sicker cohort of patients. Further studies are warranted to explore the possible hospital-level administrative benefits to closed-collaborative SICU modeling in EGS patients as well as other surgical subspecialties.

Author contributions

JWB: Manuscript writing, abstract composition, presentation at SAAS, research submission, AVB: Project conception, recruiting of authors, coordination of submission, AVB, MKK, and HKJ: Project direction, coordination of submission, writing direction and editing, JWB, KRS, and TY: Data, management and organization, IRB writing and application, RJR, SAK, and JLB: Database collection, data management, organization, and statistical analysis.

Disclosure

The authors report no proprietary or commercial interest in any product mentioned or concept discussed in this article. The research team did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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