Original Article

A closed surgical intensive care unit organization improves cardiac surgical patient outcomes

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Background: Intensive care unit (ICU) organization is a critical factor in optimizing patient outcomes. ICU organization can be divided into "OPEN" (O) and "CLOSED" (C) models, where the specialist or intensivist, respectively, assumes the role of primary physician. Recent studies support improved outcomes in closed ICUs, however, most of the available data is centered on ICUs generally or on subspecialty surgical patients in the setting of a subspecialized surgical intensive care unit (SICU). We examined the impact of closing a general SICU on patient outcomes following cardiac and ascending aortic surgery.

Methods: A retrospective cohort of patients following cardiac or ascending aortic surgery by median sternotomy was examined at a single academic medical center one year prior and one year after implementation of a closed SICU model. Patients were divided into "OPEN" (O; n=53) and "CLOSED" (C; n=73) cohorts.

Results: Cohorts were comparable in terms of age, race, and number of comorbid conditions. A significant difference in male gender (O: 60.4% *vs.* C: 76.7%, P=0.049), multiple procedure performed (O: 13.21% *vs.* C: 35.62%, P=0.019), and hospital readmission rates was detected (O: 39.6% *vs.* C: 9.6%, P=0.0003). Using a linear regression model, a closed model SICU organization decreased SICU length of stay (LOS). Using a multivariate logistic regression, being treated in a closed ICU decreased a patient's likelihood of having an ICU LOS greater than 48 hours.

Conclusions: Our study identified a decreased ICU LOS and hospital readmission in cardiac and ascending aortic patients in a closed general SICU despite increased procedure complexity. Further study is needed to clarify the effects on surgical complications and hospital charges.

Keywords: Intensive care; cardiac surgery; postoperative care; closed intensive care; length of stay (LOS)

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Introduction

High-quality surgical critical care has long been observed as an important contributor to post-operative patient recovery and long-term health. Furthermore, though intensive care units (ICUs) on average contain only 5–10% of all hospital beds, they account for up to 34% of hospital expenditures (1). Therefore, optimization of intensive care should be considered a vital step in maximizing patients' health outcomes and resource utilization.

Surgical intensive care service can currently be divided into several broad models. In an open ICU, the operating surgeon remains responsible for patients throughout postoperative care (2). Closed model ICUs are intensivist-based, with post-operative patients transferred to the critical care specialists (2). A third model, a collaborative ICU, is one in which surgeons and intensivists collectively determine care of ICU patients. In a 2007 survey conducted globally across 1,265 ICUs in 75 countries, North America had the lowest proportion of closed ICUs at 63% (3).

On August 1, 2017, an institutional policy change at the University of Arkansas for Medical Sciences (UAMS) transformed the hospital's surgical intensive care unit (SICU) from an open model to a closed model of care. Before this policy change, patient care was driven by the patient's surgical specialty provider. This organization created a new hierarchy of authority in which intensivists assume primary responsibility for patient orders and care following admission to the SICU.

Literature to date has demonstrated improved resource utilization and decreased mortality and length of ICU stay in a closed ICU model compared to an open ICU model (1-7). Most research, however, has centered on ICUs generally or on subspecialty surgical patients in the setting of a subspecialized SICU (1-4,8); thus, the impact of a closed general SICU organization on cardiac surgical patients has remained largely unexplored.

Due to the high-risk nature of cardiac surgery and relative paucity of research on the impact of non-specialized SICU modeling on specialized surgical patients, we designed this retrospective study to assess the effects of ICU organization on patient outcomes following open-heart surgery. We present this article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-22-1471/rc).

Highlight box

Key findings

- Decreased intensive care unit (ICU) length of stay (LOS) and hospital readmission in cardiac and ascending aortic patients in a closed general surgical intensive care unit (SICU) despite increased procedure complexity.

What is known and what is new?

- Recent studies support improved outcomes in closed intensive care units, however, most of the available data is centered on intensive care units generally or on subspecialty surgical patients in the setting of a subspecialized surgical intensive care unit.
- A closed general SICU organization made a difference in ICU LOS and hospital readmission rates for cardiac surgical patients.

What is the implication, and what should change now?

- This study suggests that the advantages of closed SICU organization established in prior studies may be extrapolated to hospitals whose general SICU admits cardiac surgical patients to the intensive care physicians.

Methods

This study is a retrospective, pre-post comparative group analysis of patient outcomes and resource utilization in a closed *vs.* open general SICU in a single academic institution. The primary outcomes were SICU length of stay (LOS), mortality, and SICU charges. This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study protocol was approved by the hospital institutional review board of the University of Arkansas for Medical Sciences (No. 228201) and individual consent for this retrospective analysis was waived.

Following IRB approval, data was sourced from the Arkansas Clinical Data Repository for patients who underwent cardiac or ascending aortic surgery by median sternotomy, including emergent cases, and were subsequently admitted to the SICU 1 year prior and 1 year after implementation of a closed SICU model on August 1, 2017. Patients whose surgery and admission were between August 1, 2016 to July 31, 2017 were cared for in an "OPEN" SICU in which their operating surgical service functioned as their primary team. Those whose surgery and admission fell between August 1, 2017 and July 31, 2018 were admitted to the surgical critical care physicians, comprised of critical care fellowship trained surgeons and anesthesiologists, upon admission to the SICU.

Data requisition included variables regarding demographics (age, race, gender, number of comorbid conditions), procedures performed, hospital and ICU admissions course (LOS, readmission), mortality (in-hospital and 30 days post-discharge), and SICU charges. Patient's race was defined as white, black or other. Pre-operative comorbidities were broken down into four groups based on quantity: 0 comorbidities, 1 comorbidity, 2 comorbidities and 3+ comorbidities. All chronic pre-operative pulmonary comorbidities (including chronic bronchitis, chronic obstructive pulmonary disease, obstructive sleep apnea, obesity hypoventilation syndrome, pulmonary hypertension, and empyema) as well as chronic renal comorbidities (chronic kidney disease, end stage renal disease, and renal cell cancer) were also recorded. Procedures were divided into categories of coronary artery bypass graft (CABG), valve (replacement/repair), aorta (including ascending aortic aneurysms and type A dissections), and other (9 total procedures including sternal debridement, excision of mediastinal mass, and intracardiac tumor removal). Those who underwent more than one of these procedures were categorized as "multiple procedures".

We excluded patients who, at the time of surgery, were under the age of 18, had incomplete records for the outcomes examined, were pregnant, or imprisoned. Those who were not admitted to the SICU at any time, or whose admission overlapped cohort periods were also excluded.

Statistical analysis

Bivariate analysis was conducted to compare sub-group means, OPEN SICU *vs.* CLOSED SICU. Patients with mortality in the ICU were excluded from the LOS and SICU charges analysis. Continuous variables were analyzed using student *t*-tests or Wilcoxon signed rank test. A multivariate logistic regression was conducted to determine predictors of having an ICU LOS greater than 48 hours. A generalized linear model (Poisson family and link log) was used to analyze which variables increase the likelihood of having a longer LOS in days. Data analysis was conducted using SAS 9.4 and Stata 15. Statistical significance was set at α=0.05.

Results

We identified a total of 221 patients who underwent cardiac or ascending aortic surgery by median sternotomy during our study period. Three patients were excluded from the OPEN cohort because they were imprisoned (3 OPEN) and 1 patient was excluded from the OPEN cohort because they were pregnant (1 OPEN). Five patients were excluded because their admission overlapped the cohort periods (2 OPEN, 3 CLOSED), 46 patients were excluded for incomplete chart information (27 OPEN, 19 CLOSED), and 40 patients were excluded because they were not admitted to the SICU at any time (23 OPEN, 17 CLOSED). After exclusion criteria were applied, a total of 126 patients remained, who were then divided into "OPEN" (n=53) and "CLOSED" (n=73) cohorts.

The OPEN and CLOSED cohorts did not vary significantly in age, race, number of comorbid conditions on admission, or pre-operative renal/pulmonary comorbidities (*Table 1*). There were significantly more males in the closed SICU group (*Table 1*). Distribution of procedures across the two groups was also significantly different. The most common procedure group in the OPEN cohort was CABG procedures while the most common procedure group in the CLOSED cohort was multiple procedures (*Table 1*). The closed SICU cohort had a higher percentage of valve procedures, as well as "other" and multiple procedures performed (*Table 1*). There was a significant difference in hospital readmission rates between the two groups (39.6% *vs.* 9.6%, P=0.0003). ICU LOS (days), percentage of ICU stays >48 hours, and mean SICU charges were not significantly different (*Table 1*). Mortality in hospital and within 30 days of discharge also did not vary significantly between the two groups (*Table 1*).

Subgroup analysis was conducted for all patients undergoing CABG or valve procedures (*Table 2*). The OPEN and CLOSED CABG and valve cohorts did not vary significantly in age, race, gender, or number of comorbid conditions (*Table 2*). There was a significant difference in hospital readmission rates between the two groups (32.43% *vs.* 12.20%, P=0.031). ICU LOS (days), percentage of ICU stays >48 hours, and mean SICU charges were not significantly different (*Table 2*). Mortality in hospital and within 30 days of discharge also did not vary significantly between the two groups (*Table 2*).

Controlling for number of comorbidities, multiple procedures, age, gender, and race, we found that age, gender, and race did not have a significant effect on SICU LOS (*Table 3*). In this regression model, being admitted to a closed SICU decreased a patient's chances of having a longer SICU stay (*Table 3*). Compared to patients who only had one procedure, patients who received multiple procedures had an increased likelihood of having a longer ICU LOS (*Table 3*). Compared to patients with no comorbidities, patients with three comorbidities had a significantly higher change of having a longer SICU LOS, but those with one or two comorbidities did not (*Table 3*).

Table 1 Population demographics and patient outcomes of OPEN and CLOSED cohorts

Variable	OPEN SICU (n=53)	CLOSED SICU (n=73)	P value
Age (years), mean ± SD	58.58±10.97	62.79±12.44	0.051
Male, n (%)	32 (60.4)	56 (76.7)	0.049*
Race, n (%)			0.390
White	33 (62.3)	53 (72.6)	
African American	18 (34.0)	19 (26.0)	
Other	2 (3.8)	1 (1.4)	
Comorbidities, median [IQR]	3 [4]	2 [2]	0.512
Pre-op pulmonary dysfunction, n (%)	13 (24.5)	18 (24.7)	0.987
Pre-op renal dysfunction, n (%)	7 (13.2)	10 (13.7)	0.937
Procedures, n (%)			0.019*
CABG	29 (54.72)	25 (34.25)	
Multiple	7 (13.21)	26 (35.62)	
Valve	9 (16.98)	16 (21.92)	
Aorta	7 (13.21)	4 (5.47)	
Other	4 (7.55)	5 (6.85)	
Emergent	3 (5.66)	2 (2.74)	
LOS (days), median [IQR]	7 [8]	8 [9]	0.717
ICU LOS (days), median [IQR]	4 [7]	3 [3]	0.092
ICU LOS >48 hours, n (%)	46 (86.8)	53 (72.6)	0.055
Total ICU charges ($), mean ± SD	16,785.95±25,051.12	13,787.18±16,506.13	0.728
Hospital readmission, n (%)	19 (35.9)	7 (9.6)	0.0003*
Mortality, n (%)			
In hospital	5 (9.43)	3 (4.11)	0.226
Within 30 days	1 (1.89)	1 (1.37)	0.819

*, P≤0.05. SICU, surgical intensive care unit; SD, standard deviation; IQR, interquartile range; CABG, coronary artery bypass grafting; LOS, length of stay; ICU, intensive care unit.

In a multivariate logistic regression, we also identified predictors of having an ICU stay greater than 48 hours. Number of comorbidities, gender, having multiple procedures, and having race defined as "other" were not significant (*Table 4*). In this regression model, being treated in a closed ICU decreased a patient's likelihood of having an ICU LOS greater than 48 hours (*Table 4*).

Discussion

Our study showed that after controlling for confounders, a closed model SICU organization decreases SICU LOS and hospital readmission rates in patients following open cardiac and ascending aortic surgery. Though not statistically significant, the in-hospital mortality rate in the CLOSED SICU group is more similar to that reported in the literature for this patient population of approximately 3–4.4% (9,10).

In addition to our primary outcomes, we noted a higher rate of multiple procedures performed during hospital admission in our closed cohort. Uncertain as to the cause, we first ruled out any additional policy or organizational change that may have been an influence during our study period. Regardless of the cause, increased number and

Table 2 Subgroup analysis of CABG and valve patients with outcomes of OPEN and CLOSED cohorts

Variable	OPEN SICU (n=37)	CLOSED SICU (n=41)	P value
Age (years), mean ± SD	59.7±8.71	63.9±12.21	0.082
Male, n (%)	23 (62.16)	32 (78.05)	0.124
Race, n (%)			0.842
White	22 (59.46)	27 (65.85)	
African American	14 (37.84)	13 (31.71)	
Other	1 (2.70)	1 (2.44)	
Comorbidities, median [IQR]	3 [4]	2 [2]	0.512
LOS (days), median [IQR]	7 [8]	8 [9]	0.407
ICU LOS (days), median [IQR]	4 [7]	3 [3]	0.176
ICU LOS >48 hours, n (%)	32 (86.49)	28 (68.29)	0.057
Total ICU charges ($), mean ± SD	16,424.01±27,192.01	12,236.76±12,485.95	0.728
Hospital readmission, n (%)	12 (32.43)	5 (12.20)	0.031*
Mortality, n (%)			
In hospital	3 (8.11)	0	0.063
Within 30 days	1 (2.70)	1 (2.44)	0.941

*, P≤0.05. CABG, coronary artery bypass grafting; SICU, surgical intensive care unit; SD, standard deviation; IQR, interquartile range; LOS, length of stay; ICU, intensive care unit.

Table 3 Generalized linear model identifying predictors of an increased ICU LOS

Variable	Coefficient	95% CI	P value
CLOSED SICU (reference: OPEN)	−0.31	−0.47 to −0.16	<0.001
Number of comorbidities (reference: 0)			
1	−0.06	−0.42 to 0.29	0.735
2	0.06	−0.32 to 0.44	0.749
3+	0.59	0.27 to 0.92	<0.001
Multiple procedures	0.27	0.10 to 0.43	0.002
Age	−0.001	−0.008 to 0.005	0.718
Male	0.008	−0.16 to 0.17	0.924
Race (reference: White)			
Black	−0.11	−0.28 to 0.05	0.178
Other	−0.40	−0.92 to 0.13	0.137

ICU, intensive care unit; LOS, length of stay; CI, confidence interval; SICU, surgical intensive care unit.

Table 4 Multivariate logistic regression identifying predictors of ICU stay greater than 48 hours

Variable	Odds ratio	95% CI	P value
CLOSED SICU (reference: OPEN)	0.24	0.07–0.85	0.027
Number of comorbidities (reference: 0)			
1	0.74	0.13–4.39	0.741
2	043	0.07–2.46	0.341
3+	1.20	0.23–6.24	0.831
Multiple procedures	2.33	0.64–8.44	0.197
Age	1.03	0.99–1.08	0.177
Male	0.36	0.10–1.33	0.125
Race (reference: White)			
Black	1.41	0.44–4.56	0.571
Other	0.06	0.003–1.25	0.07

ICU, intensive care unit; CI, confidence interval; SICU, surgical intensive care unit.

complexity of operations were predictably associated with longer ICU stays, effectively monopolizing the valuable resource that is SICU bed availability. Additional procedures accrue more hospital charges and complicate recovery, which could have clouded the effects of ICU organization in our evidence. One certainly would expect worse outcomes in such a setting, yet we observed reduced LOS and no difference in charges.

There was no significant difference in SICU charges between the two groups, however the gap between average means in closed *vs.* open modeling was near $3,000. If future studies could substantiate this trend, this would be a major finding that positively impacts both hospital resources and patient finances. There was a large range of SICU total charges, LOS, and number and type of procedures performed within each cohort; any number of these factors could have contributed to obscuration of significant findings regarding reduction of charges. Future research should perhaps address charges on a per-SICU-day basis to better clarify the effects on patient and hospital resource utilization. Also highlighted by our study was the significant difference observed in hospital readmission. The reduction in charges to the hospital and costs to the patient achieved by decreased readmission is intangible but likely substantive. Any statistical analysis of this effect was beyond the scope of our study.

Surgeons often possess a sense of responsibility and protection toward their patients, having invested many hours into understanding specific patient cases, performing complex surgeries, and training for years to understand the procedures and potential postoperative complications. In the setting of a closed SICU, there is potential for increased conflict if good communication is not employed (11). It can also be disconcerting for patients when their operating surgeon is no longer at the helm of their medical care, and continuity of care somewhat disrupted. Alternatively, surgical critical care physicians are trained specifically to manage high-risk patients with diverse disease etiologies and often pursue post-residency education in critical care, that they be best prepared for careers balancing high acuity patients at every step of recovery; these factors lead to concern that patient care is threatened when not admitted directly under their intensive service. We hope that the results observed in our study may lend in resolving trepidation felt by patient, surgeon, and intensivist alike, in that a closed model SICU is most beneficial to patient recovery, that critical care physicians are fully equipped to expertly manage patients following complex procedures, and that this apparent dichotomy of care reduces time spent in the SICU and chance of being readmitted as well as increase patient satisfaction (12).

There are several limitations to our study, including being a retrospective single institution analysis with a relatively small sample size. This factor restricted our ability to assess outcomes that were uncommon following cardiac surgery, namely mortality and complication rates in the SICU, as well as limited the generalizability of our findings and power of our study. There are also patient selection, institutional policy, individual surgeon, and procedure variables that affect outcomes that cannot be fully appreciated in a retrospective review, and may serve as confounders. The definition of "prolonged" ICU LOS after cardiac surgery is widely variable in the literature (24 hours to 7 days), which presents difficulty in asserting if our reported ICU LOS is a good representation of this population (13). Our institution faces similar struggles as most medium sized hospitals regarding availability of step-down units and floor beds, which may have impacted the ICU LOS outcome. There is possibility for the introduction of selection bias due to inconsistencies in data collection over the study period, though there were no hospital data acquisition policy changes during this time. Despite this, we were able to identify several improvements to patient outcomes in a closed SICU model and recognize several additional factors meriting further discussion.

Additional larger scale studies are needed to clarify the impact of a closed SICU on postoperative complications as well as hospital charges. Further studies should also address if the effects observed in a population of cardiac surgical patients may translate to patients of additional surgical subspecialties.

Conclusions

This study suggests that the advantages of closed SICU organization established in prior studies may be extrapolated to hospitals whose general SICU admits cardiac surgical patients to the intensive care physicians. Our data suggests that closed general SICU organization made a difference in ICU LOS and hospital readmission rates for cardiac surgical patients.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-22-1471/rc

Data Sharing Statement: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-22-1471/dss

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-22-1471/coif). K.K. reports academic grants from the UAMS Translational Research Institute, and is a Trauma Medical Consultant for the Arkansas Trauma System, Site Designation Verifier for the Arkansas Trauma System, Qsource consultant for the Arkansas Preventable Mortality Committee, and ATLS instructor for the Arkansas Trauma Society. K.S. reports academic grants from the NIH, consulting fees from Datafy, LLC, and stock options for Decision Healthcare INC and Hoopcare Inc. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study protocol was approved by the hospital institutional review board of the University of Arkansas for Medical Sciences (No. 228201) and individual consent for this retrospective analysis was waived.

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