Effect of Intensive Care Unit Organizational Model and Structure on Outcomes in Patients with Acute Lung Injury

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Rationale: **Prior studies supported an association between intensive care unit (ICU) organizational model or staffing patterns and outcome in critically ill patients.**

Objectives: **To examine the association of closed versus open models with patient mortality across adult ICUs in King County (WA).**

Methods: **Cohort study of patients with acute lung injury (ALI).**

Measurements and Main Results: **ICU structure, organization, and patient care practices were assessed using self-administered mail questionnaires completed by the medical director and nurse manager. We defined closed ICUs as units that required patient transfer to or mandatory patient comanagement by an intensivist and open ICUs as those relying on other organizational models. Outcomes were obtained from the King County Lung Injury Project, a population-based cohort of patients with ALI. The main endpoint was hospital mortality. Of 24 eligible ICUs, 13 ICUs were designated closed and 11 open. Complete survey data were available for 23 (96%) ICUs. Higher physician and nurse availability was reported in closed versus open ICUs. A total of 684 of 1,075 (63%) of patients with ALI were cared for in closed ICUs. After adjusting for potential confounders, patients with ALI cared for in closed ICUs had reduced hospital mortality (adjusted odds ratio, 0.68; 95% confidence interval, 0.53, 0.89; $P = 0.004$). Consultation by a pulmonologist in open ICUs was not associated with improved mortality (adjusted odds ratio, 0.94; 95% confidence interval, 0.74, 1.20; $P = 0.62$). These findings were robust for varying assumptions about the study population definition.**

Conclusions: **Patients with ALI cared for in a closed-model ICU have reduced mortality. These data support recommendations to implement structured intensive care in the United States.**

Keywords: intensive care unit; intensivist; outcome; practice patterns; Leapfrog Group

A number of intensive care unit (ICU) structure and organization factors have been associated with improved patient outcome. The presence of a critical care team (1, 2), a full-time director (3), a closed unit (4–7), 24-hour intensivist coverage (8), a stable nurse–patient ratio around the clock (1), higher hospital volume (9), pharmacist consultation on ICU rounds (10), computerized physician order entry (11), and good nurse–physician interaction (12) have all been associated with improved patient outcome. A recent systematic review indicated that high-intensity physician staffing, where intensivists manage or comanage all patients, was associated with reduced hospital and ICU mortality and hospital and ICU length of stay (13). The Leapfrog Group, a U.S. business consortium of more than 150 private and public health care sector purchasers, now recommends that board-certified critical care specialists be available during daytime hours and be able to return to the ICU or arrange for an onsite physician to do so within 5 minutes of being paged. The group estimated that applying ICU physician safety staffing standards could save more than 54,000 lives in the United States each year (14). The Task Force on Guidelines of the Society of Critical Care Medicine promoted a list of recommendations for critical care delivery in the ICU, indicating that "a multidisciplinary ICU team should be led by a full-time critical care–trained physician available in a timely fashion to the ICU 24 hours per day," and that ICUs operating in the closed format may have improved outcomes (15).

AT A GLANCE COMMENTARY

Scientific Knowledge on the Subject

Previous studies have shown possible benefits of intensivist physician staffing on outcomes in critically ill patients. However, the vast majority of these investigations were designed as before–after studies in single academic centers.

What This Study Adds to the Field

In a cohort study of patients with acute lung injury, admission to a closed-model intensive care unit was associated with reduced mortality independently of patients' characteristics. These findings support recommendations to implement closed-model intensive care units in the United States.

However, most of the evidence supporting the relationship between ICU organization and outcome is based on before–after comparisons at single academic institutions (13, 16, 17). These studies are limited because of concerns about secular trends in outcomes, ability to control for confounding variables, and generalizability of single-center studies. Relatively few studies using large cohorts of patients with well-defined critical illness syndromes have explored this question (18–22).

We used data from a population-based prospective cohort study evaluating the incidence and outcomes of acute lung injury (ALI) and data from a survey of clinicians at the study sites to address the question of the relationship between ICU organization and mortality in patients with ALI (23).

METHODS

Patient Cohort

The methods and results of the population-based prospective cohort study (the King County Lung Injury Project [KCLIP]) used in this

(*Received in original form January 31, 2007; accepted in final form June 7, 2007*)

Supported by a grant from the Swiss National Science Foundation (SCORE 3232-069341), and grants from the National Institutes of Health (SCORHL30542 and 2R01HL67939).

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Am J Respir Crit Care Med Vol 176. pp 685–690, 2007
Originally Published in Press as DOI: 10.1164/rccm.200701-165OC on June 7, 2007
Internet address: www.atsjournals.org

analysis have been described elsewhere (23). Briefly, from April 1999 through July 2000, all patients in ICUs in the Seattle area receiving invasive or noninvasive mechanical ventilation were screened by research respiratory therapists and ICU nurses using a validated algorithm to identify patients who met the definitions of the American European Consensus Conference for ALI and the acute respiratory distress syndrome (ARDS) (24). The criteria are as follows: presence of acute hypoxemia with a Pa_{O_2}:FI_{O_2} of 300 mm Hg or less (for ALI) or of 200 mm Hg or less (for ARDS), bilateral infiltrates (including very mild infiltrates) seen on a frontal chest radiograph that are consistent with pulmonary edema, and no clinical evidence of left atrial hypertension or a pulmonary artery wedge pressure of 18 mm Hg or less if measured. For the purpose of the study, the qualifying Pa_{O_2}:FI_{O_2} ratio was the worst value on the first day on which the Pa_{O_2}:FI_{O_2} ratio was 300 mm Hg or less. Detailed data were collected from the medical record, including the components of the APACHE III (Acute Physiology and Chronic Health Evaluation III) score, comorbidities, surgical status, ICU and hospital length of stay, and hospital discharge disposition. The sample size of the full cohort was 1,113. Patients who met other criteria for ALI while receiving noninvasive ventilation or receiving an FI_{O_2} of less than 0.4 were not included in the original epidemiologic cohort and are not included in this analysis. Patients with ALI from two pediatric hospitals and from three hospitals geographically outside of King County that cared for a small number of King County residents were excluded from this analysis (n = 38, 3.4%). Finally, data from the Washington State Comprehensive Hospital Abstract Reporting System (CHARS) were used to control for overall volume of mechanically ventilated patients at nonfederal hospitals in the cohort during the study period. The CHARS system is a database managed by the Department of Health designed to collect hospital inpatient discharge data.

ICU Survey of Organization, Structure, and Process of Care

We constructed two questionnaires, addressed to the medical director or the attending physician having a daily presence in the unit, and the nurse manager responsible for the unit. If one of these individuals was responsible for more than one ICU in the hospital, he or she was asked to fill out separate surveys for each ICU and these survey responses were treated independently. Surveys were distributed between June and December 2000; however, respondents were asked to assess practices during the cohort study periods. The University of Washington Institutional Review Board approved the survey.

The questionnaires were developed to obtain information about the structure and organizational characteristics of the ICUs, interactions among providers, providers' respective responsibilities, and process of care. Four domains were investigated: (*1*) organization of the unit, including intensivist and nursing staffing and availability of support staff; (*2*) structure of the ICU, including number of hospital and ICU beds, and occupancy rate; (*3*) academic involvement, including whether residents were assigned to provide any care in the ICU; and (*4*) patient care with emphasis on processes of care for patients receiving mechanical ventilation. Specific items were adapted from previous surveys on ICU structure and process (25–27), and additional questions were designed to capture the recommendations formulated by the Society of Critical Care Medicine (15, 28) and by the Leapfrog Group (14). Content validity was assessed by having each instrument reviewed by experts in the field and by small groups in each respondent category before the research began, and by using pretests with cognitive debriefing to determine if each question captured the intended domain. Reliability and validity were assessed by comparing responses with similar items from different respondents.

Our main independent variable was ICU organizational model. Closed ICUs were defined as units that transferred all patients to an intensive care team that directs their care with primary responsibility for the therapeutic plan and patient care or to units where a consultation from an intensivist who shares responsibility with the admitting physician was mandatory for all patients admitted to the ICU (15, 29). Mandatory consultants were pulmonary physicians in all units. Additional mandatory consultants were cardiologists in three units and surgeon intensivists in a trauma unit. Open ICUs were defined as units where any attending physician with ICU admitting privileges can be the physician of record and direct ICU care. In the survey, an intensivist was defined as a board-certified critical care specialist. After linking surveys to the KCLIP database, all identifying information about the hospitals was excluded from the analytic database.

Data Analysis

Descriptive statistics comparing the structures and processes of care between closed and open ICUs, and between patients cared for in open and closed ICUs, are expressed as a percentage, mean, or median with appropriate measures of variation and statistical tests depending on the distribution of the variable. Unpaired Student t test and Pearson χ^2 test for independence were used to compare structure and process of care between ICUs with a closed versus open format (organizational model). To account for clustering within ICU, generalized estimating equations were used to estimate the independent effect of ICU organizational model on hospital mortality and ICU and hospital length of stay in patients with ALI. The correlation structure was assumed to be exchangeable. Due to their skewed distribution, hospital and ICU length of stays were log transformed before fitting the regression model. The log distributions of both ICU and hospital stay appeared to be symmetric after transformation. We chose not to perform a propensity score–based analysis (30–33). Patient-level adjustments for demographic variables (age, sex, race, and surgical status) and disease severity (APACHE III score) were performed in these analyses. Although survey data were incomplete for one ICU, there was adequate information to include all 24 ICUs in multivariate models. Multivariate analyses were completed using SAS, version 9.1, for Windows (SAS Institute, Inc., Cary, NC).

RESULTS

ICU Characteristics

Sixteen hospitals with 24 ICUs, 23 medical directors, and 22 nurse managers were eligible to participate in this study. Completed surveys were received from 22 medical directors (96% of ICU directors) and 22 nurse managers (100%). One medical director did not return the questionnaire, and one director was responsible for and responded about two ICUs, yielding complete survey data on 23 of the 24 ICUs. Information on the organizational model for the nonrespondent to the survey was obtained by contacting other ICU physicians working in that ICU, providing complete data on intensivist staffing at all 24 ICUs.

The 16 hospitals and 24 ICUs varied widely in size: the median available hospital acute care beds was 258 (range, 38–639), and the median available ICU beds per unit was 15 (range, 2–48). Seven of the 16 hospitals had some affiliation with the University of Washington, of which three were primary teaching hospitals. Thirteen of the ICUs met the definition for closed-model ICU and 11 were open-model ICUs.

There was high agreement between 22 medical directors and 22 nurse manager responses with regard to ICU organizational model. Two responses were discordant (9%), and the discrepancies were resolved by recontacting the respondents for data verification.

The medical director survey indicated that 15 directors out of 22 (68%) were certified in critical care medicine; four directors with a primary specialty in cardiology did not have a critical care certification (Table 1). Depending on the ICU, the team working in closed units included pulmonologists, internists, anesthesiologists, and surgeons, whereas the comanaging physicians were pulmonologists and cardiologists. The time of coverage by a board-certified critical care specialist physically in the unit on weekdays was 8.9 ± 1.2 hours for closed units and 5.5 ± 1.2 hours for open ICUs ($P = 0.07$). During the weekend, the hours of intensivist coverage were higher in closed units compared with open ICUs (6.9 ± 1.0 vs. 5.1 ± 1.0 h, respectively; $P = 0.05$). Physicians were reported to be available by phone or present within 5 minutes in more closed units than

TABLE 1. INTENSIVE CARE UNIT STRUCTURE AND ORGANIZATION ACCORDING TO INTENSIVE CARE UNIT MODEL

Characteristics	Open ICUs (*n* = *11*)	Closed ICUs (*n* = *12*)*	Survey Respondent	*P* Value†
Director's specialty‡	n = 10§	n = 12		
Internal medicine	9	10		
Pulmonary and critical care	7	8		
Cardiology	2	2	MD	0.85‖
Surgery	1	2		
Anesthesiology	0	0		
Critical care certification, n (%)	7 (70)	8 (67)	MD	0.87
Intensivist coverage, mean h/d ± SD			MD	
Weekdays	5.5 ± 1.2	8.9 ± 1.2		0.07
Weekends	5.1 ± 1.0	6.9 ± 1.0		0.05
Intensivist available within 5 min by pager, n (%)	7 (64)	11 (92)	MD	0.10
Intensivist physically present in the unit within 5 min, n (%)	3 (27)	6 (50)	MD	0.26
Residents assigned to the ICU, mean n ± SD	1 ± 1.8	4.1 ± 3.8	MD	0.02
ICUs affiliated with the University of Washington, n (%)	5 (45)	8 (67)	MD	0.30
Nurse-to-patient ratio	1:2	1:1.75	NM	0.047
Justification of ICU admission, % ± SD¶			NM	
Intensive treatment	34.5 ± 5.0	52.9 ± 7.7		0.067
Intensive monitoring with high risk of active intervention	38.0 ± 3.5	25.4 ± 4.3		0.039
Monitoring with low risk of active intervention	20.5 ± 3.4	16.5 ± 7.4		0.65
Terminally ill patients with poor prognosis	7.0 ± 1.3	4.3 ± 1.0		0.12

Definitions of abbreviations: ICU = intensive care unit; MD = medical director; NM = nurse manager.

* One director from a closed ICU did not return the questionnaire.

† Student *t* test, comparing open- versus closed-ICU models.

‡ Numbers do not sum to group totals because some physicians reported more than one specialty.

§ Open ICUs, n = 10, because one director was responsible for two ICUs.

‖ Comparing internal medicine versus all other specialties.

¶ Examples to describe type of admission as it relates to intensity of monitoring were as follows: Intensive treatment: hemodynamically unstable patients, patients with acute respiratory distress syndrome; intensive monitoring with high risk of active intervention: acute medical or surgical illness in patients with chronic comorbid conditions, acute asthma, diabetic ketoacidosis; monitoring with low risk of active intervention: postcarotid endoarterectomy, vertebral laminectomy, postsurgical monitoring; terminally ill patients with poor prognosis: respiratory failure in patients with end-stage cancer, limits on therapy.

open units; however, the differences were not statistically significantly different. There were 4.1 ± 3.8 residents regularly assigned to the unit in closed units, and 1.0 ± 1.8 in open units ($P = 0.02$). A pharmacist involved in daily rounds provided recommendations on drug prescriptions in 83% of the closed units and in 80% of the open units. No computer-assisted drug order entry was reported by any unit.

The nurse survey indicated that the bed occupancy rate was 73 ± 23%, and tended to be higher among closed ICUs compared with ICUs organized as an open model (81 ± 18% vs. 64 ± 25%, respectively; $P = 0.08$). The source and justification of ICU admission are shown in Table 1. Overall, the indication for ICU admission was intensive treatment (45%), high-risk intensive monitoring (31%), low-risk intensive monitoring (19%), and terminally ill patients (5%). However, closed units had a higher proportion of patients admitted for intensive treatment than open units (53 vs. 35%, $P = 0.07$) and a lower proportion of patients requiring intensive monitoring with high risk of active intervention (25 vs. 38%, respectively; $P = 0.04$). The ICU nurse-to-patient ratio was reported as higher in closed compared with open ICUs during the day (1:1.75 vs. 1:2, respectively; $P = 0.05$), as well as during the night (1:1.75 vs. 1:2, respectively; $P = 0.03$). All ICUs, with the exception of one open unit, reported the ability to increase their nurse-to-patient ratio to 1:1 if necessary based on acuity. The respiratory therapist–to–patient ratio was not different between open and closed ICUs (1:3.5 in open ICUs and 1:4.6 in closed ICUs, $P = 0.109$). Protocols for patients requiring mechanical ventilation were available in 58% of closed units and in 80% of open units ($P = 0.28$). Criteria and monitoring requirements for transferring a patient out of the ICU were very similar across all types of units.

Effect of ICU Organization on Mortality in Patients with ALI

A total of 1,075 patients with ALI were cared for in the study hospitals, 684 (64%) in closed ICUs and 391 (36%) in open ICUs (Table 2). Patients cared for in the closed ICUs were more likely to be male, were younger, were less likely to receive injurious mechanical ventilation (>12 ml/kg of predicted body weight [PBW]), were more likely to receive lung protective ventilation (<6.5 ml/kg PBW) on Day 3 after onset of ALI, and had lower unadjusted mortality. There was no statistically significant difference in severity of illness in patients cared for in these ICUs as measured by either the APACHE III score or the acute physiology component of the APACHE III score. Although the majority of patients in this cohort were seen by a pulmonary consultant at some point during their illness, patients in the closed ICUs were more likely to be seen by a pulmonary consultant (77% in closed vs. 68% in open ICUs, $P < 0.01$). Duration of mechanical ventilation and ICU length of stay were not statistically different in the two types of ICUs.

In a regression model adjusting for confounding variables, patients cared for in a closed ICU had statistically significantly lower mortality than patients cared for in open ICUs (adjusted odds ratio [OR], 0.68; 95% confidence interval [CI], 0.53–0.89; $P = 0.004$; Table 3). Considering that the mortality endpoint was not a rare event and that the OR could have overestimated the relative risk, applying the Zhang and Yu correction of the OR yielded an adjusted relative risk of 0.79 (34). This relationship was robust to a number of changes in the regression model and modifications to the study cohort (*see* Figure 1). The effect of a closed ICU model was not affected by including the reported average nurse-to-patient ratio in the base model (adjusted OR, 0.74; 95% CI, 0.60–1.20; $P = 0.006$). Importantly,

TABLE 2. CHARACTERISTICS OF PATIENTS

Characteristics	Open ICU (*n* = *11*) (*n patients* = *391*)	Closed ICU (*n* = *13*) (*n patients* = *684*)	*P* Value
Hospital admit, n (%)			
From home	301 (77)	520 (76)	
From other hospital	28 (7)	66 (10)	0.34
From nursing home/other	62 (16)	98 (14)	
Male sex, n (%)	220 (56)	440 (64)	0.01
ALI risk factor, n (%)			
Sepsis	308 (79)	460 (67)	
Trauma	0 (0)	64 (9)	<0.001
Other	83 (21)	160 (23)	
Admitted postoperatively, n (%)	81 (21)	148 (22)	0.73
Pulmonary consultation, n (%)	265 (68)	530 (77)	<0.001
Tidal volume on Day 3 of ALI	n = 277	n = 482	
>12 ml/kg PBW, n (%)	85 (31)	50 (10)	<0.001
<6.5 ml/kg PBW, n (%)	14 (5)	54 (11)	0.004
Age, mean yr ± SD	66.1 ± 15.6	57.3 ± 18	<0.001
APACHE III, mean score ± SD	88.1 ± 31.3	86.9 ± 33.9	0.55
Acute physiology score from APACHE III, mean ± SD	73.2 ± 30.5	75.6 ± 32	0.22
Duration of mechanical ventilation, median d (IQR)	5.1 (2.1–11.4)	5.5 (2.1–10.2)	0.79
ICU length of stay, median d (IQR)	8.3 (3.8–14.3)	7.7 (3.6–14.2)	0.39
ICU length of stay among survivors, median d (IQR)	9.5 (4.2–15.4)	8.3 (4.4–15.1)	0.284
ICU length of stay among nonsurvivors, median d (IQR)	6.6 (3.0–13.8)	6.4 (2.7–11.4)	0.377
Hospital length of stay, median d (IQR)	14 (7–21)	15 (8–26)	0.06
Hospital mortality, n (%)	175 (45)	239 (35)	0.002

Definitions of abbreviations: ALI = acute lung injury; APACHE III = Acute Physiology and Chronic Health Evaluation III; ICU = intensive care unit; IQR = interquartile range; PBW = predicted body weight.

ICU organization was associated with reduced mortality after adjusting for hospital volume for mechanically ventilated patients (9). The relationship persisted regardless of whether the patient was ever seen by a pulmonologist in consultation. In open ICUs, 68% of patients were seen in consultation by a pulmonologist at any time during their ICU stay. Using the base model in Table 3, restricting the analysis to open ICUs, and substituting consultation by a pulmonologist for ICU organization, there was no effect of pulmonologist consultation on mortality in open ICUs (adjusted OR, 0.94; 95% CI, 0.74, 1.20; $P = 0.62$). There was no effect of ICU organization on duration of mechanical ventilation, ICU length of stay (adjusted ratio of medians in survivors: 0.99; 95% CI, 0.86, 1.13; $P = 0.87$; nonsurvivors: 1.00; 95% CI, 0.91, 1.09; $P = 0.97$), or hospital length of stay (adjusted ratio of medians in survivors: 1.06; 95% CI, 0.94, 1.20; $P = 0.34$; nonsurvivors: 1.03; 95% CI, 0.96, 1.10) in the total cohort or when analyzed separately by mortality.

TABLE 3. GENERALIZED ESTIMATING EQUATION MODEL OF ACUTE LUNG INJURY MORTALITY IN PATIENTS RECEIVING CARE IN CLOSED VERSUS OPEN INTENSIVE CARE UNITS

Variable	Odds Ratio	95% Confidence Interval	*P* Value
ICU model*	0.68	0.53, 0.89	0.004
APACHE III†	1.03	1.02, 1.03	<0.001
Age‡	1.01	1.00, 1.02	0.020
Race§	0.98	0.79, 1.22	0.846
Sex‖	0.80	0.65, 0.99	0.039
Postoperative status	0.67	0.47, 0.95	0.026
Residency program¶	0.89	0.70, 1.13	0.340
Primary risk sepsis	1.31	1.00, 1.72	0.049

Definition of abbreviations: APACHE III = Acute Physiology and Chronic Health Evaluation III; ICU = intensive care unit.

Total n = 24 ICUs and 1,075 patients.

* Comparing closed versus open (reference) ICU model.

† APACHE III score at ICU admission, 1-point difference.

‡ One-year difference.

§ White versus other.

‖ Males versus females.

¶ Residents have some role in care of critically ill patients.

DISCUSSION

ICUs that require patient transfer to an intensivist run team or mandate a coattending intensivist are associated with reduced mortality in patients with ALI (adjusted OR, 0.68; 95% CI, 0.52–0.89). The association between ICU organization and hospital mortality persisted after modifying the model to account for severity of illness, transfer status of patients, hospital volume for mechanically ventilated patients, risk factor for ALI, and academic status. This effect was independent of, and was not confounded by, whether a patient ever received consultation by a pulmonologist, suggesting that optional pulmonary consultation cannot substitute for a change in ICU organization. Recently, a report from the Committee on Manpower for Pulmonary and Critical Care Societies (COMPACCS) survey, a joint project by the American Thoracic Society, the Society of Critical Care Medicine, and the American College of Chest Physicians, indicated that only 25% of ICUs provide intensivist management to a majority of patients (35).

Although the mechanisms by which closed ICUs might reduce mortality are complex, these ICUs were different with regard to intensity of staffing, as indicated by greater presence of critical care physicians in the ICU, higher number of residents, and high nurse-to-patient ratio. Incorporating these factors into regression analyses did not account for the observed effect of a closed ICU. These findings are consistent with the effect noted in other studies of intensivist staffing, which report an approximately 30% reduction in the odds of death associated with ICUs managed by intensivists (4, 13, 36). No ICU reported use of computerized physician order entry systems. Most of the units had protocols for mechanical ventilation and sedation, and received drug recommendations by a pharmacist. Although a large number of protocols were in place in all types of ICU models, their reported availability in the survey may not reflect use and use may not affect performance (37). A previous study

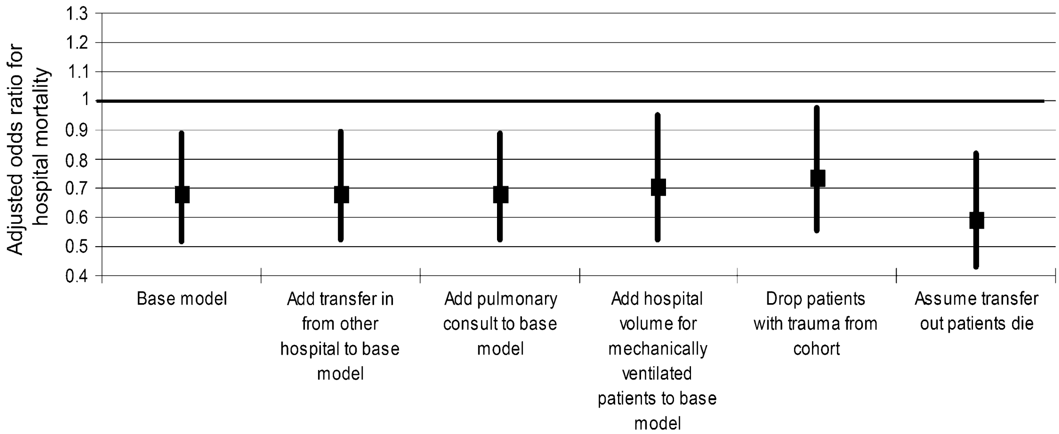

Figure 1. Sensitivity analyses of regression models of effect of closed intensive care unit on hospital mortality.

suggested that organizational characteristics of ICUs with the availability of full-time ICU physician staffing were associated with a two-thirds reduction in the probability of pulmonary artery catheterization (38). Although we have limited data on process of care for these patients, one potential explanation for the reduced mortality is that patients in open ICUs had triple the risk of receiving injurious (>12 ml/kg PBW) tidal volumes, whereas patients in closed ICUs were almost three times more likely to receive lung-protective tidal volumes (⩽6.5 ml/kg PBW) on Day 3 of mechanical ventilation after ALI onset.

These data are particularly important because they address limitations of previous studies, which were primarily before–after studies with historical controls in single academic centers and which might have suffered from residual confounding, temporal trends, and unexplained cointerventions. This study expands the limited evidence on the effect of organizational characteristics from observational cohort studies of patients undergoing abdominal aortic aneurysm surgery (1, 19) and patients sustaining trauma (18), experiencing intracerebral hemorrhage (20), or being admitted to neuroscience ICUs (16, 17), to patients with ALI, a common cause of critical illness.

This study has the potential limitations of many observational studies, including bias by indication, residual confounding, and measurement error. Patients with significant trauma were all cared for in a closed ICU in the single level 1 trauma center in the cohort. However, excluding these patients from the analysis did not affect the results in an important way. The analysis of the effect of pulmonary consultation is also subject to bias by indication because patients who are getting sicker under routine care are probably more likely to receive pulmonary consultation. This bias could not be completely accounted for in the analysis. Residual confounding is always a concern in epidemiologic studies; however, the results were robust to varying the model and after controlling for factors associated with care in a closed ICU. The survey relied on self-report of ICU structure and processes and therefore could have been inaccurate. However, items from the survey were developed from existing instruments and many were asked to each of two respondents. The most important item in the survey, ICU organization, was verified by independent agreement by both respondents and verified in the two discordant cases. Because of the small sample size of hospitals and the date of the data collection, it is difficult to use these data to extrapolate to general trends in ICU organization in the United States as a whole or to measure the differences in processes of care between ICUs. Although our regression and sensitivity analyses support the conclusion that it is the intensivist staffing model that accounts for the observed mortality effect, the observational nature of this study limits our ability to exclude the contribution of other features of these units.

Conclusions

In conclusion, only half of King County ICUs used closed models in 2000. Patients with ALI cared for in these ICUs had a 32% reduction in the odds of death after adjusting for potential confounders related to patient and ICU factors. Elective pulmonary consultation did not appear to affect mortality in open ICUs and therefore may not substitute for a closed ICU structure. Closed ICUs reduce mortality through complex mechanisms that include, but may not be limited to, intensivist staffing. The use of low tidal volume in patients with ALI was different between closed and open ICUs, and it is possible that unrecognized differences in other patient care processes existed. These data provide additional support for the effect of a closed-model ICU on the outcome of a common critical illness syndrome in a well-described population-based cohort.

Conflict of Interest Statement: None of the authors has a financial relationship with a commercial entity that has an interest in the subject of this manuscript.

Acknowledgment: The authors thank the critical care directors and ICU nurse managers for agreeing to participate to the survey and without whom this work would have not been possible.

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