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The Impact of a “Low-Intensity” Versus “High-Intensity” Medical Intensive Care Unit on Patient Outcomes in Critically Ill Veterans

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Abstract

Objective—To determine whether a low-intensity versus high-intensity medical intensive care unit (MICU) format in a Veterans Affairs (VA) hospital setting improves patient outcomes, as measured by duration of mechanical ventilation (MV), ventilator-free days (VFDs), and hospital mortality.

Design—Retrospective cohort study.

Setting—Medical intensive care unit at the San Francisco Veterans Affairs Medical Center (SFVAMC).

Patients—On July 1, 2004, the SFVAMC transitioned from a low-intensity MICU to a high-intensity MICU. All patients admitted to the MICU who required MV for 18 months before ($n = 96$) and 18 months after ($n = 131$) the transition were included in the analysis.

Measurements—We prospectively defined the primary outcome measure as the difference in the median duration of MV between groups. Secondary outcomes included VFDs and hospital mortality. Continuous variables were compared using the Wilcoxon rank sum test; dichotomous variables were compared using Fisher exact test.

Main results—The low-intensity and high-intensity MICU groups were similar in age, gender, weight, and admitting diagnosis ($P > .27$ in all cases). Acute Physiology and Chronic Health Evaluation II (APACHE II) scores were 22.0 in the low-intensity era and 20.0 in the high-intensity era ($P = .048$). Median duration of MV was significantly lower in the high-intensity MICU format compared to the low-intensity MICU format (102 vs 61 hours, P for log-rank test = .0052). After controlling for covariates, there were 4.2 more VFDs in the high-intensity era (95% CI 1.9 to 6.6 days). The high-intensity era was associated with a reduced hospital mortality rate (27% vs 40%) and an adjusted odds ratio of 0.34 (95% CI 0.15 to 0.74).

Conclusions—For critically ill veterans admitted to an MICU requiring MV, a high-intensity ICU structure is associated with more favorable mechanical ventilatory outcomes and lower mortality.

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Declaration of Conflicting Interests

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Keywords

closed intensive care unit; open intensive care unit; mechanical ventilation; ventilator-free days; outcomes; high-intensity; low-intensity

Introduction

Nearly 1.5 million people in the United States require admission to an intensive care unit (ICU) with mechanical ventilation (MV) each year.¹ Advances in management of critically ill patients and MV have improved morbidity, mortality, and quality of ICU care. However, these advances are costly, labor intensive, and require highly specialized staff. Critical care services can account for more than one third of a hospital budget and an estimated 0.5% to 1% of the US' national gross domestic product.^{2–4}

Across the United States, there is a wide variation in ICU organizational structure. Various conceptual models have been proposed to explain the organizational structures of ICUs. The most common model presents an “open” versus “closed” model of ICU care. In the “open” model, patients are admitted and managed by a primary clinical service. Critical care specialists may be present to provide consultation. In the “closed” model patients requiring ICU-level care are transferred to a dedicated critical care team.⁵

Another model of ICU structure describes “high- intensity” versus “low- intensity” staffing. In the “high- intensity” model, the ICU is either a “closed” ICU or it is an “open” ICU with a mandatory intensivist consult who is present in the ICU throughout the day. In the “low” intensity model, the ICU is “open” with either an elective (i.e., non-mandatory) intensivist consultation or there is no intensivist available at all.⁶

Previous studies have demonstrated improved clinical outcomes in closed ICU structures compared to open structures; similar improvements have been found with high-intensity compared to low-intensity structures.^{7–16} Possible reasons for these findings include greater physician experience in treating critically ill patients, more consistent physician presence in the ICU, and faster response to acute clinical problems.¹⁷

Despite a growing body of literature supporting high-intensity models of ICU care in a variety of patient populations, to date these studies have examined academic university-based institutions or community-based hospitals. On July 1, 2004, the San Francisco Veterans Administration Hospital medical intensive care unit (MICU) transitioned from a low-intensity staffing to a high-intensity staffing model, providing the opportunity to compare 2 eras of clinical ICU care. We used this opportunity to design a nonrandomized retrospective trial to evaluate whether a high-intensity ICU organizational structure improves outcomes in critically ill veterans requiring MV. The purpose of our study was to examine the transition of an ICU in the Veterans Administration Health Care System (VA) from a low-intensity staffing model to a high-intensity staffing model and determine its effects on the served patient population. The VA is a large US Government-sponsored health maintenance organization that provided medical care to nearly 5.5 million veterans in 2008.¹⁸ To our knowledge, no prior study has evaluated the effects of changing ICU physician staffing structures in the VA system.

Critical care medicine has changed in important ways since most of the studies on ICU structure were published. Our study provided the opportunity to reevaluate the effects of transitioning from a low-intensity to high-intensity ICU structure in an era in which several key advances in critical care have been established, such as low tidal volume for acute respiratory distress syndrome (ARDS), daily interruption of sedatives, daily spontaneous

breathing trials, early goal directed therapy for sepsis, intensive insulin therapy, and induced hypothermia for cardiac arrest.^{19–24} This is especially important because a recent study found that critical care physician management was associated with poorer, and not superior, patient outcomes.²⁵

Materials and Methods

Setting

The San Francisco Veterans Administration Medical Center (SFVAMC) operates a 124-bed teaching hospital located in San Francisco, California, affiliated with the University of California, San Francisco. The hospital operates an 18-bed ICU shared between an MICU, surgical ICU (SICU), and coronary care unit (CCU). The division of beds is flexible and reflects the needs of the daily patient census. The hospital serves as a referral center for an 8-county area in northern California.

Study Period

On July 1, 2004, the MICU and CCU changed from a low-intensity format to a high-intensity organizational structure, while the SICU maintained a low-intensity organizational format. Two 18-month periods were evaluated for the present study—the “Low-Intensity ICU Era” and the “High-Intensity ICU Era.” The study period of the low-intensity format lasted from January 1, 2003, until June 31, 2004. A 6-month adjustment period was allowed; the study period of the high-intensity format lasted from January 1, 2005, until June 31, 2006.

Low-Intensity ICU Era

Under the old system, patients were admitted to the MICU or CCU by residents from the medical service after discussing the case with the pulmonary and critical care attending or fellow. The medical service comprised of 6 teams of 1 senior medical resident (postgraduate year [PGY] 2 or 3), 1 medical intern, and a fourth-year medical student serving as a sub-intern. Upon transfer to the ICU, the primary responsibility for patient management, including all order-writing, remained with the medical house staff, but the attending of record became the MICU or CCU attending (American Board of Internal Medicine certified pulmonary and critical care specialists or cardiologists, respectively). Subinterns were not permitted to manage ICU patients; if one of their hospitalized patients became ill and required transfer to the ICU, the intern on the same medical team assumed care of the patient. Each medicine team rounded individually with the intensivist attending and a fellow training in pulmonary/critical care medicine or cardiology (depending on MICU or CCU assignment) every morning. Notably, the MICU attending and fellow also served as the pulmonary consult service; the cardiology attending also served as the cardiology consult service. The attending and fellows did not remain in the ICU throughout the day but were available via pager for questions or emergencies. Because of the responsibilities of the pulmonary service, the pulmonary/critical care attending and fellow spent roughly 30% to 40% of the workday attending to critical care issues and 60% to 70% of the workday attending to pulmonary medicine responsibilities.

Overnight ICU coverage was provided by the on-call medicine team who was also responsible for cross-coverage on all inpatients on the medicine service, as well as hospital admissions to the medical service. The on-call team received face-to-face formal signout on ICU patients from the primary team covering each patient. Upon discharge from the ICU, the house staff remained constant, but the ward medicine attending assumed responsibility as the attending of record.

Evidence-based protocols for ventilator-associated pneumonia, low-tidal volume ventilation for the ARDS, early goal-directed therapy for sepsis, daily interruption of sedation, daily spontaneous breathing trials, strict glycemic control, therapeutic hypothermia for cardiac arrest, deep venous thrombosis prophylaxis, and gastrointestinal ulcer prophylaxis were in place prior to the start of the study.

High-Intensity ICU Era

On July 1, 2004, the MICU was reorganized into a high-intensity structure. In this new system, patients were admitted to the MICU or CCU after screening by a senior member of the dedicated critical care team (senior medicine resident or pulmonary/critical care fellow). The attending of record in the ICU continued to be the intensivist, but all order-writing privileges belonged to the critical care team. Members of the ward medical service no longer actively managed patients. The team consisted of an intensivist board certified in critical care, a fellow in pulmonary and critical care medicine, 3 senior medicine residents (PGY 3), an anesthesia resident (PGY3), and 1 surgical intern (PGY 1). The intensivist and pulmonary fellow dedicated their full workday to critical care coverage. Overnight coverage was provided by one of the senior medicine or anesthesia residents from the critical care team. Daily morning and afternoon rounds led by the intensivist were held on all MICU patients. Joint rounds were held with the dedicated ICU team, cardiology attending, and fellow on all CCU patients each morning.

An additional “part-time” critical care attending was added to the high-intensity ICU system due to the increased number of patients and work responsibilities related to a high-intensity-staffed MICU and the introduction of mandatory critical care consults for SICU patients present in the ICU for more than 72 hours. Anesthesiologists who were board certified in critical care were added to the attending pool to provide additional expertise in postoperative critical care issues. The “part-time” attendings were present for morning and afternoon rounds dedicating roughly 50% of their workday to critical care. This time was split evenly between the MICU and SICU, adding approximately a 25% full-time equivalent (FTE) to the MICU.

Evidence-based protocols as listed above were not changed in the high-intensity period of study.

Patient Enrollment

Consecutive patients admitted to the MICU or CCU requiring endotracheal intubation and MV were included in the study. Patients were identified by reviewing a database created by respiratory therapists and maintained by the director of the ICU that recorded the date and time of all intubations and extubations.

Repeat admissions to the ICU, defined as discharge from and then readmission to the ICU within the same hospital stay, were excluded. Patients already intubated at the initiation of either study period were excluded from analysis; patients intubated prior to the end of the study periods were included and followed through their entire hospitalization.

Data Collection

Information was retrospectively collected using the Veterans Health Information Systems and Technology Architecture (VistA) electronic health record via the graphical user interface known as the Computerized Patient Record System (CPRS).

Basic demographic characteristics were collected, including age, gender, and weight. Admitting diagnoses were determined from review of the admission notes. The clinical

indication for endotracheal intubation and MV was ascertained from review of the intubation procedure note and the daily progress note immediately following intubation. Severity of illness was measured by the Acute Physiology and Chronic Health Evaluation II (APACHE II) system.²⁶ Scores were calculated using the worst values obtained within the first 24 hours of admission to the ICU. If an arterial blood gas was not obtained within the first 24 hours of admission, it was assumed to be normal. Arterial blood gas samples were unavailable in 3 patients—1 in the low-intensity era and 2 in the high-intensity era.

Outcome Assessment

The primary outcome was defined as the duration of MV. Duration of MV was defined as the time between intubation and the initial time of extubation when the patient had a period lasting ≥ 24 consecutive hours without return to MV. Secondary outcomes included other MV outcomes (28-day ventilator-free days [VFDs]), death (ICU and hospital), and length of stay (ICU and hospital). Ventilator-free days were defined as the total number of days that patients were alive and free from MV for a period lasting ≥ 24 consecutive hours during the first 28 days after initiation of MV.²⁷ If patients returned to MV after a period of extubation, the subsequent days were not counted as VFDs.²⁷ If patients died, they were not credited with VFDs. Recently, VFDs have been adapted as the primary study outcome for the National Heart Lung and Blood Institute (NHLBI) ARDS Network Clinical Trials Network as it incorporates both the duration of MV and survival.²⁷ Ventilator-free day has the advantage of showing improvement if an intervention reduces either duration of MV alone or in combination with reduced mortality.²⁷

In accordance with the ICU protocols, patients in both study periods underwent daily assessment for interruption of sedative infusions and daily spontaneous breathing trials to determine readiness for extubation.^{21, 22}

Statistical Methods

Statistical analysis was performed using SAS 9.1 (Cary, North Carolina). Bivariate analysis were conducted using the chi-square test for categorical variables, the *t* test for normally distributed continuous variables, and the Wilcoxon test for nonnormal continuous variables.

Kaplan-Meier curves were used to compare the duration of MV in the low-intensity versus high-intensity ICU eras. Patients were censored for death (*n* = 74) or transfer to a long-term ventilator facility (*n* = 2). The log-rank test was used to compare the low-intensity and high-intensity ICU eras. Cox proportional hazards analysis was then used to examine the impact of low-intensity versus high-intensity ICU structure after controlling for variables that may influence the prognosis in mechanically ventilated patients: age, gender, APACHE II score, weight, and Do Not Resuscitate (DNR) status.^{26, 28, 29} We used an analogous approach to analyze hospital and ICU length of stay. Logistic regression analysis was used to evaluate the impact of ICU structure on mortality using a similar approach.

The study design was approved by the Institutional Review Boards of the SFVAMC and the University of California, San Francisco.

Results

Patient Characteristics

Two hundred twenty-seven patients met inclusion criteria. A total of 96 patients were enrolled in the low-intensity ICU era and 131 patients were enrolled in the high-intensity ICU era. There were no statistical differences in the demographic characteristics between the 2 patient populations including age, weight, or gender (Table 1).

Patients in the low-intensity versus high-intensity eras had slightly different median APACHE II score of 22.0 versus 20.0 ($P = .048$; Table 1). Cardiac failure, respiratory failure, and sepsis were the most common admitting diagnoses in both groups and were not statistically different.

Patient census and intensivist staffing—In the low-intensity era, the average daily medicine team size was 6.8 patients with 0.9 MICU patients per team. The daily MICU census overall was 5.6 patients. In the high-intensity era, the average daily MICU census was 6.0 patients. In the low-intensity era, attending intensivists dedicated approximately 0.3 to 0.4 FTE to the MICU compared to the high-intensity era, where 1.25 FTEs were provided between the full-time and part-time attendings.

Impact of ICU Structure on MV Outcomes

The Kaplan-Meier curves for duration of MV show that the high-intensity era was associated with a reduction of the duration of MV (Figure 1). There was a substantively shorter median duration of MV in the low-intensity ICU era compared to the high-intensity ICU era (102 vs 61 hours, P for log-rank test = .0052). After controlling for age, sex, APACHE II score, DNR status, and weight, increased intensity of staffing the MICU was associated with an average of 4.2 greater VFDs (95% CI 1.9 to 6.6 days). The high-intensity ICU era was also related to a shorter duration of MV after controlling for covariates (HR 1.66; 95% CI 1.18 to 2.32; Table 2).

ICU structure and mortality outcomes—Hospital mortality decreased in the high-intensity ICU (35 of 131 patients, or 27%) era compared with the low-intensity ICU era (38 of 96 patients, or 40%). Based on APACHE II scores, actual mortality was similar to estimated mortality in the low-intensity era (40.0% vs 42.4%) II, whereas actual mortality was lower than estimated mortality in the high-intensity era (27% vs 35.5%). Compared to the low-intensity ICU era, the high-intensity ICU era was associated with a decreased mortality in both unadjusted (OR 0.58; 95% CI 0.33 to 1.01) and adjusted analysis (OR 0.34; 95% CI 0.15 to 0.74; Table 2). Intensive care unit mortality similarly decreased in the high-intensity ICU era (Table 2).

ICU structure and length of stay—There was no clear impact of ICU structure on length of stay. Hospital stay was similar in the low- and high-intensity ICU eras (median 23 vs 27 days, respectively; P value for log rank test = .62). Intensive care unit length of stay was also similar for the low- and high-intensity ICU eras (12 vs. 10 days, $P = .17$). In Cox proportional hazards analysis controlling for covariates, there was no statistical association between ICU structure and length of stay ($P = .91$ for hospital and $P = .13$ for ICU length of stay).

Discussion

We found that the transition from a low-intensity to high-intensity MICU in a VA hospital was associated with a reduction in the duration of MV and mortality. These clinical outcomes improved without any appreciable change in the length of ICU or hospital stay.

These findings are consistent with previous studies comparing the effect of closed-model and high-intensity staffed ICUs to open-model and low-intensity staffed ICUs in both community and university settings.^{5–14} Importantly, our study updates these findings as it has been 10 years since the effects of organizational change on a medical ICU have been studied. Carson et al first published a study on the effects of organizational change.⁵ In this study, the University of Chicago MICU changed from an open to closed ICU in 1994. The

authors demonstrated improved outcomes including the ratio of actual mortality to predicted mortality in the closed model but did not find reduced duration of MV or reductions in overall mortality rates. Since their study, numerous studies have demonstrated reduced mortality in high-intensity staffed ICUs caring for general ICU patients as well as those with trauma, intracranial hemorrhage, abdominal aortic aneurysm repair, and esophageal resection.⁶

A notable exception to the literature on ICU structure and patient outcomes is the recent study reporting an association between critical care physician management and increased mortality in a national database of ICU admissions.²⁷ As the authors noted, selective involvement of intensivists in the care of sicker patients could have confounded their results. Our study, which evaluated a change in ICU structure, was not affected by this selection bias. In this light, our findings suggest that patients benefit from a high-intensity ICU structure.

Since the Carson study, there have been several important advances in critical care. Significant advances include: early goal-directed therapy for sepsis, induced hypothermia following cardiac arrest, stricter control of serum glucose, daily interruption of sedative infusions and daily spontaneous breathing trials in mechanically ventilated patients, and, importantly, the widespread adoption of lung-protective strategies for ARDS.^{19–24} Each of these studies has demonstrated improved outcomes in critically ill patients but, in practice, require a greater level of physician involvement in patient care.

In our study, although there were no adjustments made to evidence-based protocols, adherence rates were not recorded in the 2 eras. It is our suspicion that adherence rates remained stable or increased with the presence of a full-time dedicated ICU team because one of the goals of a higher intensity organizational structure is the improved ability to adhere to best-practice guidelines, especially practices that are time- and labor-intensive. Perhaps, most importantly, our study confirms that even in the era of critical care protocols and bundles, high-intensity ICU staffing continues to be associated with improvements in key outcome measures including decreased duration of MV and mortality.

To our knowledge, no study to date has evaluated the effect of organizational change in a VA patient population and hospital structure. The VA acts as the largest single provider of health care in the United States and operates 126 ICUs throughout the country.¹⁸ Our findings indicate that transitioning to a high-intensity ICU can shorten the duration of MV and save lives in the VA system, which has major implications for the large population it serves.

In our study, during the low-intensity era, a pulmonary/critical care physician attended to ICU patients in the morning and then performed duties as an inpatient pulmonary consultant, sleep medicine specialist, and outpatient clinic physician during the remainder of the day. Although the setting was a VA hospital, this practice is similar to experience of many pulmonary/critical care physicians in community hospitals with small ICUs. Indeed, a report from the Committee on Manpower for Pulmonary and Critical Care Societies (COMPACCS) survey showed most ICUs in the United States would be defined as “open” or “low-intensity” and that intensivists manage a majority of patients in only 25% of ICUs.^{30,31}

These findings have important implications for health care providers and policymakers. This study supports previous findings in university and community hospital settings that a closed or high-intensity model of ICU structure improves outcomes. Pronovost et al estimated that staffing ICUs with intensivists in nonrural ICUs alone could save 162 000 lives annually.³² Similarly, the Leapfrog Group, a consortium of Fortune 500 companies, created health care

specifications including an ICU physician staffing standard. The group estimates more than 54 000 lives could be saved annually by applying the ICU physician staffing standard.³³ As a single-payer system, the government could effect significant change on the landscape of critical care in the United States by introducing a high-intensity ICU model for all VA hospitals. Transitioning to a high-intensity ICU model in 126 VA MICUs might translate to substantive improvements in the quality of care of critically ill veterans in the United States and could save lives.

The strength of our study, that it was conducted in the VA system, is also a limitation, as there are features of our MICU that are unique to VA hospitals. But, the similarities in the staffing pattern in the “low-intensity era” to ICUs in smaller community hospitals may allow our findings to be generalizable to practices outside of the VA system.

Another limitation is that it is not possible to separate out which specific aspects of our high-intensity system, such as team structure or physician specialty, were responsible for the observed clinical benefits. Also, it is not clear whether improved outcomes are the result of the greater presence of a dedicated intensivist board certified in critical care or, more simply, by increased physical presence of physicians in the ICU allowing for improved response times and closer evaluation of patients. The addition of afternoon rounds permitted more frequent formal assessments of patients. It also improved continuity of care by permitting the on-call ICU resident to revisit any pressing issues with the entire ICU team.

Ultimately, these data indicate that a high-intensity ICU system with higher intensity physician staffing with critical care specialists appears to translate into important clinical benefits for patients.

Conclusion

Since the publication of Carson’s landmark study on the improvement in ICU outcomes after transitioning from an open to closed ICU structure, others have found similar results in a variety of patient populations and hospital settings. We have shown in a VA patient population and ICU setting that transitioning from a “low-intensity” to “high-intensity” MICU physician staffing structure substantively reduces duration of MV, increases VFDs, and reduces hospital mortality in critically ill mechanically ventilated patients.

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Figure 1. Intensive care unit (ICU) structure and the duration of mechanical ventilation. Kaplan-Meier curve showing the duration of mechanical ventilation in the low-intensity versus high-intensity ICU eras. $P = .0052$ for difference in the 2 ICU eras by log-rank test.

Table 1Characteristics of Participants During the Low-Intensity Versus High-Intensity Era^a

Characteristic	Low-Intensity ICU Era (n = 96)	High-Intensity ICU Era (n = 131)	P Value for Comparison
Age (years)	68 (13)	67 (12)	.60
Sex (% male)	95 (99%)	129 (98%)	.75
DNR/DNI at some point during ICU stay	10 (10%)	24 (18%)	.09
Weight (kg)	78 (22)	82 (26)	.27
APACHE II score	22 (7)	20 (7)	.048
Admitting diagnosis (type)			.96
Respiratory	35 (36%)	51 (39%)	
Cardiovascular	31 (30%)	38 (29%)	
Sepsis	13 (14%)	19 (15%)	
Other	17 (18%)	23 (18%)	

Abbreviations: APACHE, Acute Physiology and Chronic Health Evaluation; ICU, intensive care unit. DNR, Do Not Resuscitate; DNI, Do Not Intubate.

^aFormat is n (%) for categorical variables or mean (SD) for continuous variables.

Table 2**Low-Intensity Versus High-Intensity ICU Era and Clinical Outcomes**

Variable	Relative Risk Measure ^a (95% CI)	
	Unadjusted	Adjusted
Death (odds ratio)		
All deaths	0.58 (0.33 to 1.01); <i>P</i> = .056	0.34 (0.15 to 0.74); <i>P</i> < .007
Deaths in ICU	0.55 (0.29 to 1.00); <i>P</i> = .053	0.44 (0.20 to 0.95); <i>P</i> = .037
Duration of mechanical ventilation (hazards ratio)	1.60 (1.15 to 2.23); <i>P</i> = .006	1.66 (1.18 to 2.32); <i>P</i> = .004

Abbreviations: APACHE, Acute Physiology and Chronic Health Evaluation; ICU, intensive care unit.

^aDeath was analyzed using logistic regression; the odds ratio (OR) indicates the risk of death for the low-intensity era vs. the high-intensity era. Duration of mechanical ventilation was analyzed using Cox Proportional Hazards regression analysis; the hazards ratio (HR) compares the time of mechanical ventilation in the low-intensity era versus the high-intensity era. An HR > 1 indicates a shorter duration of mechanical ventilation (ie, liberated from the ventilator earlier). Adjusted analysis controlled for age, sex, APACHE II score, DNR status, and weight.