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TITLE: Nighttime Intensivist Staffing, Mortality, and Limits on Life Support: A Retrospective Cohort Study

RUNNING HEAD: Nighttime intensivist staffing and ICU outcomes

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ABSTRACT

Background: Evidence regarding nighttime physician staffing of intensive care units (ICUs) is suboptimal. We aimed to determine how nighttime physician staffing models influence patient outcomes.

Methods: We performed a multicenter retrospective cohort study in a multicenter registry of US ICUs. The exposure variable was the ICU's nighttime physician staffing model. The primary outcome was hospital mortality. Secondary outcomes included new limitations on life support, ICU length-of-stay, hospital length-of-stay, and duration of mechanical ventilation. Daytime physician staffing was studied as a potential effect modifier.

Results: The study included 270,742 patients in 143 ICUs. Compared to nighttime staffing with an attending intensivist, nighttime staffing without an attending intensivist was not associated with hospital mortality (OR 1.03; 95% CI 0.92, 1.15; p=0.65). This relationship was not modified by daytime physician staffing (interaction p=0.19). When nighttime staffing was subcategorized, neither attending non-intensivist nor physician trainee staffing was associated with hospital mortality, compared to attending intensivist staffing. However, nighttime staffing without any physician was associated with reduced odds of hospital mortality (OR 0.79; 95% CI 0.68, 0.91; p=0.002) and new limitations on life support (OR 0.83; 95% CI 0.75, 0.93; p=0.001). Nighttime staffing was not associated with ICU or hospital length-of-stay. Nighttime staffing with an attending non-intensivist was associated with a slightly longer duration of mechanical ventilation (HR 1.05; 95% CI 1.02, 1.09; p<0.001).

Conclusions: We found little evidence that nighttime physician staffing models impact patient outcomes. ICUs without physicians at night may exhibit reduced hospital mortality, possibly attributable to differences in end-of-life care practices.

ABBREVIATIONS LIST

ICU – intensive care unit

US – United States

MPM_0-III – Mortality Prediction Model-III

CPR – cardiopulmonary resuscitation

INTRODUCTION

Most available evidence suggests that intensivists improve outcomes of critically ill patients,[1-3] leading experts to speculate that more exposure to intensivists could be better still.[4] However, previous studies of the effectiveness of nighttime intensivists have yielded mixed results.[5-9] One retrospective cohort study found that among 22 US ICUs with "low-intensity" daytime physician staffing (i.e., absence of routine care by intensivists during the day), ICUs that employed in-hospital intensivists at night had lower risk-adjusted mortality than did ICUs without nighttime intensivists. No such differences were seen in ICUs with "high intensity" daytime staffing (i.e., mandatory involvement of intensivists as primary physicians or consultants).[9] The absence of benefit of nighttime intensivists in ICUs with high-intensity daytime staffing was subsequently confirmed in a randomized trial[8] and meta-analysis of observational studies.[10] However, we do not yet understand the effects of other specific forms of nighttime staffing (such as staffing by non-intensivist attending physicians), the effects of these staffing models in a sample composed of primarily community-based ICUs, nor the effects of these staffing models on important non-mortal outcomes such as length-of-stay and duration of mechanical ventilation.

Given the resource-intensiveness of staffing ICUs with attending physicians of any kind, and particularly intensivists, at night, it is essential to clarify how the full range of possible nighttime ICU staffing models influences patient-centered outcomes. Further, because intensivists may play an important role in decisions to limit life support, which could in turn affect both mortality and length-of-stay, it is critical to assess whether the relationships between nighttime staffing models and clinical outcomes are mediated by differences in end-of-life decision making.

We therefore conducted a retrospective cohort study of nighttime physician staffing models in the largest sample of United States (US) ICUs to date, using the Project IMPACT database, a voluntary clinical registry of primarily US ICUs. We had three specific aims: (1) to determine whether previously detected mortality reductions with nighttime intensivists in low-intensity ICUs were reproducible, (2) to determine whether rates of limitations on life support differ among nighttime staffing models, and (3) to study the effects of nighttime staffing on other clinical outcomes, such as length-of-stay and duration of mechanical ventilation.

MATERIALS AND METHODS

We conducted a retrospective cohort study using the Project IMPACT database (Cerner Corporation, Kansas City, MO). IMPACT is a multicenter, voluntary (therefore non-random) ICU clinical registry used for benchmarking purposes, which is frequently used in critical care outcomes research.[11-14] Each ICU uses a trained data collector and a standardized electronic form to collect data on ICU and hospital organization, structure, and processes of care, and on clinical characteristics of admitted patients. Data collectors specifically reported the in-hospital physician and non-physician staffing of ICUs, including whether the daytime and nighttime physicians, if any, were “critical care attending physicians” (attending intensivists), non-critical care attending physicians, or trainees). The characteristics of IMPACT ICUs reflect those of US ICUs as a whole,[11] and prior work has demonstrated the validity of key data fields.[15] This study was deemed exempt from review by the Institutional Review Board of the University of Pennsylvania because it was a secondary analysis of an existing database with no patient identifiers.

Patients

We initially included all patients admitted to US ICUs included in IMPACT for whom complete data were collected between 2001 and 2008 (Figure 1). We excluded ICUs with less than 20 admissions per quarter, ICUs that were enrolled in the registry for less than one year, and ICUs with no data for daytime or nighttime staffing. We also excluded one ICU covered by advanced practitioners (nurse practitioners or physician assistants) overnight because effects attributable to that staffing model could not be differentiated from other characteristics of that ICU. We excluded patients who were ineligible for risk adjustment using the Mortality Prediction Model –III (MPM_0-III) score; that is, those patients for whom the MPM_0-III is not validated (patients less than 18 years of age, burn patients, coronary care patients, and CT surgery patients).[16] For patients with multiple admissions to a study ICU (during the same hospitalization or in a subsequent hospitalization), we excluded readmissions to maintain the independence of observations.

Study variables

The primary exposure was the in-hospital physician staffing during nighttime hours, which we defined in two ways. First, we created a binary variable indicating the presence or absence of a nighttime intensivist, yielding analyses of the effect of nighttime intensivists compared to all other staffing models, and enabling direct comparison with previous studies.[8,9] Second, we categorized nighttime staffing as (1) attending intensivist physician, (2) attending non-intensivist physician, (3) trainee physician (i.e., resident or fellow), or (4) no physician. This categorization sought to clarify the effect of different levels of physician experience available during nighttime hours on patient outcomes. Because some ICUs changed staffing models over time, we assigned each patient's exposure as the staffing model employed at the time of ICU admission.

The primary outcome was hospital mortality. Patients discharged to hospice were counted as having died during the hospitalization, as it was assumed that these patients would die within a short time after discharge and counting them as survivors could bias the results.[17] Secondary outcomes included any implementation of a new limitation on life support during the ICU admission, ICU and hospital length-of-stay, and duration of mechanical ventilation among the subgroup of mechanically ventilation patients.

Limitations on life support were coded using the following categories: (1) no limitations on care; (2) an order to withhold cardiopulmonary resuscitation (CPR), (3) an order to withhold CPR plus one or more of the following: mechanical ventilation, cardioversion, dialysis and/or other potentially life-prolonging therapies; and (4) an order for comfort measures only or hospice care. These data were available at the time of ICU admission for all patients, and at the time of ICU discharge for all patients still alive. For patients who survived the ICU stay, we considered any increase in these ordered categories from admission to discharge as the implementation of a new limitation on life support. For patients who died in the ICU, we considered a new limitation to have occurred if there was no event code for CPR on either the day of death or the preceding day.

We selected potential confounders a priori based on prior work.[9,11-13] Hospital- and ICU-level covariates included affiliation with a medical school, affiliation with a critical care fellowship program, and the regional location of the hospital. Patient-level covariates included severity of illness as measured by MPM_0-III score,[16,18] gender, race, location prior to ICU admission, presence of several chronic medical conditions, pre-hospital functional status, insurance status, reason for ICU admission, and type of admission. Details of all variable definitions are provided in the Supplemental Material (e-Table 1).

We pre-specified three variables as potential effect modifiers of the relationship between nighttime staffing and the primary outcome of hospital mortality: daytime physician staffing model of the ICU, medical vs. surgical reason for ICU admission, and severity of illness. Daytime physician staffing was defined as high-intensity for ICUs that required an ICU physician to be the primary attending or a consultant, and low-intensity for ICUs in which intensivist involvement was optional or unavailable, as in a prior multicenter observational study.[9] We hypothesized that the effects of nighttime intensivists may be greater among medical than surgical patients because medical patients may be more likely to have acute illnesses that may benefit from immediate expert decision making, and that the effects may be particularly large among more severely ill patients.

Statistical analysis

We performed standard descriptive statistics to summarize ICU and patient characteristics and used the chi-square test and ANOVA, as appropriate, to compare characteristics across the different staffing models. To test the independent association of nighttime staffing with mortality and with new decisions on life support we used generalized estimating equations with robust variance estimators to account for the correlated nature of patients within ICUs. We tested for effect modification for the pre-specified variables described above by including interaction terms using the binary definition of nighttime staffing in separate models.

For all secondary outcomes, we performed analyses using the categorical definition of nighttime staffing, in order to study the effects of nighttime staffing at a more granular level. To test the independent association of nighttime staffing on duration of mechanical ventilation, ICU length-of-stay, and hospital length-of-stay, we used multivariable time-to-event models with censoring on death. Models were stratified by center and used robust standard errors, to account for clustering within ICUs. The modeled events were extubation when assessing duration of mechanical ventilation, and ICU or hospital discharge for the corresponding length-of-stay analyses. A hazard rate greater than 1 favors nighttime attending intensivist staffing according to our modeling strategy.

We included all potential confounding variables as covariates in all multivariable models. Patients with missing data for any model covariates were excluded from multivariable analyses. Because of the small proportion of patients excluded for missing data and the similar distributions of missingness across the categories of nighttime staffing (e-Tables 2 and 3), we felt that exclusion of these patients would be unlikely to introduce a bias and did not attempt imputation or any alternate approach for the missing data. As a check of this assumption, we repeated the primary analysis after excluding ICUs in the highest quartile of number of patients with any missing data to confirm that no bias was introduced by excluding patients with missing data from the primary analysis as described above. In an additional sensitivity analysis, we repeated the primary analysis using the categorical variable for nighttime staffing with mortality redefined such that patients discharged to hospice were considered alive at the time of discharge, as discharge to hospice may be considered a positive outcome.

An alpha <0.05 was considered statistically significant for all statistical tests. All analyses were performed using Stata 12 (StataCorp, College Station, TX).

RESULTS

The final analytic dataset included 270,742 patients in 143 ICUs in 102 hospitals (Figure 1). Table 1 summarizes characteristics of study ICUs. The majority of ICUs (106 ICUs, 74%) had low-intensity daytime physician staffing. Forty-three (29%) ICUs had in-hospital attending intensivist physicians at night and 5 (4%) ICUs had no physician available during nighttime hours. Table 2 summarizes characteristics of included patients.

The overall hospital mortality was 14.9%. In the multivariable models examining nighttime staffing as a binary variable, there was no significant difference between nighttime staffing with or without an attending intensivist with respect to hospital mortality, among all patients or in analyses stratified by daytime staffing model (Table 3). There was no significant interaction between nighttime staffing model and daytime staffing intensity (interaction p-value 0.19). In the multivariable models examining nighttime staffing as an ordered categorical variable, neither non-intensivist attending physicians (OR 1.07; 95% CI 0.94, 1.21; p=0.32) nor trainee physicians (OR 1.10; 95% CI 0.93, 1.30; p-0.27), were associated with hospital mortality, compared to nighttime staffing with attending intensivist physicians. By contrast, nighttime staffing with no physician was independently associated with a lower risk of hospital mortality (OR 0.79; 95% CI 0.68, 0.91; p=0.002) (Figure 2). Results were similar in stratified analyses of medical and surgical patients (Table 4; interaction p-value 0.35) and in sensitivity analyses (e-Table 4). Nighttime staffing model was not differentially effective among patients with different severities of illness (interaction p-value 0.873).

Neither non-intensivist attending staffing (OR 1.02; 95% CI 0.91, 1.16; p=0.68) nor trainee staffing (OR 1.00; 95% CI 0.81, 1.22; p=0.98) during nighttime hours were associated with the odds of new limitations on life support compared to nighttime staffing with intensivists. However, nighttime staffing with no physician was independently associated with reduced odds of new limitations on life support (OR 0.83; 95% CI 0.75, 0.93; p=0.001) (Figure 2). Correspondingly, deaths in ICUs with no physicians during nighttime hours were more likely to be preceded by CPR than were deaths in ICUs with nighttime intensivist staffing (16.6% vs. 13.1%; chi-square p=0.006; e-Table 5).

The median duration of mechanical ventilation was 1.6 days (IQR 0.6, 4.7). The median ICU length-of-stay was 1.9 days (IQR 1.0, 3.8) and hospital length-of-stay was 7 days (IQR 3, 13). Compared to nighttime staffing with attending intensivists, staffing with an attending non-intensivist was associated with significantly longer duration of mechanical ventilation (Table 5). There were no other significant associations of any nighttime staffing model with the duration of mechanical ventilation, ICU length-of-stay, or hospital length-of-stay.

DISCUSSION

This study of more than 270,000 patients admitted to 143 U.S. ICUs identified no benefit of nighttime intensivist staffing compared to either nighttime staffing with non-intensivist attending physicians or trainee physicians (residents and/or fellows) with regards to mortality. These results were consistent in the one-quarter of ICUs with high-intensity daytime staffing models and the three-quarters of ICUs with low-intensity daytime staffing models. They were also consistent among both medical and surgical patients, and independent of patients' severity of illness. Furthermore, these nighttime staffing models were not associated with differences in ICU or hospital length-of-stay.

These results complement and extend the existing evidence regarding nighttime physician staffing of ICUs with high-intensity daytime staffing. The observation that nighttime intensivist staffing is not associated with hospital mortality in ICUs with high-intensity daytime staffing corroborates the findings of both a prior multicenter observational study and a single-center randomized trial.[8,9] The current work extends these observations regarding mortality by suggesting, in a large sample of ICUs, that nighttime intensivist staffing is also not associated with other outcomes, including ICU and hospital length-of-stay or duration of mechanical ventilation. Together, these studies provide consistent and convincing evidence that nighttime intensivist staffing is not of clinical benefit in ICUs with daytime availability of intensivsts.

However, these results conflict with a prior study suggesting benefit of nighttime staffing in ICUs without mandatory involvement of an intensivist during the day.[9] The prior study included two ICU samples – one sample of 49 ICUs overrepresented by academic centers with high-intensity daytime staffing and resident nighttime staffing, and one sample of 112 ICUs which more closely reflected the diversity of US ICUs. Although the 143 ICUs in the present study possess many organizational characteristics that closely reflect the characteristics of US ICUs in general,[6,8,9] this sample is also not randomly selected. Thus, unmeasured differences in important characteristics of the underlying ICUs – including those that may or may not be related to the chosen physician staffing models – may explain the divergent results.

Surprisingly, we also found that admission to an ICU with no physician present during nighttime hours was associated with the lowest mortality risk. Confidence in this finding is somewhat augmented by the observation that patients admitted to these ICUs were, if anything, older and sicker than patients admitted to other ICUs (Table 2). However, confidence is substantially tempered by the small number of

ICUs that lacked any physician staffing. If this unexpected result is real, our data reveal a mechanism that could explain it: patients admitted to ICUs without nighttime physician staffing were less likely to have new limitations on life support. Our results cannot determine whether this association is directly related to the lack of physicians, differences in interactions between daytime and nighttime staff, or is mediated by unmeasured patient or ICU characteristics. Nonetheless, the finding that physician staffing models may be associated with differences in end-of-life care, suggested by this study and others,[19,20] highlights the need to measure practices of withholding and withdrawing life support in all studies comparing mortality rates among ICUs with different organizational characteristics.

In addition to the difficulties of accounting for unmeasured confounding by ICU organizational characteristics, other limitations of this study merit consideration. First, the primary outcome of mortality is limited in this, and all, ICUs studies. Intensivists play an important role in end-of-life care and in offering palliative care as an alternative to life support, which would not be adequately captured in a simple mortality measure. Though we explored this in a preliminary fashion through the analyses of limitations on life support, further study is needed to better understand the degree to which such practices may affect the validity of mortality as an outcome. Second, although the study hospitals in this dataset more closely resemble US critical care organizationally than prior studies, the voluntary nature of the registry may select for hospitals that are particularly motivated to improve quality, potentially limiting generalizability. Third, this dataset is somewhat dated, as complete data were collected only through 2008. Although there may have been practice changes in critical care since then, such changes would only affect our comparison if they occurred differentially across the staffing models. Fourth, because our algorithm for identifying new limitations on life support does not distinguish between simple do-not-resuscitate orders and more substantive limitations on life support, a degree of outcome misclassification may have occurred. Fifth, though the analyses accounted for severity of illness, the MPM-III score may not provide complete risk adjustment. Last, the number of ICUs with no physician staffing at night was small, such that unique ICU characteristics that may be unrelated to nighttime staffing may have influenced the results.

CONCLUSIONS

This study adds to a body of observational and randomized evidence that nighttime intensivist staffing does not reduce mortality or length-of-stay for critically ill patients in ICUs with high-intensity daytime staffing models. Additionally, in countering the results of a prior multicenter observational study regarding the effects of nighttime staffing in ICUs with low-intensity daytime staffing, this study provides impetus and the requisite equipoise for future randomized trials of different nighttime physician staffing models in such ICUs. Finally, the observation that the absence of nighttime physicians of any kind is associated with both lower mortality and reduced odds of patients having new limitations on life support suggests that future studies exploring associations between ICU organizational characteristics and mortality may need to account for how different ICUs approach end-of-life decision making.

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Table 1: ICU Characteristics

Characteristic	ICUs* n=143	Patients n=270,742
Number of ICU beds		
<12	39 (27)	51441 (19)
16-24	50 (35)	85717 (32)
17-24	34 (24)	87347 (32)
>24	20 (14)	46237 (17)
Daytime critical care physician staffing		
High-intensity	37 (26)	87461 (32)
Low-intensity	106 (74)	183281 (68)
Highest level of in-hospital provider at night		
Attending intensivist physician	43 (29)	85425 (32)
Attending non-intensivist physician	43 (30)	77244 (29)
Trainee physicians	54 (38)	95510 (35)
No physician	5 (4)	12563 (5)
ICU type~		
Mixed medical/surgical	76 (54)	168720 (63)
Medical, including CCU	27 (19)	37203 (14)
Surgical	35 (25)	62090 (23)
Neurological	2 (1)	1110 (0.4)
Cardio-thoracic	2 (1)	387 (0.1)
Affiliation with medical school[+]		
Primary	32 (25)	68065 (25)
Secondary	90 (61)	163903 (61)
None	21 (15)	38774 (14)
Affiliation with critical care fellowship program[+]		
Primary	33 (23)	84072 (31)
Secondary	17 (12)	19101 (7)
None	93 (65)	167569 (62)

All data are presented as n (%).
*In some cases, ICUs changed characteristics during the course of their participation in Project IMPACT (e.g., increased in size from 10 beds to 14 beds). Such ICUs were assigned to the category into which the highest proportion of patients fell.
~Data on ICU type are missing for one ICU (1232 patients); therefore, proportions presented are with denominators of 142 ICUs and 269,510 patients.
[+]Affiliation with a medical school or critical care fellowship program was self-reported and defined as "primary" if the hospital was the primary teaching site; "secondary" if it was site for student/fellow rotations but not the primary teaching hospital; and "none" if neither were true.

Table 2: Patient characteristics

Characteristic	All patients (n=270,742)	Attending intensivist (n=85,425)	Attending non-intensivist (n=77,244)	Trainee (n=95,510)	Non-physician (n=12,563)	p-value
Age in years, median (IQR)	62 (47, 75)	60 (45, 74)	63 (48, 75)	62 (47, 75)	66 (51, 77)	<0.001
Male gender, %	54.2	55.6	53.9	53.2	52.7	<0.001
Race, %						<0.001
White	79.8	77.1	84.0	78.2	83.4	
Black	14.3	17.8	11.9	13.6	10.5	
Other	5.9	5.1	4.1	8.2	6.1	
Chronic conditions, %						
ESRD	4.3	4.3	4.4	4.3	4.1	0.173
Respiratory disease	6.7	6.0	6.7	6.5	12.1	<0.001
Cardiovascular disease	4.8	3.5	4.9	4.5	16.5	<0.001
GI/liver disease	2.9	2.8	2.8	3.1	3.4	<0.001
Metastatic cancer	4.2	4.5	3.3	4.5	6.5	<0.001
HIV	0.6	0.8	0.4	0.5	0.6	<0.001
Type of ICU admission, %						<0.001
Medical	65.9	63.2	69.8	65.2	64.4	
Post-op, scheduled	21.7	20.9	20.2	23.9	19.3	
Post-op, unscheduled	12.5	15.9	9.9	10.9	16.2	
Any mechanical ventilation, %	13.6	16.2	10.6	13.9	12.7	<0.001
Any vasopressor, %	20.7	22.4	19.2	20.2	22.3	<0.001
MPM_0-III probability of mortality, median (IQR)	0.08 (0.03, 0.17)	0.08 (0.03, 0.18)	0.08 (0.03, 0.17)	0.07 (0.03, 0.16)	0.09 (0.04, 0.19)	<0.001

All p-values were estimated using a chi-square test comparing values for each category of nighttime staffing, with the exception of age and MPM_0-III, for which the p-values were estimated using ANOVA models.

Table 3: Risk adjusted odds ratios for mortality for staffing without a nighttime intensivist

ICUs	No. of patients	OR*	95% CI	p-value
All	258,655	1.03	0.92, 1.15	0.65
Stratified by daytime staffing model				
High-intensity	84,179	1.11	0.83, 1.49	0.48
Low-intensity	174,476	0.98	0.88, 1.09	0.74

*Compared to staffing with a nighttime intensivist.
ICU-level variables for risk adjustment were affiliation with a medical school, affiliation with a critical care fellowship program, and the regional location. Patient level variables for risk adjustment were MPM_0-III score, gender, race, location prior to ICU admission, presence of chronic medical conditions, pre-hospital functional status, insurance status, reason for ICU admission, and type of admission.

Table 4: Risk adjusted odds ratios for mortality for nighttime staffing models, stratified by type of admission

	Medical n=170,469			Surgical n=88,186		
Nighttime staffing	**OR**	**95% CI**	**p-value**	**OR**	**95% CI**	**p-value**
Attending intensivist	**REF**			**REF**		
Attending non-intensivist	1.09	0.98, 1.22	0.12	1.08	0.86, 1.35	0.50
Trainee	1.15	0.98, 1.36	0.08	1.03	0.83, 1.28	0.80
Non-physician	0.83	0.73, 0.95	0.006	0.67	0.53, 0.84	0.001

ICU-level variables for risk adjustment were affiliation with a medical school, affiliation with a critical care fellowship program, and the regional location. Patient level variables for risk adjustment were MPM_0-III score, gender, race, location prior to ICU admission, presence of chronic medical conditions, pre-hospital functional status, insurance status, reason for ICU admission, and type of admission.

Table 5: Risk adjusted hazard rates* for secondary outcomes

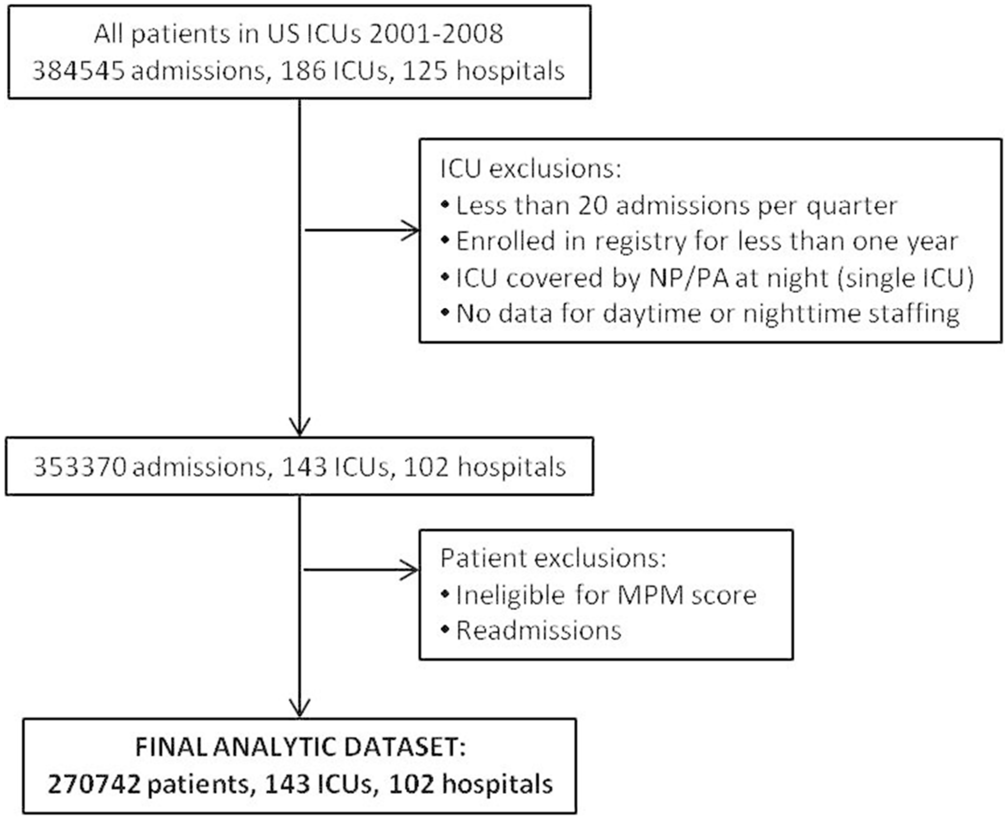
	Duration of mechanical ventilation n=56,644			ICU length-of-stay n=258,407			Hospital length-of-stay n=258,645		
Nighttime staffing	**HR**	**95% CI**	**p-value**	**HR**	**95% CI**	**p-value**	**HR**	**95% CI**	**p-value**
Attending intensivist	**REF**			**REF**			**REF**		
Attending non-intensivist	1.05	1.02,1.09	< 0.001	1.00	0.93,1.08	0.90	1.01	0.93,1.10	0.74
Trainee	1.02	0.91,1.15	0.75	0.98	0.88,1.10	0.77	0.99	0.88,1.12	0.87
Non-physician	1.06	0.93,1.20	0.35	1.01	0.93,1.08	0.88	1.00	0.94,1.05	0.97

*A hazard rate (HR) greater than 1 favors attending intensivist staffing.
ICU-level variables for risk adjustment were affiliation with a medical school, affiliation with a critical care fellowship program, and the regional location. Patient level variables for risk adjustment were MPM_0-III score, gender, race, location prior to ICU admission, presence of chronic medical conditions, pre-hospital functional status, insurance status, reason for ICU admission, and type of admission

Figure 1: ICU and patient exclusions

Figure 2: Odds ratios for association of nighttime staffing model with in-hospital mortality and new limitations on life-sustaining therapy

The reference group for all categories is nighttime staffing with an intensivist attending physician.
Analyses of in-hospital mortality included 258,655 patients.
Analyses of new limitations on care included 255,801.
~p=0.002
*p=0.001



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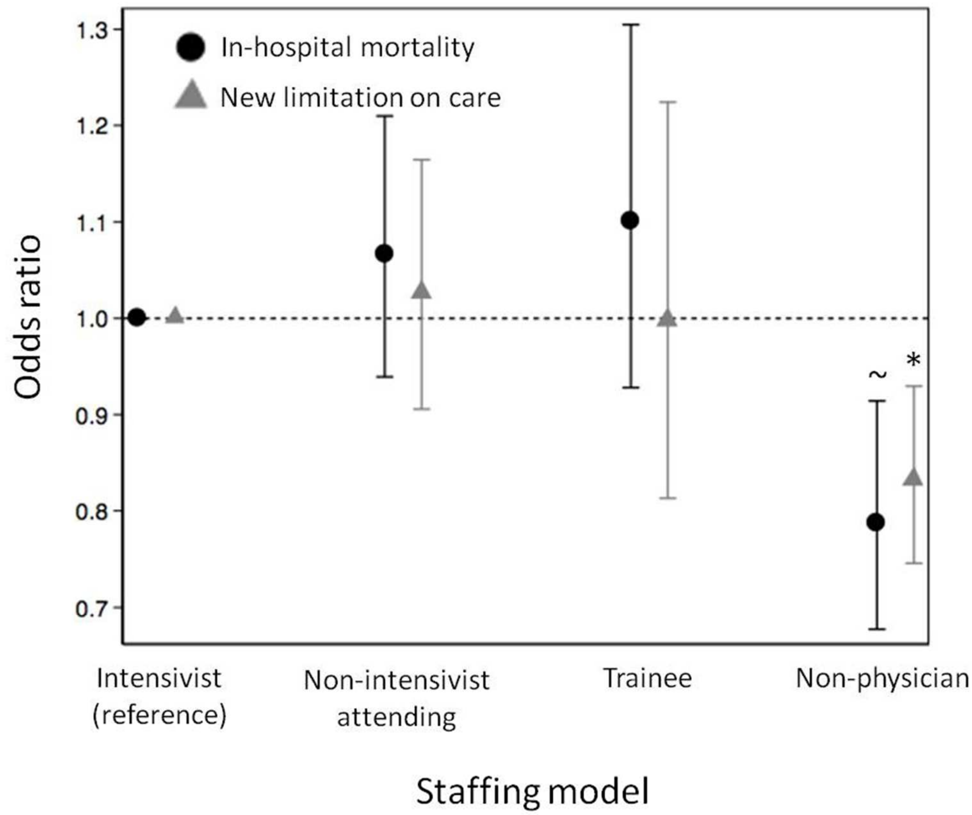

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Nighttime Intensivist Staffing, Mortality, and Limits on Life Support: A Retrospective Cohort Study
Meeta Prasad Kerlin, Michael O. Harhay, Jeremy M. Kahn, Scott D. Halpern

SUPPLEMENTAL MATERIAL

e-Table 1: Variable definitions

Variable	**Definition and categories**
Outcomes	
Hospital mortality	Vital status at the time of hospital discharge
New limitation on therapy	Any new limitation(s) on therapy during the ICU admission
Duration of mechanical ventilation	Duration of mechanical ventilation, in hours
ICU LOS	Duration of ICU admission, in hours
Hospital LOS	Duration of hospital admission, in days
Exposure	
Nighttime staffing	
Binary	Presence or absence of in-person intensivist attending physician during nighttime hours
Categorical	Ordered categories of the most experienced clinicians available in person during nighttime hours • Intensivist attending physician • Non-intensivist attending physician • Trainee • Non-physician
Potential confounders	
Hospital- and ICU-level	
Affiliation with medical school	Self-reported level of affiliation with an accredited medical school • No affiliation • Secondary affiliation (e.g., site for student rotations but not primary teaching hospital) • Primary clinical site for a medical school
Affiliation with critical care fellowship	Self-reported level of affiliation with an accredited critical care fellowship program • No affiliation • Secondary affiliation (e.g., site for fellow rotations but not primary teaching hospital) • Primary clinical site for a fellowship program
Regional location	Geographic location of the hospital according to regions defined by the American Hospital Association

Potential confounders (continued)	
Patient-level	
MPM-III score	Predicted risk of death
Gender	• Male • Female • Other or unknown
Race	• American Indian/Alaska Native/Australia • Asian/Pacific • Black/African American/African European • Latin/Hispanic • White/Caucasian • Other or unknown
Location prior to ICU admission	• Emergency department • General medical ward • Step-down ward • Another ICU within the same hospital • Procedure (e.g., operating room) • Another acute care hospital • Rehabilitation or skilled nursing facility • Other
Presence of chronic medical conditions	• Liver disease • Pulmonary disease • Renal disease • HIV • Chronic immunosuppression • Hematologic malignancy • Metastatic cancer
Pre-hospital functional status	• Independent • Partially dependent • Fully dependent
Insurance status	• Private • Medicare • Medicaid • Self-pay • Other or unknown
Reason for ICU admission	• Active treatment • Observation
Type of admission	• Medical • Scheduled surgical • Emergent surgical

e-Table 2: Summary of patient exclusions due to missing data

Analysis	n (%)
Multivariable analysis of mortality	12,087 (4.4%)
Multivariable analysis of limitations on therapy	14,941 (5.5%)

e-Table 3: Proportion of patients with missing data, stratified by nighttime staffing model

	Proportion of patients with any missing data for covariates included in multivariable models	
Nighttime staffing	**Median**	**IQR**
Attending intensivist	0.012	0.006, 0.041
Attending non-intensivist	0.015	0.006, 0.056
Trainee	0.023	0.006, 0.032
Non-physician	0.016	0.005, 0.030

e-Table 4: Sensitivity analyses

Nighttime staffing model	OR	p	95% CI
Redefining patients discharged to hospice as alive at hospital discharge			
Attending intensivist	Reference		
Attending non-intensivist	1.04	0.58	0.90,1.21
Trainee	1.08	0.36	0.91,1.27
Non-physician	0.75	0.002	0.62,0.90
Excluding ICUs highest quartile of proportion of patients with any missing data for covariates included in multivariable models*			
Attending intensivist	Reference		
Attending non-intensivist	1.07	0.523	0.88, 1.30
Trainee	1.03	0.758	0.84, 1.26
Non-physician	0.80	0.012	0.67, 0.95

Included 190,960 patients in 108 ICUs.

e-Table 5: CPR events prior to ICU deaths

Nighttime staffing	ICU deaths n	CPR prior to death n (%)
Attending intensivist	8241	1077 (13.1)
Attending non-intensivist	5877	753 (12.8)
Trainee	8281	1147 (13.9)
Non-physician	977	162 (16.6)

Chi-square p-value=0.006