CHEST

# Nighttime Intensivist Staffing, Mortality, and Limits on Life Support

## A Retrospective Cohort Study

*Meeta Prasad Kerlin, MD, MSCE; Michael O. Harhay, MPH; Jeremy M. Kahn, MD; and Scott D. Halpern, MD, PhD*

**BACKGROUND:** Evidence regarding nighttime physician staffing of 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 with 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; $P = .65$). This relationship was not modified by daytime physician staffing (interaction $P = .19$). When nighttime staffing was subcategorized, neither attending nonintensivist nor physician trainee staffing was associated with hospital mortality compared with 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; $P = .002$) and new limitations on life support (OR, 0.83; 95% CI, 0.75-0.93; $P = .001$). Nighttime staffing was not associated with ICU or hospital length of stay. Nighttime staffing with an attending nonintensivist was associated with a slightly longer duration of mechanical ventilation (hazard ratio, 1.05; 95% CI, 1.02-1.09; $P < .001$).

**CONCLUSIONS:** We found little evidence that nighttime physician staffing models affect patient outcomes. ICUs without physicians at night may exhibit reduced hospital mortality that is possibly attributable to differences in end-of-life care practices. CHEST 2015; 147(4):951-958

Manuscript received February 28, 2014; revision accepted September 17, 2014; originally published Online First October 16, 2014.

**ABBREVIATIONS:** IMPACT = International Mission for Prognosis and Analysis of Clinical Trials in Traumatic Brain Injury; IQR = interquartile range; $MPM_0$-III = Mortality Prediction Model-III

**AFFILIATIONS:** From the Pulmonary, Allergy, and Critical Care Division, Department of Medicine (Drs Kerlin and Halpern), Center for Clinical Epidemiology and Biostatistics (Drs Kerlin and Halpern and Mr Harhay), and Department of Medical Ethics and Health Policy (Dr Halpern), Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA; Leonard Davis Institute of Health Economics (Drs Kerlin and Halpern and Mr Harhay), P30 Roybal Center on Behavioral Economics and Health (Dr Halpern), and Fostering Improvement in End-of-Life Decision Science (FIELDS) Program (Dr Halpern), University of Pennsylvania, Philadelphia, PA; and Clinical Research, Investigation, and Systems Modeling of Acute Illness (CRISMA) Center (Dr Kahn), Department of Critical Care, University of Pittsburgh School of Medicine, Pittsburgh, PA.

Part of this article has been presented in abstract form at the American Thoracic Society 2013 International Congress, May 17-22, 2013, Philadelphia, PA.

**FUNDING/SUPPORT:** This project was supported in part by a grant from the National Heart, Lung, and Blood Institute [K08HL116771 to Dr Kerlin] and a grant from the Agency for Healthcare Research and Quality [K08HS018406 to Dr Halpern].

**CORRESPONDENCE TO:** Meeta Prasad Kerlin, MD, MSCE, Pulmonary, Allergy, and Critical Care Division, Perelman School of Medicine, University of Pennsylvania, 3600 Spruce St, W Gates Bldg, Rm 05011, Philadelphia, PA 19104; e-mail: prasadm@uphs.upenn.edu



**DOI:** 10.1378/chest.14-0501

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 (ie, absence of routine care by intensivists during the day), ICUs that employed in-hospital intensivists at night had lower risk-adjusted mortality than those without nighttime intensivists. No such differences were seen in ICUs with high-intensity daytime staffing (ie, 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 (eg, staffing by nonintensivist attending physicians); the effects of these staffing models in a sample comprising primarily community-based ICUs; or the effects of these staffing models on important nonmortal outcomes, such as length of stay and duration of mechanical ventilation.

Given the resource intensiveness of staffing ICUs with attending physicians, particularly intensivists, at night, it is essential to clarify how the full range of possible nighttime ICU staffing models influences patient-centered outcomes. Furthermore, because intensivists may play an important role in decisions to limit life support, which in turn could 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.

FOR EDITORIAL COMMENT SEE PAGE 867

we conducted a retrospective cohort study of nighttime physician staffing models in the largest sample, to our knowledge, of US ICUs to date, using the Project IMPACT (International Mission for Prognosis and Analysis of Clinical Trials in Traumatic Brain Injury) 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 are 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). IMPACT is a multicenter, voluntary (therefore nonrandom) ICU clinical registry used for benchmarking purposes and frequently used in critical care outcomes research.[11-14] Each ICU uses a trained data collector and standardized electronic form to gather data on ICU and hospital organization, structure, and processes of care and on clinical characteristics of admitted patients. Data collectors specifically report the in-hospital physician and nonphysician staffing of ICUs, including whether the daytime and nighttime physicians, if any, are critical care attending physicians (attending intensivists), noncritical 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] The present 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 enrolled in IMPACT for whom complete data were collected between 2001 and 2008 (Fig 1) and excluded ICUs with < 20 admissions per quarter, that were enrolled in the registry for < 1 year, and 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. Patients who were ineligible for risk adjustment using the Mortality Prediction Model-III ($MPM_0$-III) score were excluded (ie, those for whom the $MPM_0$-III is not validated, including patients aged < 18 years, burn patients, coronary care patients, and cardiothoracic 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 model during nighttime hours, which we defined in two ways. First, we created

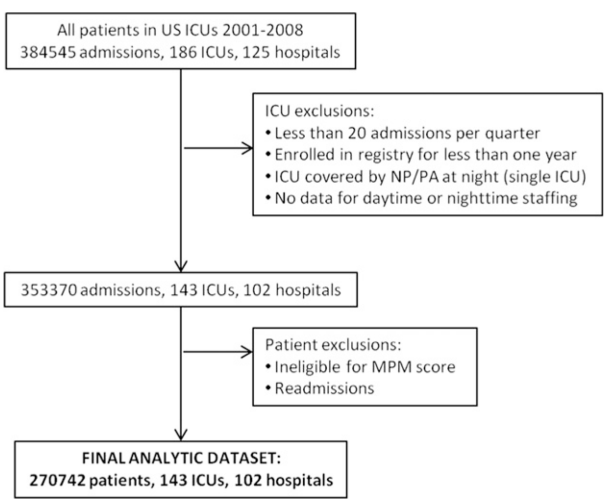


Figure 1 – *ICU and patient exclusions. MPM = Mortality Prediction Model; NP = nurse practitioner; PA = physician assistant.*

a binary variable indicating the presence or absence of a nighttime intensivist, yielding analyses of the effect of nighttime intensivists compared with 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 nonintensivist physician, (3) trainee physician (ie, resident, fellow), or (4) no physician. This categorization clarified 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 used at the time of ICU admission.

The primary outcome was hospital mortality. Patients discharged to hospice were counted as having died during the hospitalization because 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.

Limitations on life support were coded using the following categories: (1) no limitations on care; (2) an order to withhold CPR; (3) an order to withhold CPR plus one or more of the following: mechanical ventilation, cardioversion, dialysis, and 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 previous work.[9,11-13] Hospital- and ICU-level covariates included affiliation with a medical school, affiliation with a critical care fellowship program, and regional location of the hospital. Patient-level covariates included severity of illness as measured by $MPM_0$-III score,[16,18] sex, race, location prior to ICU admission, presence of several chronic medical conditions, prehospital functional status, insurance status, reason for ICU admission, and type of admission. Details of all variable definitions are provided in e-Table 1.

We prespecified 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 are greater among medical than surgical patients because medical patients are more likely to have acute illnesses that may benefit from immediate expert decision-making and that the effects are particularly large among more severely ill patients.

### *Statistical Analysis*

We performed standard descriptive statistics to summarize ICU and patient characteristics and used the $\chi^2$ test and analysis of variance, as appropriate, to compare characteristics across the different staffing models. To test the independent association of nighttime staffing with mortality and 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 aforementioned prespecified variables 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 to study the effects of nighttime staffing at a more granular level. To test the independent association of nighttime staffing on the 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 SEs to account for clustering within ICUs.

**TABLE 1** ] ICU Characteristics

| Characteristic | ICUs[a] (n = 143) | Patients (N = 270,742) |
|---|---|---|
| No. ICU beds | | |
| <12 | 39 (27) | 51,441 (19) |
| 16-24 | 50 (35) | 85,717 (32) |
| 17-24 | 34 (24) | 87,347 (32) |
| >24 | 20 (14) | 46,237 (17) |
| Daytime critical care physician staffing | | |
| High intensity | 37 (26) | 87,461 (32) |
| Low intensity | 106 (74) | 183,281 (68) |
| Highest level of in-hospital provider at night | | |
| Attending intensivist physician | 43 (29) | 85,425 (32) |
| Attending nonintensivist physician | 43 (30) | 77,244 (29) |
| Trainee physicians | 54 (38) | 95,510 (35) |
| No physician | 5 (4) | 12,563 (5) |
| ICU type[b] | | |
| Mixed medical/surgical | 76 (54) | 168,720 (63) |
| Medical, including CCU | 27 (19) | 37,203 (14) |
| Surgical | 35 (25) | 62,090 (23) |
| Neurologic | 2 (1) | 1,110 (0.4) |
| Cardiothoracic | 2 (1) | 387 (0.1) |
| Affiliation with medical school[c] | | |
| Primary | 32 (25) | 68,065 (25) |
| Secondary | 90 (61) | 163,903 (61) |
| None | 21 (15) | 38,774 (14) |
| Affiliation with critical care fellowship program[c] | | |
| Primary | 33 (23) | 84,072 (31) |
| Secondary | 17 (12) | 19,101 (7) |
| None | 93 (65) | 167,569 (62) |

Data are presented as No. (%). CCU = critical care unit; IMPACT = International Mission for Prognosis and Analysis of Clinical Trials in Traumatic Brain Injury.

[a]In some cases, ICUs changed characteristics during the course of their participation in Project IMPACT (eg, increased in size from 10 beds to 14 beds). Such ICUs were assigned to the category into which the highest proportion of patients fell.

[b]Data on ICU type are missing for one ICU (1,232 patients); therefore, proportions presented are with denominators of 142 ICUs and 269,510 patients.

[c]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 the site for student/fellow rotations but not the primary teaching hospital, and none if neither were true.

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 < 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 covariate 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, 3), we believed that exclusion of these patients would unlikely 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 missing data to confirm that no bias was introduced by excluding patients with missing data from the primary analysis as described. 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 because discharge to hospice may be considered a positive outcome.

An $\alpha < .05$ was considered significant for all statistical tests. All analyses were performed using Stata 12 (StataCorp LP) statistical software.

## Results

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

The overall hospital mortality was 14.9%. In the multivariable models examining nighttime staffing as a binary variable, no significant difference was found between nighttime staffing with or without an attending intensivist with respect to hospital mortality among all patients and in analyses stratified by daytime staffing model (Table 3). There was no significant interaction between nighttime staffing model and daytime staffing intensity (interaction $P = .19$). In the multivariable

**TABLE 2** ] Patient Characteristics

| Characteristic | All Patients (N = 270,742) | Attending Intensivist (n = 85,425) | Attending Nonintensivist (n = 77,244) | Trainee (n = 95,510) | Nonphysician (n = 12,563) | *P* Value |
|---|---|---|---|---|---|---|
| Age, y | 62 (47-75) | 60 (45-74) | 63 (48-75) | 62 (47-75) | 66 (51-77) | < .001 |
| Male sex | 54.2 | 55.6 | 53.9 | 53.2 | 52.7 | < .001 |
| Race | | | | | | < .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 condition | | | | | | |
| ESRD | 4.3 | 4.3 | 4.4 | 4.3 | 4.1 | .173 |
| Respiratory disease | 6.7 | 6.0 | 6.7 | 6.5 | 12.1 | < .001 |
| Cardiovascular disease | 4.8 | 3.5 | 4.9 | 4.5 | 16.5 | < .001 |
| GI/liver disease | 2.9 | 2.8 | 2.8 | 3.1 | 3.4 | < .001 |
| Metastatic cancer | 4.2 | 4.5 | 3.3 | 4.5 | 6.5 | < .001 |
| HIV | 0.6 | 0.8 | 0.4 | 0.5 | 0.6 | < .001 |
| Type of ICU admission | | | | | | < .001 |
| Medical | 65.9 | 63.2 | 69.8 | 65.2 | 64.4 | |
| Postoperative, scheduled | 21.7 | 20.9 | 20.2 | 23.9 | 19.3 | |
| Postoperative, unscheduled | 12.5 | 15.9 | 9.9 | 10.9 | 16.2 | |
| Any mechanical ventilation | 13.6 | 16.2 | 10.6 | 13.9 | 12.7 | < .001 |
| Any vasopressor | 20.7 | 22.4 | 19.2 | 20.2 | 22.3 | < .001 |
| $MPM_0$-III probability of mortality | 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) | < .001 |

Data are presented as median (interquartile range) or %. All *P* values were estimated using a $\chi^2$ 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 analysis of variance models. ESRD = end-stage renal disease; $MPM_0$-III = Mortality Prediction Model-III.

**TABLE 3** ] Risk-Adjusted ORs for Mortality for Staffing Without a Nighttime Intensivist

| ICU | No. Patients | OR[a] | 95% CI | *P* Value |
|---|---|---|---|---|
| All | 258,655 | 1.03 | 0.92-1.15 | .65 |
| Stratified by daytime staffing model | | | | |
| High intensity | 84,179 | 1.11 | 0.83-1.49 | .48 |
| Low intensity | 174,476 | 0.98 | 0.88-1.09 | .74 |

ICU-level variables for risk adjustment were affiliation with a medical school, affiliation with a critical care fellowship program, and regional location. Patient-level variables for risk adjustment were $MPM_0$-III score, sex, race, location prior to ICU admission, presence of chronic medical conditions, prehospital functional status, insurance status, reason for ICU admission, and type of admission. See Table 2 legend for expansion of abbreviation.
[a]Compared with staffing with a nighttime intensivist.

models examining nighttime staffing as an ordered categorical variable, neither nonintensivist attending physicians (OR, 1.07; 95% CI, 0.94-1.21; *P* = .32) nor trainee physicians (OR, 1.10; 95% CI, 0.93-1.30; *P* = .27) were associated with hospital mortality compared with 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* = .002) (Fig 2). Results were similar in stratified analyses of medical and surgical patients (interaction *P* = .35) (Table 4) and in sensitivity analyses (e-Table 4). Nighttime staffing model was not differentially effective among patients with different severities of illness (interaction *P* = .873).

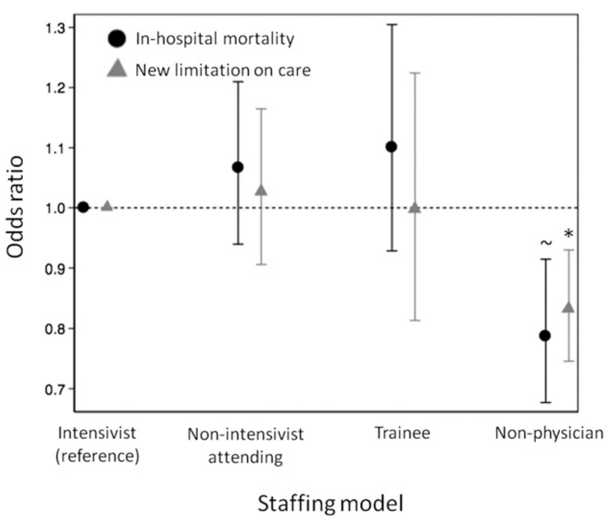


Figure 2 – *ORs for association of a nighttime staffing model with in-hospital mortality and new limitations on life-sustaining therapy. The reference group for all categories is nighttime staffing with an intensivist attending physician. Analyses of in-hospital mortality included 258,655 patients. Analyses of new limitations on care included 255,801 patients.* ~P = *.002.* *P = *.001.*

Neither nonintensivist attending staffing (OR, 1.02; 95% CI, 0.91-1.16; *P* = .68) nor trainee staffing (OR, 1.00; 95% CI, 0.81-1.22; *P* = .98) during nighttime hours were associated with the odds of new limitations on life support compared with 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* = .001) (Fig 2). Correspondingly, deaths in ICUs with no physicians during nighttime hours were more likely to be preceded by CPR than deaths in ICUs with nighttime intensivist staffing (16.6% vs 13.1%, $\chi^2$ *P* = .006) (e-Table 5).

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

## Discussion

This study of > 270,000 patients admitted to 143 US ICUs identified no benefit of nighttime intensivist staffing compared with either nighttime staffing with nonintensivist attending physicians or trainee physicians (residents and fellows) with regard 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 medical and surgical patients and independent of 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, suggesting that in a large sample of ICUs, nighttime intensivist staffing is not associated with other outcomes, including ICU and hospital length of stay or duration of mechanical ventilation. Together,

**TABLE 4** ] Risk-Adjusted ORs for Mortality for Nighttime Staffing Models, Stratified by Type of Admission

| Nighttime Staffing | Medical (n = 170,469) | | | Surgical (n = 88,186) | | |
|---|---|---|---|---|---|---|
| | OR | 95% CI | *P* Value | OR | 95% CI | *P* Value |
| Attending intensivist | Reference | … | … | Reference | … | … |
| Attending nonintensivist | 1.09 | 0.98-1.22 | .12 | 1.08 | 0.86-1.35 | .50 |
| Trainee | 1.15 | 0.98-1.36 | .08 | 1.03 | 0.83-1.28 | .80 |
| Nonphysician | 0.83 | 0.73-0.95 | .006 | 0.67 | 0.53-0.84 | .001 |

ICU-level variables for risk adjustment were affiliation with a medical school, affiliation with a critical care fellowship program, and regional location. Patient-level variables for risk adjustment were $MPM_0$-III score, sex, race, location prior to ICU admission, presence of chronic medical conditions, prehospital functional status, insurance status, reason for ICU admission, and type of admission. See Table 2 legend for expansion of abbreviation.

these studies provide consistent and convincing evidence that nighttime intensivist staffing is not of clinical benefit in ICUs with daytime availability of intensivists.

However, these results conflict with another study that suggested benefit of nighttime staffing in ICUs without mandatory involvement of an intensivist during the day.[9] The study included two ICU samples: one of 49 ICUs overrepresented by academic centers with high-intensity daytime staffing and resident nighttime staffing and one of 112 ICUs that 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] the sample also is 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 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, the 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. The present results cannot be used to determine whether this association is directly related to the lack of physicians and 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, as 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 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

**TABLE 5** ] Risk-Adjusted HRs[a] for Secondary Outcomes

| Nighttime Staffing | Duration of Mechanical Ventilation (n = 56,644) | | | ICU Length of Stay (n = 258,407) | | | Hospital Length of Stay (n = 258,645) | | |
|---|---|---|---|---|---|---|---|---|---|
| | HR | 95% CI | *P* Value | HR | 95% CI | *P* Value | HR | 95% CI | *P* Value |
| Attending intensivist | Reference | … | … | Reference | … | … | Reference | … | … |
| Attending nonintensivist | 1.05 | 1.02-1.09 | < .001 | 1.00 | 0.93-1.08 | .90 | 1.01 | 0.93-1.10 | .74 |
| Trainee | 1.02 | 0.91-1.15 | .75 | 0.98 | 0.88-1.10 | .77 | 0.99 | 0.88-1.12 | .87 |
| Nonphysician | 1.06 | 0.93-1.20 | .35 | 1.01 | 0.93-1.08 | .88 | 1.00 | 0.94-1.05 | .97 |

ICU-level variables for risk adjustment were affiliation with a medical school, affiliation with a critical care fellowship program, and regional location. Patient-level variables for risk adjustment were $MPM_0$-III score, sex, race, location prior to ICU admission, presence of chronic medical conditions, prehospital functional status, insurance status, reason for ICU admission, and type of admission. HR = hazard ratio. See Table 2 legend for expansion of other abbreviation.
[a]An HR > 1 favors attending intensivist staffing.

and all ICU 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. Although 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 because 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, although the analyses accounted for severity of illness, the $MPM_0$-III score may not provide complete risk adjustment. Finally, 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, the present 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.


## Acknowledgments

**Author contributions:** M. P. K. had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. M. P. K., M. O. H., J. M. K., and S. D. H. contributed to the study concept and design; data interpretation; and writing, revision, and approval of the manuscript.

**Financial/nonfinancial disclosures:** The authors have reported to *CHEST* the following conflicts of interest: Dr Kahn's institution receives grant funding from the US government and the Gordon and Betty Moore Foundation; has received speaking honoraria and travel reimbursement from the American Thoracic Society, the Society of Critical Care Medicine, the Canadian Critical Care Society, the UK Intensive Care Society, the International Symposium on Intensive Care and Emergency Medicine, and the National Association of Long-term Care Hospitals; and has received consultancy fees from the US Department of Veterans Affairs on the topic of ICU telemedicine. Drs Kerlin and Halpern and Mr Harhay have reported that no potential conflicts of interest exist with any companies/organizations whose products or services may be discussed in this article.

**Role of sponsors:** The funding agencies played no role in the development of the research or the manuscript. The Cerner Corporation, which owns IMPACT, made no contributions to the study beyond providing the data.

**Other contributions:** The authors thank Andrew Kramer, PhD (Cerner Corporation), for providing the data for this study and Sarah Ratcliffe, PhD (University of Pennsylvania), for assisting with analytic programming.

**Additional information:** The e-Tables can be found in the Supplemental Materials section of the online article.


## References


1. Hanson CW III, Deutschman CS, Anderson HL III, et al. Effects of an organized critical care service on outcomes and resource utilization: a cohort study. *Crit Care Med*. 1999;27(2):270-274.
2. Pronovost PJ, Angus DC, Dorman T, Robinson KA, Dremsizov TT, Young TL. Physician staffing patterns and clinical outcomes in critically ill patients: a systematic review. *JAMA*. 2002;288(17):2151-2162.
3. Vincent JL. Need for intensivists in intensive-care units. *Lancet*. 2000;356(9231):695-696.
4. Rubenfeld GD, Angus DC. Are intensivists safe? *Ann Intern Med*. 2008;148(11):877-879.
5. Blunt MC, Burchett KR. Out-of-hours consultant cover and case-mix-adjusted mortality in intensive care. *Lancet*. 2000;356(9231):735-736.
6. Gajic O, Afessa B, Hanson AC, et al. Effect of 24-hour mandatory versus on-demand critical care specialist presence on quality of care and family and provider satisfaction in the intensive care unit of a teaching hospital. *Crit Care Med*. 2008;36(1):36-44.
7. Garland A, Roberts D, Graff L. Twenty-four-hour intensivist presence: a pilot study of effects on intensive care unit patients, families, doctors, and nurses. *Am J Respir Crit Care Med*. 2012;185(7):738-743.
8. Kerlin MP, Small DS, Cooney E, et al. A randomized trial of nighttime physician staffing in an intensive care unit. *N Engl J Med*. 2013;368(23):2201-2209.
9. Wallace DJ, Angus DC, Barnato AE, Kramer AA, Kahn JM. Nighttime intensivist staffing and mortality among critically ill patients. *N Engl J Med*. 2012;366(22):2093-2101.
10. Wilcox ME, Chong CA, Niven DJ, et al. Do intensivist staffing patterns influence hospital mortality following ICU admission? A systematic review and meta-analyses. *Crit Care Med*. 2013;41(10):2253-2274.
11. Brown SE, Ratcliffe SJ, Kahn JM, Halpern SD. The epidemiology of intensive care unit readmissions in the United States. *Am J Respir Crit Care Med*. 2012;185(9):955-964.
12. Gabler NB, Ratcliffe SJ, Wagner J, et al. Mortality among patients admitted to strained intensive care units. *Am J Respir Crit Care Med*. 2013;188(7):800-806.
13. Wagner J, Gabler NB, Ratcliffe SJ, Brown SE, Strom BL, Halpern SD. Outcomes among patients discharged from busy

intensive care units. *Ann Intern Med*. 2013;159(7):447-455.

14. Levy MM, Rapoport J, Lemeshow S, Chalfin DB, Phillips G, Danis M. Association between critical care physician management and patient mortality in the intensive care unit. *Ann Intern Med*. 2008;148(11):801-809.
15. Cook SF, Visscher WA, Hobbs CL, Williams RL; Project IMPACT Clinical Implementation Committee. Project IMPACT: results from a pilot validity study of a new observational database. *Crit Care Med*. 2002;30(12): 2765-2770.
16. Higgins TL, Teres D, Copes W, Nathanson B, Stark M, Kramer A. Updated Mortality Probability Model (MPM-III). *Chest*. 2005;128(4_Meeting Abstracts):348S.
17. Reineck LA, Pike F, Le TQ, Cicero BD, Iwashyna TJ, Kahn JM. Hospital factors associated with discharge bias in ICU performance measurement. *Crit Care Med*. 2014;42(5):1055-1064.
18. Juneja D, Singh O, Nasa P, Dang R. Comparison of newer scoring systems with the conventional scoring systems in general intensive care population. *Minerva Anestesiol*. 2012;78(2): 194-200.
19. Reineck LA, Wallace DJ, Barnato AE, Kahn JM. Nighttime intensivist staffing and the timing of death among ICU decedents: a retrospective cohort study. *Crit Care*. 2013;17(5):R216.
20. Quill CM, Ratcliffe SJ, Harhay MO, Halpern SD. Variation in decisions to forgo life-sustaining therapies in US ICUs. *Chest*. 2014;146(3):573-582.