The Association of ICU Acuity With Outcomes of Patients at Low Risk of Dying

Kelly C. Vranas, MD[1,2]; Jeffrey K. Jopling, MD, MSHS[1,3]; Jennifer Y. Scott, MS[1]; Omar Badawi, PharmD, MPH[4,5,6]; Michael O. Harhay, PhD[7,8]; Christopher G. Slatore, MD, MS[2,9]; Meghan C. Ramsey, MD[1,10]; Michael J. Breslow, MD[4]; Arnold S. Milstein, MD, MPH[1]; Meeta Prasad Kerlin, MD, MSCE[11]

[1]Clinical Excellence Research Center, Department of Medicine, Stanford University, Stanford, CA.

[2]Division of Pulmonary and Critical Care, Department of Medicine, Oregon Health & Science University, Portland, OR.

[3]Department of Surgery, Stanford University, Stanford, CA.

[4]Department of Research and Development, Philips Healthcare, Baltimore, MD.

[5]Department of Pharmacy Practice and Science, University of Maryland School of Pharmacy, Baltimore, MD.

[6]Institute for Medical Engineering and Science, Massachusetts Institute of Technology, Cambridge, MA.

[7]Department of Biostatistics, Epidemiology and Informatics, University of Pennsylvania, Philadelphia, PA.

[8]Center for Health Equity Research and Promotion, Corporal Michael J. Crescenz VA Medical Center, Philadelphia, PA.

[9]Health Services Research & Development, VA Portland Health Care System, Portland, OR.

[10]Division of Pulmonary and Critical Care, Department of Medicine, Stanford University, Stanford, CA.

[11]Pulmonary, Allergy and Critical Care Division, Department of Medicine, University of Pennsylvania, Philadelphia, PA.

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For information regarding this article, E-mail: vranas@ohsu.edu

Objective: Many ICU patients do not require critical care interventions. Whether aggressive care environments increase risks to low-acuity patients is unknown. We evaluated whether ICU acuity was associated with outcomes of low mortality-risk patients. We hypothesized that admission to high-acuity ICUs would be associated with worse outcomes. This hypothesis was based on two possibilities: 1) high-acuity ICUs may have a culture of aggressive therapy that could lead to potentially avoidable complications and 2) high-acuity ICUs may focus attention toward the many sicker patients and away from the fewer low-risk patients.

Design: Retrospective cohort study.

Setting: Three hundred twenty-two ICUs in 199 hospitals in the Philips eICU database between 2010 and 2015.

Patients: Adult ICU patients at low risk of dying, defined as an Acute Physiology and Chronic Health Evaluation-IVa–predicted mortality of 3% or less.

Exposure: ICU acuity, defined as the mean Acute Physiology and Chronic Health Evaluation IVa score of all admitted patients in a calendar year, stratified into quartiles.

Measurements and Main Results: We used generalized estimating equations to test whether ICU acuity is independently associated with a primary outcome of ICU length of stay and secondary outcomes of hospital length of stay, hospital mortality, and discharge destination. The study included 381,997 low-risk patients. Mean ICU and hospital length of stay were 1.8 ± 2.1 and 5.2 ± 5.0 days, respectively. Mean Acute Physiology and Chronic Health Evaluation IVa–predicted hospital mortality was 1.6% ± 0.8%; actual hospital mortality was 0.7%. In adjusted analyses, admission to low-acuity ICUs was associated with worse outcomes compared with higher-acuity ICUs. Specifically, compared with the highest-acuity quartile, ICU length of stay in low-acuity ICUs was increased by 0.24 days; in medium-acuity ICUs by 0.16 days; and in high-acuity ICUs by 0.09 days (all $p < 0.001$). Similar patterns existed for hospital length of stay. Patients in lower-acuity ICUs had significantly higher hospital mortality (odds ratio, 1.28 [95% CI, 1.10–1.49] for low-; 1.24 [95% CI, 1.07–1.42] for medium-, and 1.14 [95% CI, 0.99–1.31] for high-acuity ICUs) and lower likelihood of discharge home (odds ratio, 0.86 [95% CI, 0.82–0.90] for low-, 0.88 [95% CI, 0.85–0.92] for medium-, and 0.95 [95% CI, 0.92–0.99] for high-acuity ICUs).

Conclusions: Admission to high-acuity ICUs is associated with better outcomes among low mortality-risk patients. Future research should aim to understand factors that confer benefit to patients with different risk profiles. (*Crit Care Med* 2018; 46:347–353)

Key Words: Acute Physiology and Chronic Health Evaluation; critical care; intensive care units; patient acuity; resource allocation

Every year, more than 5 million patients are admitted to ICUs across the United States, with costs of roughly $82 billion or 0.66% of the gross domestic product (1, 2). Such spending is driven largely by the number of ICU beds and their utilization (3). The number of ICU beds in the United States steadily increased by 26% from 1985 to 2000 despite a concurrent decrease in the total number of hospital beds (4). The increased supply of ICU beds in the United States is associated with increased ICU utilization (5, 6), even by patients unlikely to benefit from critical care (7).

Patients at low risk of dying comprise a substantial proportion of ICU admissions in the United States. Multiple studies in different healthcare settings have shown that up to 50% of patients admitted to ICUs are unlikely to require or benefit from critical care interventions or could have received equivalent care in non-ICU settings (8–10). These data highlight the potential opportunity to improve the efficiency and value of critical care in the United States. Furthermore, there is an additional concern that ICU admission could actually expose such patients to undue risks. For example, hospitals that use ICU care more frequently for certain low-risk conditions are more likely to perform invasive procedures and incur higher costs, but without an associated improvement in hospital mortality (11). In addition, ICU patients at low risk of dying who experience longer than expected ICU lengths of stay (LOS) have significantly higher mortality and increased resource consumption compared with patients of similar acuity with LOS in the expected range, suggesting that these outcomes may be, in part, due to complications suffered while in the ICU (12).

Characterizing the treatment environment associated with improved outcomes for patients at low risk of dying will inform efforts to improve the efficiency, value, and quality of ICU-based care. We sought to evaluate whether there is an association of admission to ICUs with higher average patient severity (defined as high-acuity ICUs) compared with ICUs with lower average patient severity (defined as low-acuity ICUs) with outcomes of patients at low risk of dying. We hypothesized that admission to high-acuity ICUs would be associated with worse outcomes among low mortality-risk patients. This hypothesis was based on two possibilities: 1) that high-acuity ICUs may have a culture of aggressive therapy that could lead to potentially avoidable complications and 2) that high-acuity ICUs may focus attention toward the many sicker patients and away from the fewer low-risk patients.

METHODS

Study Design and Data Source

We conducted a retrospective cohort study using the Philips eICU Research Institute Database, which aggregates granular clinical and administrative data from an organizationally and geographically diverse mix of over 320 participating hospitals in the United States (13–15). Further details are available in the **supplemental data** (Supplemental Digital Content 1, http://links.lww.com/CCM/C976).

Patients and Variables

The cohort included patients 18 years old or older admitted to 322 ICUs between 2010 and 2015 who were at low risk of in-hospital mortality, defined as Acute Physiology and Chronic Health Evaluation (APACHE) IVa–predicted hospital mortality of 3% or less. APACHE IVa is a validated ICU severity-of-illness adjustment system that uses physiologic variables to predict ICU and hospital mortality and LOS (16). This definition of low-risk patients was chosen a priori based on both expert consensus and prior literature demonstrating a hospital mortality of 2.5% for ICU patients admitted primarily for monitoring purposes, who were otherwise at low risk of requiring active ICU therapies (10). It was also in line with results of a study performed in the VA Healthcare System that demonstrated low (< 2%) 30-day predicted mortality for patients admitted to the ICU (9).

Figure 1 summarizes patient selection. We excluded admissions to ICUs during years with less than 100 total admissions and/or less than 95% valid APACHE IVa data in a calendar year. We also excluded patients with invalid or incomplete data to calculate an APACHE IVa score; patients with unknown or "other" sex; and patients transferred to or from other facilities. For patients with multiple ICU admissions, we excluded all subsequent readmissions.

Primary Exposure

The primary exposure was ICU acuity, defined by the mean APACHE IVa score for all patients admitted during a calendar year regardless of their risk profile. After confirming a near-normal distribution, we categorized ICU acuity into quartiles of low-, medium-, high-, and highest-acuity per ICU-year, to facilitate comparison of ICUs and interpretability of the results. ICUs could change categories of acuity across individual years of the study period, depending on the relative mean APACHE IVa score in a given year. The mean range of annual APACHE IVa scores for lowest-acuity ICUs was 34.4 to less than 50.0; medium-acuity was 50.0 to less than 54.0; high-acuity was 54.0 to less than 58.0, and highest-acuity was 58.0 to 78.4.

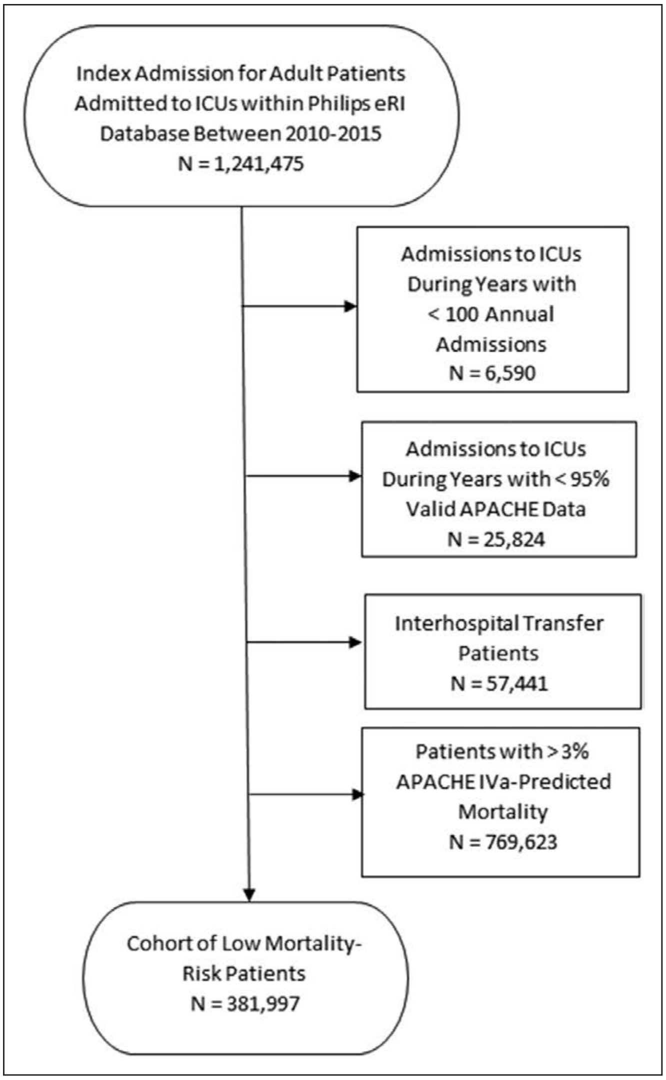

Figure 1. Combined ICU- and patient-level exclusion criteria. APACHE = Acute Physiology and Chronic Health Evaluation, eRI = eICU Research Institute.

Outcomes

The primary outcome variable was ICU LOS. Secondary outcomes were hospital LOS, ICU and hospital mortality, and likelihood of discharge to home. For the outcome of likelihood of discharge to home, decedents were included in the analysis as not being discharged to home.

Other Variables

Potential confounders chosen a priori included patient demographics, location prior to ICU admission, admitting diagnosis, ICU type, hospital teaching status and number of beds, and patient APACHE IVa score. Further details of potential confounders are available in the supplemental data (Supplemental Digital Content 1, http://links.lww.com/CCM/C976).

Analysis

We summarized all variables using standard descriptive statistics. We estimated unadjusted differences between ICU acuity levels using chi-square tests and Wilcoxon rank sum tests, as appropriate.

We performed patient-level multivariable analyses using generalized estimating equations to test for adjusted differences in ICU and hospital LOS. We built three models for the primary outcome of ICU LOS: 1) a simple model including only the exposure variable of ICU acuity; 2) a model including the exposure variable and patient APACHE IVa scores; and 3) a fully adjusted model, including all covariates identified a priori. There was no difference in effect size or statistical significance for the exposure variable between the second and third models for the primary outcome. Therefore, we used the model adjusted for patient APACHE IVa scores for both primary and secondary analyses in order to optimize computational efficiency and because APACHE IVa scores are based on several of the covariates we had included in the fully adjusted model.

Next, we fit logit models on the secondary outcomes of ICU and hospital mortality, and hospital discharge to home. We also conducted two sensitivity analyses using: 1) ICU acuity as a continuous variable and 2) a broadened definition of low-risk patients defined as APACHE IVa–predicted hospital mortality of less than 5%, which represents the median mortality of all patients in the cohort regardless of risk profile. Full details of our model-building strategies are available in the supplemental data (Supplemental Digital Content 1, http://links.lww.com/CCM/C976).

Finally, we performed several restricted analyses to explore possible mechanisms for our findings. First, we excluded trauma patients and patients admitted for coronary bypass graft (CABG) surgery because these patients represented the majority of LOS outliers (defined as LOS > 99^{th} percentile). Patients undergoing CABG surgery also represented the majority of patients with APACHE IVa scores greater than 70. Second, we evaluated the role of total annual ICU patient volume by adding it to the model. Third, we excluded patients admitted with diabetic ketoacidosis (DKA) and neurologic diagnoses because the prevalence of these diagnoses differed substantially between low- versus highest-acuity ICUs (**Table 1**). All analyses utilized a p value of 0.05 or less as a threshold for significance and were completed using Stata version 14 (StataCorp, LLC, College Station, TX). All data were de-identified, and the study was considered exempt from human subjects review by both the Stanford University and Veteran Affairs Portland Health Care System Institutional Review Boards.

RESULTS

Characteristics of Patients

The final analysis included 381,997 low mortality-risk patients admitted to 322 ICUs in 199 hospitals. Mean ICU and hospital LOS were 1.8 ± 2.1 and 5.2 ± 5.0 days, respectively. Mean APACHE IVa–predicted hospital mortality was 1.6% ± 0.8%; actual hospital mortality was 0.7% (**Supplemental Table** 1, Supplemental Digital Content 1, http://links.lww.com/CCM/C976). Slightly more than half of the ICUs (52.2%) were mixed medical/surgical ICUs, and the rest were specialty ICUs. The average annual patient volume was 990 ± 569, with a minimum

TABLE 1. Characteristics and Unadjusted Outcomes of Low-Mortality Risk[a] Patients Based on Admission to ICUs of Variable Acuity Levels

Characteristics	Low-Acuity ICUs (*n* = 100,987)	Med-Acuity ICUs (*n* = 98,309)	High-Acuity ICUs (*n* = 90,392)	Highest-Acuity ICUs (*n* = 92,309)
Age, mean ± SD[b]	53.8 ± 16.4	54.8 ± 16.3	52.8 ± 16.5	52.2 ± 16.7
Male, *n* (%)	56,926 (56.4)	57,227 (58.2)	51,758 (57.3)	53,092 (57.5)
Race, *n* (%)				
White	75,419 (74.7)	73,697 (75.0)	68,952 (76.3)	66,816 (72.4)
Black	11,688 (11.6)	12,585 (12.8)	9,999 (11.1)	12,305 (13.3)
Other	13,880 (13.7)	12,027 (12.2)	11,441 (12.7)	13,188 (14.3)
APACHE IVa score, mean ± SD	31.9 ± 11.1	35.3 ± 11.9	35.5 ± 12.0	37.0 ± 12.5
APACHE IVa–predicted hospital mortality, mean % ± SD	1.6 ± 0.8	1.5 ± 0.8	1.6 ± 0.8	1.6 ± 0.8
Admission source, *n* (%)				
Emergency department	49,491 (49.0)	46,865 (47.7)	46,666 (51.6)	47,876 (51.9)
Operating room	24,432 (24.2)	30,570 (31.1)	23,486 (26.0)	21,196 (23.0)
Ward transfer	6,104 (6.0)	5,954 (6.1)	6,498 (7.2)	6,627 (7.2)
Direct admit	7,980 (7.9)	5,732 (5.8)	5,579 (6.2)	5,732 (6.2)
Other	12,980 (12.9)	9,188 (9.3)	8,163 (9.0)	10,878 (11.8)
Admitting diagnosis, *n* (%)				
Cardiac	29,051 (28.8)	35,838 (36.5)	26,074 (28.8)	22,834 (24.7)
Diabetic ketoacidosis	5,787 (5.7)	6,950 (7.1)	7,876 (8.7)	9,702 (10.5)
Gastrointestinal bleeding	3,941 (3.9)	4,150 (4.2)	4,241 (4.7)	5,132 (5.6)
Neurologic	13,168 (13.0)	7,480 (7.6)	7,508 (8.3)	6,985 (7.6)
Overdose	6,239 (6.2)	6,422 (6.5)	7,028 (7.8)	7,920 (8.6)
Respiratory	1,528 (1.5)	1,663 (1.7)	1,381 (1.5)	1,426 (1.5)
Sepsis	6,196 (6.1)	6,292 (6.4)	6,646 (7.4)	8,000 (8.7)
Trauma	6,946 (6.9)	3,599 (3.7)	3,983 (4.4)	3,857 (4.2)
Other	28,131 (27.9)	25,915 (26.4)	25,655 (28.4)	26,453 (28.7)
ICU LOS, mean days ± SD	1.8 ± 2.1	1.8 ± 2.2	1.7 ± 2.1	1.7 ± 2.2
ICU mortality, *n* (%)	257 (0.3)	284 (0.3)	266 (0.3)	228 (0.2)
Hospital LOS, mean days ± SD	4.7 ± 4.7	5.3 ± 5.1	5.2 ± 5.1	5.5 ± 5.3
Hospital mortality, *n* (%)	647 (0.6)	707 (0.7)	601 (0.7)	592 (0.6)

APACHE = Acute Physiology and Chronic Health Evaluation, LOS = length of stay.
[a]Low-mortality risk defined as APACHE IVa–predicted hospital mortality between 0 and 3%.

of 112 and maximum of 2,964 patients. Hospitals varied widely in their number of hospital beds, and 80% of the ICUs were non-teaching (i.e., not members of Council of Teaching Hospitals and Health Systems) (**Supplemental** Table 2, Supplemental Digital Content 1, http://links.lww.com/CCM/C976) (17). Additional data including characteristics of *all* patients in the study cohort (regardless of risk profile) and stratified by ICU acuity are available in **Supplemental** Table 3 (Supplemental Digital Content 1, http://links.lww.com/CCM/C976).

Table 1 summarizes characteristics and unadjusted outcomes of the low-risk patients based at admission to ICUs of variable acuity levels. The emergency department was the most common admission source across all quartiles of ICU acuity, followed by the operating room. Cardiac diagnoses represented the most common reason for admission. Unadjusted analyses revealed a slight increase in ICU LOS (1.8 ± 2.1 vs 1.7 ± 2.2 d; $p < 0.001$) and decrease in hospital LOS (4.7 ± 4.7 vs 5.5 ± 5.3 d; $p < 0.001$) for low-risk patients admitted to low-acuity ICUs

TABLE 2. Results of Multivariable Analyses Demonstrating ICU and Hospital Length of Stay Outcomes[a] for Low-Mortality Risk[b] ICU Patients Based on ICU Acuity

	Predicted Difference in Days (95% CI)	
ICU Acuity	ICU LOS	Hospital LOS
Highest-acuity	1.64 d	4.81 d
High-acuity	+ 0.09 (0.07–0.12)	+ 0.10 (0.04–0.17)
Medium-acuity	+ 0.16 (0.13–0.19)	+ 0.29 (0.21–0.36)
Low-acuity	+ 0.24 (0.21–0.28)	+ 0.37 (0.28–0.46)

LOS = length of stay.
[a]All $p < 0.001$.
[b]Low-mortality risk defined as Acute Physiology and Chronic Health Evaluation-IVa–predicted hospital mortality between 0 and 3%.

compared with patients admitted to highest-acuity, respectively. There were no significant differences in unadjusted ICU mortality (0.3% vs 0.2%, $p = 0.742$) or hospital mortality (0.6% vs 0.6%, $p = 0.986$).

Comparison by ICU Acuity

Results of the log-gamma and linear multivariable models were comparable and demonstrated a significant association of increasing average ICU acuity with decreased ICU LOS in a dose-dependent fashion (**Table 2**). Specifically, admission of low mortality-risk patients to low-acuity ICUs was associated with longer ICU LOS (difference of 0.24 d; $p < 0.001$) compared with admission to of those to the highest-acuity ICUs. Similarly, admission to low-acuity ICUs was associated with longer hospital LOS (difference of 0.37 d; p < 0.001). These findings were consistent across all levels of patient APACHE score (**Fig. 2**). Increasing average ICU acuity was also associated with decreased hospital mortality and increased odds of discharge home from the hospital (**Table 3**). Admission to the highest-acuity ICUs was associated with decreased ICU mortality compared with any other category of ICU acuity.

Additional Analyses

For the primary outcome of ICU LOS, a sensitivity analysis using ICU acuity as a continuous variable again demonstrated that higher ICU acuity was associated with decreased ICU LOS. Our findings were also robust in a sensitivity analysis defining low-risk patients as those with an APACHE IVa–predicted mortality of less than 5%. In a restricted analysis excluding CABG and trauma patients (who comprised the majority of LOS outliers within the study cohort), the overall pattern of results was the same and statistically significant, though the effect size decreased. The addition of annual ICU volume for patients across all illness severities as a fixed effect in the model resulted in no change in effect size. Finally, in a restricted analysis excluding patients admitted with DKA or neurologic diagnoses, the association between ICU acuity and ICU LOS was essentially unchanged (**Supplemental** Table 4, Supplemental Digital Content 1, http://links.lww.com/CCM/C976).

DISCUSSION

We found that admission of low mortality-risk patients to low-acuity ICUs was associated with longer ICU and hospital LOS, higher hospital mortality, and lower likelihood of discharge home from the hospital than those admitted to higher-acuity ICUs. These results are contrary to our hypothesis that admission to high-acuity ICUs would be associated with worse outcomes among patients at low risk of dying. Instead, our findings suggest that ICUs that routinely care for severely ill patients may perform better in the care of less sick ICU patients and that these outcomes are robust in nonsurgical patients and independent of overall annual ICU volume.

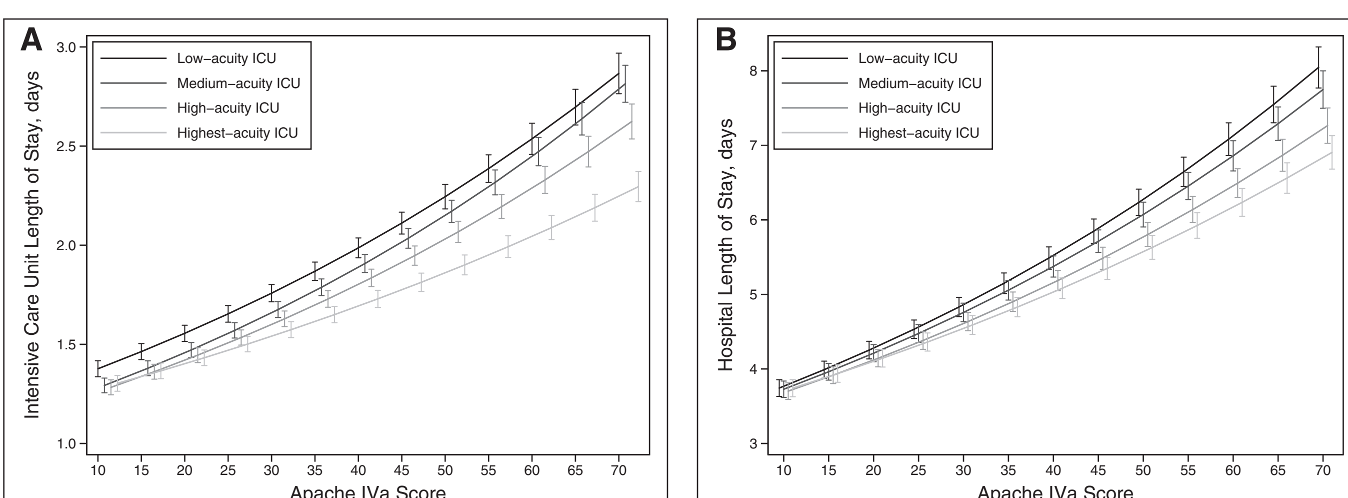

Figure 2. Expected ICU length of stay (**A**) and hospital length of stay (**B**) based on patient Acute Physiology and Chronic Health Evaluation (APACHE) IVa score.[a,b,c] Each line represents the relationship between patient APACHE[a] IVa score and predicted ICU length of stay, stratified by quartiles of ICU acuity. APACHE IVa scores < 10 or > 70 were collapsed into two groups given the small number of patients in the study cohort with scores beyond these thresholds. [b]Margins plot of log-gamma model including interaction term between ICU acuity and APACHE IVa score. [c]Chi-square tests comparing the interactions between APACHE and ICU acuity in aggregate for ICU and hospital LOS were significant at $p < 0.001$ ($\chi^2 = 62.64$ and 47.63, respectively).

TABLE 3. Results of Multivariable Analyses Demonstrating the Association of ICU Acuity With ICU and Hospital Mortality, and Odds of Discharge Home From Hospital Among Low Mortality-Risk[a] ICU Patients

ICU Acuity	ICU Mortality OR (95% CI)	Hospital Mortality OR (95% CI)	Discharge to Home OR (95% CI)
Highest-acuity	Reference	Reference	Reference
High-acuity	1.30 (1.07–1.59)	1.14 (0.99–1.31)	0.95 (0.92–0.99)
Medium-acuity	1.29 (1.06–1.58)	1.24 (1.07–1.42)	0.88 (0.85–0.92)
Low-acuity	1.32 (1.07–1.64)	1.28 (1.10–1.49)	0.86 (0.82–0.90)

OR = odds ratio.

[a]Low-mortality risk defined as Acute Physiology and Chronic Health Evaluation-IVa–predicted hospital mortality between 0 and 3%.

There are several possible explanations for our findings. First, high-acuity ICUs may be more frequently located within larger, tertiary or quaternary care hospitals that provide a broader range of specialty services and tend to be busier than smaller hospitals. As such, high-acuity ICUs may experience more external pressure to discharge less sick patients earlier, to accommodate more severely ill patients who could derive greater benefit from ICU care, thus leading to shorter ICU LOS. Wagner et al (18) recently demonstrated that increases in ICU strain (measured as average ICU acuity, census, and admissions) on the days of ICU discharge were associated with significantly shorter ICU LOS without any association with subsequent death, hospital LOS, or likelihood of being discharged home from the hospital. These findings suggest that ICUs under pressure, as is common in high-acuity ICUs, may safely discharge low mortality-risk ICU patients earlier. Taken together, these findings also highlight the potential opportunity to safely reduce the provision of high-cost, low-value ICU care for this group of patients, particularly in low-acuity ICUs within the United States.

Second, at the ICU level, high-acuity ICUs may more effectively implement and standardize evidence-based organizational structures and processes of care. For example, the use of daily checklists and interprofessional rounds has been associated with improved ICU mortality and LOS (19, 20). Staffing models that include ready availability of critical care specialists and low patient-to-nurse ratios have been also associated with improved patient outcomes (21, 22). In addition, clinical protocols for sedation management, adherence to low tidal volume mechanical ventilation approaches for patients with acute respiratory distress syndrome, and ventilator liberation strategies have demonstrated mortality benefit in randomized clinical trials (23–27). Future research investigating whether high-acuity ICUs are more adherent than low-acuity ICUs to such evidence-based practices is warranted and could be particularly useful in understanding possible mechanisms for our findings. Furthermore, qualitative methods including medical ethnography could offer additional insights into the relationship between ICU culture, available resources, adherence to evidence-based practices, and patient outcomes. Such research may enable the identification of previously unmeasured and potentially modifiable features of critical care delivery systems that are associated with improved outcomes for patients with different risk profiles across a variety of healthcare settings.

Interestingly, our results were independent of overall ICU volume. Prior studies have demonstrated a significant association of higher ICU admission volume with improved outcomes among critically ill adult patients (28–32). In the largest systematic review and meta-analysis published on this topic to date, patients at the highest risk of death were most likely to benefit from admission to a high-volume center. However, ICU and/or hospital-level organizational factors were found to be major determinants of the observed volume-outcome relationship (30). Our study adds to the literature by focusing on ICU acuity rather than volume as the primary exposure. Our results may also inform debates regarding regionalization of critical care by offering additional insight into potential ICU- and hospital-level factors that enable certain ICUs to perform better than others, specifically in the care of low-risk ICU patients who represent an important target in efforts to improve the overall value of critical care.

Our study has several limitations. First, there is a lack of consensus regarding the definition of low-risk patients. Although the definition used for this study was chosen a priori based on both expert consensus and literature review, the threshold of 3% or less predicted mortality is somewhat subjective. Second, ICUs include a diverse mix that vary in size, location, teaching status, and ICU type across the United States, but are all participants in a tele-ICU program, which is in itself an ICU-level intervention. Third, our study could not measure the association of ICU acuity with outcomes of low-risk patients after discharge from the hospital because the Philips eICU data set does not collect post-hospital discharge data. However, we would expect any adverse effects to be apparent closer to the time of ICU discharge. Fourth, we did not have access to data on other hospital characteristics such as ICU staffing models. Although we cannot exclude the influence of staffing patterns on outcomes in our study, recent literature has demonstrated that high-intensity daytime staffing may not be associated with improved mortality after accounting for interprofessional rounds, protocols, and other organizational factors (33). We also were not able to assess the availability of hospital beds downstream of the ICU, which may contribute to ICU LOS. However, the finding that average ICU acuity had similar relationships with both ICU and hospital LOS suggests that hospital bed availability was unlikely to be a major factor.

There is also risk of misclassification of ICU acuity. It is possible that some ICUs in our cohort may appear to be higher-acuity units due to faulty recording of Glasgow Coma Scale (GCS). GCS is an important component of the APACHE IVa score that is subject to potentially inaccurate assessment in the setting of sedative medications, which are commonly administered to critically ill patients (34). However, this issue is common across all studies that use APACHE IVa scoring for severity adjustment. In addition, our study focuses on comparisons between the low-acuity and highest-acuity ICUs, therefore maximizing the differences between the exposure variables. Finally, as an observational study, we cannot rule out the possibility that there is unmeasured confounding, such as patient characteristics, rather than ICU factors, that may drive the observed associations.

In summary, we found that admission to high-acuity ICUs is associated with better outcomes for ICU patients at low risk of dying. These results improve our understanding of factors that may influence outcomes for low-risk ICU patients and highlight the potential opportunity to improve the value and efficiency of care for this important and substantial patient population.

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