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ICU capacity strain and adherence to prophylaxis guidelines

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Abstract

Purpose—To examine the relationship between different measures of capacity strain and adherence to prophylaxis guidelines in the intensive care unit (ICU).

Materials and Methods—We conducted a retrospective cohort study within the Project IMPACT database. We used multivariable logistic regression to examine relationships between ICU capacity strain and appropriate usage of venous thromboembolism prophylaxis (VTEP) and stress ulcer prophylaxis (SUP).

Results—Of 776,905 patient-days eligible for VTEP, appropriate therapy was provided on 68%. Strain as measured by proportion of new admissions (OR 0.91, 95% CI 0.90 – 0.91) and census (OR 0.97, 95% CI 0.97 – 0.98) was associated with decreased odds of receiving VTEP. With increasing strain as measured by new admissions, the degradation of VTEP utilization was more severe in ICUs with closed (OR 0.85, 95% CI 0.83 – 0.88) than open (OR 0.91, 95% CI 0.91 – 0.92) staffing models (interaction p-value < 0.001). Of 185,425 patient-days eligible for SUP, 48% received appropriate therapy. Administration of SUP was not significantly influenced by any measure of strain.

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Conclusions—Rising capacity strain in the ICU reduces the odds that patients will receive appropriate VTEP but not SUP. The variability among different types of ICUs in the extent to which strain degraded VTEP use suggests opportunities for systems improvement.

Keywords

surge capacity; intensive care units; venous thromboembolism; gastrointestinal hemorrhage; prophylaxis

Introduction

The patient population in the United States is growing older, becoming more complex, and is expected to require increasing critical care services in the coming years (1, 2). Increasing demand for services without concomitant increases in resources will lead to rising ICU capacity strain, defined as a time-varying influence on the ICUs ability to provide high-quality care for critically ill patients (3).

Patients cared for in ICUs on days of elevated capacity strain incur small incremental risks for hospital mortality (4) and ICU readmissions (5). Increasing strain may exert detrimental effects on processes of care. For example, the time physicians allocate to individual ICU patients is inversely associated with the strain that day (6).

Potential adverse effects on processes of care are important to understand because they often signal the possibility of low-quality care that could worsen a variety of patient outcomes. Because ICU patients are known to experience numerous medication errors (7, 8), the present study explores whether certain types of medication errors, namely failures to provide venous thromboembolism prophylaxis (VTEP¹) and stress ulcer prophylaxis (SUP), occur more commonly on days of high ICU capacity strain. We also seek to identify types of ICUs in which these hypothesized relationships between strain and medication errors may be strongest. This is significant for ICU physicians, nurses, pharmacists, and administrators, because the study poses a question with a clinically relevant, actionable target.

We focus first on VTEP because it is strongly recommended for almost all critically ill patients (9), and has recently been identified as a patient safety topic of national concern (10, 11). VTE is associated with increased morbidity and mortality (12, 13), yet adherence to VTEP in the ICU is known to be variable (14–17). Second, we examine SUP because it is also strongly recommended in many critically ill patients, especially those receiving mechanical ventilation (18). Such recommendations are supported by evidence that gastrointestinal bleeding from stress ulcers is associated with increased morbidity and mortality among ICU patients (19, 20).

Thus, understanding how strain may induce errors of omission in VTEP and SUP, and particularly whether certain types of ICUs may be relatively immune or susceptible to these adverse effects, may help to improve the future quality of ICU care. Specifically, elucidating

¹VTEP = venous thromboembolism prophylaxis, SUP = stress ulcer prophylaxis

the mechanism through which strain may increase patient morbidity and mortality provides a direct target for care process interventions in the ICU.

Materials and Methods

Data

We performed a retrospective cohort study using the Project IMPACT database (21) to examine prophylaxis adherence patterns, accounting for patient and ICU characteristics. Preliminary results from this study were previously reported in a conference poster (22).

The primary exposure variables included three objective measures of capacity strain that stem from a conceptual model (3) and have been shown to correlate with clinicians' perceptions of strain (23): 1) standardized ICU census, 2) ICU acuity, and 3) proportion of new admissions on a given day. We also evaluated whether patients were admitted on a weekend or weekday, a potential marker of capacity. The standardized census was calculated by including patients in the ICU on a given day for greater than two hours, then subtracting the yearly mean and dividing by the yearly standard deviation for that ICU in the given year. ICU acuity was calculated as the average predicted probability of death of all patients in the unit excluding the index patient, using the mortality-prediction model (MPM₀-III) (24). The proportion of new admissions was calculated as the proportion of the total census that had been admitted on a given day. Weekend admissions were those in which the time of admission to the ICU fell on a Saturday or a Sunday.

The primary outcome was documented receipt of appropriate prophylaxis for each eligible patient-day. In sensitivity analyses we examined receipt of appropriate prophylaxis at any time during the first three eligible days of ICU admission, and of receipt of appropriate prophylaxis at any eligible time during the entire ICU admission. To explore whether certain types of ICUs were better able to accommodate the effects of strain on prophylaxis administration, we explored interactions between strain and various ICU-level characteristics, including annual volume, daytime intensivist staffing model, nighttime staffing model, and resident physician staffing.

Study Population

Eligible patients were admitted to an ICU between April 1, 2001 and December 30, 2008. ICUs with less than 20 patients per quarter, those outside the United States, and those contributing patients to the database for less than one year were excluded (4). Patients who were younger than 18 years at the time of admission, not eligible for MPM₀-III scoring, and those with established limitations on life support at the time of discharge from the ICU were also excluded. Patients who died while in the ICU were included in the analyses on their day of death as long as they met all other eligibility criteria. Two separate, non-exclusive subsets of the data were extracted based on eligibility criteria for receipt of VTEP and SUP. See figure 1 below for a full description of the derivation of the analytic sample.

Patients were considered eligible for VTEP if they did not have active bleeding as an admission diagnosis, and remained eligible for VTEP on all ICU days up to two days prior to a documented bleeding event, if one was recorded. VTEP was considered as having been

received if either pharmacologic (e.g. unfractionated heparin, low-molecular-weight heparin, warfarin, or other anticoagulant) or mechanical (e.g. intermittent compression device) prophylaxis was documented as administered on a given day. Patients receiving full-dose anticoagulation for other indications were considered to be receiving sufficient prophylaxis. Because the process of deciding upon and administering full-dose anticoagulation for a serious diagnosis such as pulmonary embolism or acute myocardial infarction may be significantly less susceptible to capacity strain than provision of simple prophylaxis, this choice would tend to bias our results towards the null hypothesis. Patients were considered eligible for SUP once they were mechanically ventilated for greater than 48 hours by noon on a given day, even if they were extubated later the same day. SUP was considered as having been received if pharmacologic (e.g. proton-pump inhibitor, histamine-2 receptor antagonist, or sucralfate) prophylaxis was documented as administered on a given day.

Statistical Analysis

In primary analyses we examined these outcomes at the patient-day level. Single-variable logistic regression was used to select potentially important patient covariates from the available data set. We hypothesized *a priori* that patient demographics, location, admission purpose, and severity (see table 3) could confound relationships between capacity strain and use of prophylaxis, and hence forced the following patient-level covariates into the final models: age, gender, race, insurance status, admission origin, admission purpose, presence of chronic medical conditions, mechanical ventilation (except in the SUP group where all patients were ventilated > 48 hours), and severity of illness. Severity of illness of each index patient was adjusted for using the Morality Probability Models (MPM₀-III) score (24). The log transformation was used for this value to account for the non-linear relationship with the primary outcome. Each model also included the four primary exposures of capacity- and strain-related covariates calculated for each patient-day as mentioned above.

ICU-year was included as a fixed effect in all analyses to adjust for correlation of outcomes within ICUs and to prevent confounding by practice differences among ICUs or within ICUs over time. (25, 26). We also used robust standard errors at the patient level (27), since the same patient is more likely to receive similar treatment on different days of the same hospitalization. In sensitivity analyses examining receipt of prophylaxis during the first three eligible calendar days of the ICU stay and over eligible days of the entire ICU stay, we used mean values of all time-varying strain measures across these days.

We considered p values of less than 0.05 to be significant. The data preparation and analysis were performed using the R programming language version 3.0 (28) and Stata version 12.1 (29). This study was considered to be exempt by the Institutional Review Board of the University of Pennsylvania.

Results

There were 185,304 unique patients eligible for 776,905 days of VTEP across 155 ICUs. There were 27,030 unique patients eligible for 185,425 days of SUP across 155 ICUs. The mean probability of death as predicted by MPM₀-III was 12.4% (IQR 3.5 – 15.9) in the VTEP group and 19.2% (IQR 6.5 – 25.5) in the SUP group. On eligible patient-days in the

VTEP group, adherence for prophylaxis was 39.5% for pharmacologic, 48.7% for mechanical, and 67.7% for at least one type. In the SUP group prophylaxis was given on only 47.8% of eligible patient-days. Other baseline characteristics of the patient population are summarized in table 1. The ICU characteristics are described in supplemental table 1.

Primary analysis: fully adjusted multivariable logistic regression

Bivariable analyses demonstrated significant correlations between measures of capacity strain and prophylaxis use (table 2). In fully adjusted models, VTEP adherence decreased as both the proportion of new admissions (OR 0.91, 95% CI 0.90 – 0.91) and ICU census (OR 0.97, 95% CI 0.97 – 0.98) increased. Adherence was also lower among weekend admissions (OR 0.97, 95% CI 0.94 – 0.99). ICU acuity (OR 1.00, 95% CI 0.99 – 1.01) was not associated with changes in the odds of receiving prophylaxis (table 3). In the SUP group, none of the strain measures were associated with the odds of receiving prophylaxis in adjusted analyses (table 3).

Medical, non-operative patients had significantly lower odds of receiving prophylaxis compared to routine surgical patients for both VTEP (OR 0.68, 95% CI 0.65 – 0.72) and SUP (OR 0.78, 95% CI 0.68 – 0.90). Being mechanically ventilated was associated with significantly higher odds of receiving VTEP (OR 4.00, 95% CI 3.85 – 4.17). Increased severity of illness of the patient as measured by MPM₀-III was associated with increased odds of receiving appropriate VTEP (OR 3.95, 95% CI 3.38 – 4.62) but with decreased odds of receiving appropriate SUP (OR 0.74, 95% CI 0.58 – 0.95).

We also found that black compared to white race was associated with decreased odds of receiving VTEP (OR 0.95, 95% CI 0.92 – 0.98) but was not related to the odds of receiving SUP (OR 1.00, 95% CI 0.91 – 1.09). Among patient-days eligible for VTEP, having Medicare (OR 0.96, 95% CI 0.92 – 0.99) or Medicaid (OR 0.92, 95% CI 0.89 – 0.96) compared to private insurance was associated with lower odds of receiving prophylaxis. This pattern was also evident for patient-days eligible for SUP with Medicare (OR 0.90, 95% CI 0.82 – 0.99) and Medicaid (OR 0.89, 95% CI 0.80 – 0.99). Female gender had no effect on the odds of receiving either VTEP (OR 1.02, 95% CI 1.00 – 1.04) or SUP (OR 0.97, 95% CI 0.91 – 1.04).

Sensitivity Analyses: Three-day and full-visit composite outcomes

The results for the three strain measures were generally consistent in the sensitivity analyses in which the outcome was whether or not patients received indicated prophylaxis at any point during their first three eligible days, or at any point during all eligible days (table 4). The one difference was that the significant association between weekend admission and decreased VTEP adherence in the primary analysis was not found in the sensitivity analyses.

We also conducted post-hoc analyses to explore the surprisingly low rates of overall SUP adherence. As would be expected if the variable were properly coded, gastrointestinal bleeding was strongly associated with use of SUP (supplemental table 2). Of the 27,030 eligible patients, the majority either always (41.5%) or never (36.2%) received SUP during their ICU stay (see supplemental figure 1). The adherence rate for SUP was 60% in the first three days of the ICU stay and then declined over time (supplemental figure 2). Among

those patients who did receive SUP at some point, the adherence rate was 69.6% over all eligible patient-days. In order to explore the relationship between capacity strain and potentially differing practice or documentation patterns across ICUs, we re-examined strain in ICUs in which SUP adherence rates were greater than 80%, a marker that SUP was both heavily utilized and documented, and still found no significant relationships with any measures of capacity strain (see supplemental table 4).

Interactions between strain and ICU characteristics

There was a significant interaction between ICU staffing model (open vs closed) and admissions, such that the degradation in VTEP utilization with increased admissions was more severe in ICUs with closed (OR 0.85, 95% CI 0.83 – 0.88) than in ICUs with open staffing models (OR 0.91, 95% CI 0.91 – 0.92) (interaction p-value <0.001). There was also a significant interaction between admissions and nighttime staffing (interaction p-value <0.001). While all night coverage schemes were associated with decreased odds of receiving VTEP with increasing admissions, those staffed by nurse practitioners (NPs) were most sensitive to the effect of admissions (OR 0.83, 95% CI 0.77 – 0.90). Table 5 presents all tests for interactions with ICU characteristics, and supplemental figures 6 – 10 present forest plots of the significant interaction effects by level.

Discussion

In this retrospective cohort study, we found that increased ICU capacity strain was associated with decreased odds of appropriate use of VTEP. This association was significant for capacity strain as measured by ICU census and proportion of new admissions, but not as measured by overall ICU acuity. Furthermore, we found that ICUs with closed staffing models were more sensitive to strain than open ICUs, as exhibited by their greater decrements in VTEP with increasing levels of strain. Rates of appropriate SUP use, however, did not vary significantly with changes in ICU capacity strain by any measure.

We posit that increased strain hinders normal processes of care, including administration of medications, use of appropriate order sets and bundles, and lucid clinical decision making. This provides a plausible mechanism to explain prior evidence of increased mortality associated with a high proportion of new admissions on a given day, and of more pronounced effects in ICUs with closed staffing model (4). Indeed, this explanation is particularly plausible because closed ICUs may have difficulty diffusing the increased caretaking and decision-making burdens under conditions of increased capacity strain.

In addition to these mechanistic insights, this study reveals a discrete and actionable care process – VTEP prophylaxis – which ICUs may choose to monitor closely when experiencing increased capacity strain. Perhaps as importantly, the study identifies a similar care process – SUP prophylaxis – that may not require such increased vigilance during times of high strain, as we observed no significant decrements in SUP prophylaxis rates with rising strain. One explanation for the divergent results may be that strain not only affects processes of care directly, but also increases internal, cognitive demand for busy clinicians. Thus, the decisions to administer anticoagulation to complex, critically ill patients may be more susceptible to strain because they require consideration of changing anticoagulation

parameters, bleeding risks, and need for procedures. By contrast, decisions to administer antacids and other forms of SUP confer little risk and may therefore be relatively immune to increased strain.

Another difference between VTEP and SUP is that the strength of evidence and guidelines for SUP in the ICU are less established (30–32). Further, it is not known which ICUs in this study used pharmacologic prophylaxis (33, 34) as opposed to enteral feeding alone, which may lessen the need for pharmacologic SUP (35), resulting in undocumented practice variation.

While not associated with capacity strain in this study, SUP adherence rates did demonstrate two interesting patterns. The first was high adherence in the first three eligible days, followed by a rapid decline. This pattern stands in stark contrast to VTEP, which increased early in the admission and then plateaued. This suggests distinct mechanisms through which VTEP and SUP are considered, ordered, and delivered. It is possible that VTEP, with more clear evidence for use in the ICU, is more likely to be included in pre-made order sets and care bundles, and is more likely to receive attention from local quality initiatives throughout a patient's ICU stay. SUP, on the other hand, may be found commonly in admission order sets and so has higher rates of documented administration closer to the time of admission, but not in an ongoing fashion throughout a patient's entire ICU admission. It is also possible that as critically ill patients began to receive enteral feeding, some providers determined that pharmacologic SUP was no longer necessary and stopped giving it.

Another interesting feature of SUP adherence rates is the dichotomous administration pattern at the patient rather than at the ICU level. This may reflect variation in specific provider practice patterns, patient-level contraindications not captured in the data set, or perhaps use of enteral feeding in place of pharmacologic prophylaxis for some patients given the lack of clear guidelines on SUP use in the ICU.

Although female gender has been associated with decreased receipt of appropriate treatment for sepsis (36) and acute respiratory distress syndrome (37), our study showed no difference in receipt of prophylaxis by gender for either VTEP or SUP. Prior research examining the influence of poverty and insurance status on critical care patients has been inconclusive. Although neighborhood poverty level does not affect mortality for patients in the ICU at 30 days and at one year (38), uninsured patients do receive fewer critical care services, and lack of insurance may be an independent risk factor for death in the ICU (39). In both the VTEP and SUP groups, patients with Medicare, Medicaid, and self-pay had lower odds of receiving appropriate prophylaxis compared to those with private insurance. It remains unclear from the data available in this study if this represents some bias in the distribution of limited resources under increased strain, or if insurance status is a marker of other residual confounders of clinical severity. Prior research has shown no difference in mortality between blacks and whites in the ICU, but has demonstrated differences in resource utilization rates and length of stay, suggesting either under-treatment of blacks or over-treatment of whites (40). Our study showed a slight decrease in odds of receiving VTEP for blacks, consistent with prior work on racial differences in ICU-based resource allocation (40).

Strengths of this study include the use of a large, representative database of differently sized ICUs throughout the United States, the use of fixed effects and clustering methods to account for clustering of exposures by time, ICU, and patient, and the use of outcomes that are clear and dichotomous.

Nonetheless, these findings must be interpreted in the context of limitations. First, our database did not include data about specific processes of care such as use of checklists, tele-ICU practices (41), default order sets, or of other potentially significant staffing patterns such as nurse-patient ratios (42) and presence of a clinical pharmacist on rounds. Second, the selection of participating ICUs in the IMPACT database is not random, and this may introduce a selection bias towards centers already involved or interested in close monitoring of outcomes and processes of care. In this sample, therefore, adherence rates to prophylactic guidelines may be higher than in non-selected ICUs, and response to strain may be facilitated by more robust support systems and processes in place. This would tend to bias our study towards finding smaller effects of capacity strain. Third, we could not measure daily platelet counts or INRs that could portend daily contraindications to VTEP. However, the inability to gauge these contraindications would tend to reduce the signal-to-noise ratio in analyses relating capacity strain and appropriate prophylaxis. Thus, we may have underestimated the impact of capacity strain on VTEP provision.

Fourth, the data set does not include patient-days after 2008. This may reduce the generalizability of the findings to hospitals that are increasingly utilizing electronic ordering and documentation systems. Fifth, the study results do not apply to patients undergoing cardiac surgery, presenting with acute myocardial infarction, or with ICU readmissions, as these patients were excluded due to ineligibility for MPM₀-III scoring.

Sixth, we do not have meta-data regarding the quality of data collection in each ICU in Project IMPACT, and so we are unable to separate the effects of strain on data collection from those on administration of prophylaxis. Finally, we did not evaluate whether non-adherence to VTEP or SUP was associated with clinical endpoints such as mortality or morbidity.

Conclusions

We have shown that increased ICU capacity strain is associated with reduced use of appropriate VTEP, and that open staffing models respond more robustly under such strain. This is significant because it identifies a potential target for future interventions aimed at specific processes of care, and opens further questions about ICU organizational models and their ability to respond to variations in capacity strain. This is relevant for health care providers, administrators, and policy makers concerned about value and safety in the ICU. It also elucidates a potential mechanism through which capacity strain, as described in previous studies, may increase mortality. Adherence to SUP guidelines in the ICU does not vary with capacity or strain, and is likely related to other staffing and process-related variables not captured in our data set. This suggests the importance of identifying which ICU practices and processes are susceptible to strain and how such effects might be mitigated.

Some suggested solutions to maintaining the integrity of care delivery under capacity strain include promoting teamwork and culture (43), use of mnemonic checklists (44), education and risk stratification guidelines (45), pre-printed order sheets and menu-driven computer decision-support tools (14), and intensive organizational self-analysis and reflection (46). These and other approaches should be studied systematically in ICUs with increased capacity strain to evaluate their efficacy in promoting robust care delivery under increased strain.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.
Derivation of the analytic sample

Table 1

Patient-day characteristics

Variable and Count (Proportion)	VTEP	SUP
Patient-Days	776,905	185,425
Unique Patients	185,304	27,030
Age	59 (IQR 45 – 72)	56 (IQR 42 – 69)
Gender		
Male	431,608 (0.56)	112,386 (0.61)
Female	345,101 (0.44)	73,008 (0.39)
Race		
White	600,958 (0.77)	142,141 (0.77)
Black	111,485 (0.14)	27,490 (0.15)
Insurance		
Private	241,144 (0.31)	61,976 (0.33)
Medicare	357,214 (0.46)	70,267 (0.38)
Medicaid	74,798 (0.10)	20,865 (0.11)
Self Pay	69,894 (0.09)	22,885 (0.12)
Government/Other	26,085 (0.03)	7,540 (0.04)
Patient Type		
Scheduled Post-op	170,505 (0.22)	19,075 (0.10)
Non-scheduled Post-op	126,635 (0.16)	48,363 (0.26)
Medical/Non-operative	479,765 (0.62)	117,987 (0.64)
Admission Source		
Emergency Department	282,264 (0.36)	66,554 (0.36)
Another hospital	46,321 (0.06)	13,627 (0.07)
General Care	105,925 (0.14)	24,589 (0.13)
Stepdown unit	28,919 (0.04)	10,152 (0.05)
Procedure	270,380 (0.35)	54,382 (0.29)
SNF/Rehab	5,039 (0.006)	1,344 (0.007)
Another ICU	21,727 (0.03)	10,103 (0.05)
Other	16,198 (0.02)	4,663 (0.02)
Chronic Disease Burden		
Respiratory	61,898 (0.08)	17,080 (0.09)
Cardiovascular	38,230 (0.05)	7,801 (0.04)
Renal	30,848 (0.04)	4,830 (0.03)
Gastrointestinal	16,918 (0.02)	4,417 (0.02)
Immune Suppression	12,211 (0.02)	2,760 (0.01)
HIV	4,826 (0.006)	1,490 (0.008)
Receipt of VTEP		
Mechanical	378,107 (0.49)	
Pharmacologic	306,503 (0.39)	
Both	158,913 (0.20)	

Variable and Count (Proportion)	VTEP	SUP
Either	525,697 (0.68)	
Neither	251,208 (0.32)	
Receipt of SUP		88,649 (0.48)

Table 2

Bivariable relationships between capacity strain and receipt of prophylaxis by patient-day

Variable	VTEP			SUP		
	Odds Ratio	95% CI	p-value	Odds Ratio	95% CI	p-value
Census	0.92	0.92 – 0.92	<0.001	1.00	0.99 – 1.01	0.829
Acuity	1.05	1.04 – 1.05	<0.001	0.95	0.94 – 0.96	<0.001
Admissions	0.76	0.76 – 0.76	<0.001	1.00	0.99 – 1.01	0.995
Weekend	0.99	0.98 – 1.00	0.295	1.06	1.05 – 0.99	<0.001

Table 3
Primary analysis results – multivariable logistic regression for prophylaxis adherence by patient-day

Variable	Odds Ratio	95% CI	p-value	Odds Ratio	95% CI	p-value
Capacity Strain						
Census	0.97	0.97 – 0.98	<0.001	1.01	0.98 – 1.03	0.521
Acuity	1.00	0.99 – 1.01	0.935	1.01	0.97 – 1.05	0.625
Admissions	0.91	0.90 – 0.91	<0.001	0.99	0.98 – 1.01	0.373
Weekend admission	0.97	0.94 – 0.99	0.009	1.05	0.99 – 1.12	0.099
Race						
White	1.00			1.00		
Black	0.95	0.92 – 0.98	0.002	1.00	0.91 – 1.09	0.917
Gender						
Male	1.00			1.00		
Female	1.02	1.00 – 1.04	0.072	0.97	0.91 – 1.04	0.392
Patient Type						
Post-op, routine	1.00			1.00		
Post-op, unscheduled	0.98	0.94 – 1.02	0.344	1.03	0.92 – 1.16	0.583
Medical, non-operative	0.68	0.65 – 0.72	<0.001	0.78	0.68 – 0.90	0.001
Patient Origin						
Emergency Department	1.00			1.00		
Another hospital	1.19	1.13 – 1.25	<0.001	0.96	0.85 – 1.10	0.593
General care	1.18	1.14 – 1.23	<0.001	0.87	0.79 – 0.96	0.008
Step-down unit	1.22	1.13 – 1.31	<0.001	0.79	0.67 – 0.92	0.003
Procedure	1.23	1.17 – 1.29	<0.001	0.92	0.82 – 1.04	0.195
SNF/Rehab	0.92	0.78 – 1.07	0.286	0.38	0.27 – 0.55	<0.001
Another ICU	1.55	1.42 – 1.70	<0.001	0.74	0.63 – 0.86	<0.001
Other	0.74	0.67 – 0.81	<0.001	0.81	0.65 – 1.01	0.060
Insurance						
Private	1.00			1.00		
Medicare	0.96	0.92 – 0.99	0.009	0.90	0.82 – 0.99	0.029
Medicaid	0.92	0.89 – 0.96	<0.001	0.89	0.80 – 0.99	0.039

Variable	Odds Ratio	95% CI	p-value	Odds Ratio	95% CI	p-value
Self	0.92	0.89 – 0.96	<0.001	1.02	0.92 – 1.14	0.677
Government/Other	1.00	0.93 – 1.07	0.912	1.03	0.87 – 1.21	0.743
Chronic Diseases						
Respiratory	1.11	1.05 – 1.16	<0.001	0.68	0.61 – 0.78	<0.001
Cardiovascular	0.88	0.83 – 0.93	<0.001	0.79	0.67 – 0.93	0.004
Renal	0.56	0.52 – 0.59	<0.001	0.93	0.75 – 1.18	0.572
Gastrointestinal	0.70	0.65 – 0.76	<0.001	1.01	0.82 – 1.27	0.893
Immune Suppression	0.93	0.85 – 1.03	0.155	0.94	0.72 – 1.22	0.648
HIV	0.93	0.80 – 1.08	0.295	0.80	0.56 – 1.15	0.223
Other						
Mechanical ventilation	4.00	3.85 – 4.17	<0.001			
log(MPM ₀ -III)	3.95	3.38 – 4.62	<0.001	0.74	0.58 – 0.95	0.019
Age < 65	1.01	0.98 – 1.04	0.647	1.15	1.05 – 1.26	0.002

Table 4

Sensitivity analyses using composite outcomes of receiving prophylaxis

Capacity Strain	Total Visit				First 3 days			
	Odds Ratio	95% CI	p-value		Odds Ratio	95% CI	p-value	
VTEP								
Census	0.96	0.94 – 0.97	<0.001		0.96	0.95 – 0.98	<0.001	
Acuity	1.00	0.98 – 1.02	0.714		1.00	0.98 – 1.02	0.727	
Admissions	0.87	0.86 – 0.88	<0.001		0.91	0.89 – 0.92	<0.001	
Weekend admission	1.00	0.98 – 1.03	0.809		1.00	0.98 – 1.03	0.899	
SUP								
Census	1.08	1.02 – 1.14	0.011		1.15	0.91 – 1.45	0.241	
Acuity	0.97	0.90 – 1.04	0.344		1.02	0.83 – 1.25	0.837	
Admissions	0.88	0.80 – 0.97	0.008		1.11	0.89 – 1.40	0.115	
Weekend admission	1.08	1.00 – 1.14	0.047		0.78	0.54 – 1.06	0.027	

Table 5

Secondary analysis – p-values for interactions between ICU characteristics and strain

ICU variable	Strain variable	VTEP	SUP
ICU Volume	Census	0.092	0.016
	Acuity	0.014	0.212
	Admissions	0.001	0.396
	Weekend	0.301	0.654
ICU Model	Census	0.489	0.525
	Acuity	0.805	0.471
	Admissions	<0.001	0.121
	Weekend	0.070	0.340
Night Coverage	Census	0.413	0.346
	Acuity	0.225	0.852
	Admissions	<0.001	0.699
	Weekend	0.831	0.867
Resident Coverage	Census	0.420	0.001
	Acuity	0.890	0.711
	Admissions	<0.001	0.596
	Weekend	0.142	0.223