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Hospital Contributions to Variability in the Use of Intensive Care Units among Elderly Medicare Recipients

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Abstract

Objective—Hospitals vary widely in ICU admission rates across numerous medical diagnoses. The extent to which variability in ICU use is specific to individual diagnoses or is a function of the hospital, regardless of disease, is unknown.

Design—Retrospective cohort study

Setting—1,120 acute care hospitals with ICU capabilities

Patients—Medicare beneficiaries ≥65 years old admitted for five medical diagnoses (acute myocardial infarction, congestive heart failure, stroke, pneumonia, and chronic obstructive pulmonary disease) and a surgical diagnosis (hip fracture treated with arthroplasty) in 2010.

Interventions—None

Measurements and Main Results—We used multi-level models to calculate risk- and reliability-adjusted ICU admission rates, examined the correlation in ICU admission rates across diagnosis and calculated intraclass correlation coefficients and median odds ratios (MOR) to quantify the variability in ICU admission rate that was attributable to hospitals. We also examined the ability of a high ICU-use hospital for one condition to predict high ICU use for other conditions. We identified 348,462 patients with one of the eligible conditions. ICU admission rates were positively correlated within hospitals for included medical diagnoses (r range 0.38 to 0.59, $p<0.01$). The top hospital quartile of ICU use for CHF had a sensitivity of 50 to 60% and specificity of 79 to 81% for detecting top quartile hospitals for each other conditions. After

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adjustment for patient and hospital characteristics, hospitals accounted for 17.6% (95% CI 16.2–19.1%) of variability in ICU admission, corresponding to a MOR of 2.3, compared to 25.8% (95% CI 24.5–27.1) and MOR 2.8 for diagnosis. This suggests a patient with median baseline risk of ICU admission would more than double his/her odds of ICU admission if moving to a higher-utilizing hospital.

Conclusions—Hospitals account for a significant proportion of variation independent of measured patient and hospital characteristics, suggesting the need for further work to evaluate the causes of variation at the hospital level and potential consequences of variation across hospitals.

Keywords

Health Services Research; Health Care Delivery; Intensive Care Units; Physician Practice Patterns; Health Care Utilization; Health Care Quality

INTRODUCTION

There is wide variation in ICU use between hospitals for several diagnoses. For example, a recent analysis of discharge data from 61,249 patients admitted for pulmonary embolism demonstrated four-fold variation in ICU utilization without improvements in mortality, readmissions, or costs (1). Similarly, Gershengorn and colleagues examined patients admitted with diabetic ketoacidosis and found significant variation in ICU utilization not associated with differences in mortality or length of stay (2). Safavi and colleagues utilized a national sample of patients with heart failure and found four-fold variation in ICU admission rates that was not associated with differences in mortality (3). Meanwhile, a recent study by Valley, et al, revealed a potentially protective effect to ICU admission for pneumonia (4). This suggests that hospitals vary dramatically in how the ICU is used; yet, greater use of the ICU is not consistently associated with improved outcomes for all conditions (1–5).

In light of uncertainty about the cost-effectiveness of ICU care for selected conditions, a number of specialty societies have issued disease-specific triage guidelines (6–8) to ensure the ICU is being used for all and only individuals who most stand to benefit. Such a disease-specific approach will only reduce inefficiency in ICU utilization if the primary driver is uncertainty among providers in using available clinical data to determine appropriate triage. Guidelines will be less effective if disease- and patient-specific factors do not fully account for variability, which instead may be driven by hospital or provider-specific factors external to the patient. Moreover, this disease-specific approach is limited by the uptake and application of guidelines by clinicians (9, 10). Aside from disease-specific uncertainty surrounding triage, alternative sources of variability across hospitals may include variation in hospital-specific features such as cultural norms regarding monitoring or aggressiveness of care, ICU bed availability, cognitive biases, or perhaps perceived skill of non-ICU nursing (11–15).

To measure the extent to which use of the ICU is a hospital-specific characteristic, and thereby guide efforts aimed at improving ICU efficiency, we examined elderly patients hospitalized with several common diagnoses and sought to determine whether levels of ICU utilization were consistent within hospitals across conditions. We hypothesized that if hospital-level drivers were predominant, ICU utilization rates would be consistent across conditions within a hospital. In contrast, if the primary drivers were disease-specific decision-making, there should be a low correlation within hospitals between diagnoses given the variability of US hospital practice.

MATERIALS AND METHODS

Study Design

We performed a retrospective cohort study using the Medicare Provider Analysis and Review (MedPAR) dataset, which includes discharge abstracts for nearly all fee-for-service Medicare beneficiaries admitted to Medicare-certified hospitals. We used the American Hospital Association's Annual Survey from 2010 to ascertain data on hospital characteristics.

We identified all age 65–90 Medicare beneficiaries admitted to U.S. acute care hospitals in 2010 with primary discharge diagnoses of congestive heart failure (CHF), acute myocardial infarction (AMI), stroke, pneumonia, chronic obstructive pulmonary disease (COPD) or hip fracture treated with arthroplasty. We selected these conditions because they comprise a significant proportion of admissions, often lead to ICU admission, and represent a variety of treating specialties. We included hip fracture treated with arthroplasty to determine if patterns observed across medical conditions were generalizable to surgical conditions. Hip fracture and arthroplasty was selected because it is among the most common surgical DRGs in this population, carries a moderate risk of ICU admission, and is performed across the age groups in the study. We used International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes to identify patients for each included condition (see Supplemental Digital Content); when available (CHF, AMI and COPD) we used Medicare's established methods (used for performance reporting) to identify patients (16). Pneumonia patients were identified using both primary discharge diagnoses and secondary diagnoses with respiratory failure or sepsis as primary diagnoses (17).

To improve reliability of hospital-based estimates, we excluded hospitals admitting fewer than three patients to the ICU for any of the six conditions and hospitals with fewer than two total ICU beds or with missing data on ICU beds. We excluded patients hospitalized via hospital transfer and readmissions (Supplemental Figure 1). Although these exclusions reduced the number of included hospitals, they reduced the risk of spurious associations due to unmeasured differences among patients in non-representative hospitals.

Variables

ICU Admission Rates—For each condition, we identified patients admitted to an ICU as those with at least one ICU day during the admission. ICU days included coronary care unit (CCU), surgical intensive care, neurologic intensive care, and other intensive care units. We excluded psychiatric and intermediate care ICUs. Using hierarchical methods (described below), we estimated ICU admission rates for each condition within each hospital.

Adjustment Variables—Patient-level adjustment variables included demographic data (age, gender, urban or rural residence, and ZIP code median income), comorbidities (18) and admission-specific markers of severity including admission source (emergency department, ambulatory clinic/physician or other), presence of organ system failure (19), and use of invasive or non-invasive mechanical ventilation (NIV) (see Supplemental Digital Content for ICD-9-CM codes). Hospital-level variables included size, ICU capacity (fraction of total beds that are ICU), total and condition-specific discharges over the study period, teaching status (medical school affiliation and resident workforce), nursing workforce (fraction of nurses to beds grouped into ≤1.5, >1.5–2.5, and >2.5), presence of intermediate care, and capabilities for organ transplantation, interventional cardiology, neurology, neurosurgery, and cardiac surgery.

Statistical Analysis

Within-hospital correlation of ICU admission rates—We first estimated hospital- and condition-specific ICU admission rates using empirical Bayes posterior estimates from an empty multilevel logistic regression model with individual hospitalizations nested within hospitals. This technique accounts for the poor reliability of ICU admission rates among hospitals with few cases (10, 20, 21). We estimated the extent to which each condition-specific ICU admission rate was correlated with other condition-specific ICU admission rates within hospitals using Spearman rank-correlations across pairs of conditions. We interpreted correlations of 0.1–0.3 as low, 0.3–0.5 as moderate, and >0.5 as high(22).

To determine the extent to which risk-adjusted ICU utilization is consistent within hospitals across all conditions, we first generated risk-adjusted ICU admission rates. To do so, we entered the above patient- and hospital-level variables into a logistic regression model with ICU admission as the outcome to generate a condition-specific linear risk score that we included in all risk-adjusted models. This technique improves model simplicity and reduce the likelihood of nonconvergence (21). We then determined the rank of each hospital for each condition-specific ICU admission rate separately, and combined these rankings into a single data set. Using these data, we fit a hierarchical linear model with patients nested in hospitals and ICU admission rank as the dependent variable. The intraclass correlation coefficient (ICC) generated from this model represents the degree to which a given hospital is ranked similarly in its use of the ICU across all six conditions.

To further explore the correlations in ICU admission across diagnoses, we performed two additional analyses to examine how well a high ICU admission rate for one condition predicted high ICU admission rates for the other conditions. For the first analysis, we used CHF as a predictor, flagging hospitals in the top quartile of ICU utilization for CHF. We calculated the sensitivity, specificity, and positive and negative likelihood ratios of being flagged in the top quartile for CHF for predicting high utilization for each of the other conditions. In a second analysis using pneumonia as a predictive condition, we began by grouping hospitals by their ICU utilization rates for pneumonia. We then excluded pneumonia patients and plotted predictive margins from the risk- and reliability-adjusted models for ICU admission described above. Pneumonia and CHF were used for these analyses because they were common and both moderate in their risk for ICU admission.

Attributing variation in ICU use to hospital versus diagnosis—To quantify the extent to which variation in ICU use was attributable to hospitals, diagnoses, or patients, we generated a series of hierarchical mixed-effects logistic regression models, with patients nested in diagnosis groups nested in individual hospitals using a patient's ICU admission status as the dependent variable. Models were adjusted for patient and hospital characteristics using the risk score discussed above. Using these models, we calculated two-way ICCs to quantify the observed variability in ICU admission rates attributable to diagnoses or hospitals (23). The ICC quantifies the proportion of variance stemming from each level of a multilevel model. This value is strongly influenced by the variance of the outcome – ICU utilization – in the sample being measured. As a result, the ICC measured in the six diagnoses we chose for analysis may not generalize to that for other conditions. We also calculated median odds ratios (MOR) for diagnoses and hospitals. For the hospital level, the MOR represents the median increase in odds of ICU admission that a patient with median baseline probability of ICU admission would experience if moving to another hospital with a greater risk. It also represents the median value of all odds ratios comparing ICU admission rates in two randomly selected hospitals, one a higher ICU admission hospital and one a lower ICU admission hospital (24).

Outcomes—We also calculated hospital- and condition-specific risk-adjusted 30-day mortality rates and lengths of stay and compared these across hospitals. Length of stay was defined as all hospital days including those spent in intensive and general care, and 30-day mortality was defined as death from any cause within 30 days of the index hospitalization.

Sensitivity analyses—We performed several post-hoc analyses to examine how our study inclusion and exclusion criteria impacted our primary results. First, to determine whether higher-use hospitals were also more likely to use mechanical ventilation (raising the possibility that their patients may be sicker), we examined the rates of mechanical ventilation across centers with higher versus lower use of the ICU among the 6 conditions. Second, we repeated analyses after adjusting the number of included conditions to three, using only CHF, COPD and pneumonia, to see how the results would be influenced by including a larger set of hospitals. To see if our choice of diagnoses influenced the results, we also performed an analysis with three additional conditions (adding colectomy, trauma, and GI bleed to the initial six, see Supplemental Digital Content for ICD-9-CM codes). Next, in two separate analyses, we adjusted our exclusion criteria to exclude hospitals that admitted fewer than 6 patients with each condition to the ICU and excluded patients discharged via transfer to explore how the inclusion of smaller hospitals and differences in transfer practices was impacted our observed results. Finally, to explore hospitals' abilities to provide respiratory support outside of the ICU and how this correlated with ICU use among other conditions, we included use of NIV (for all patients independent of diagnosis) as a seventh diagnosis and repeated our analysis.

Analytics—All data management and analysis were conducted using SAS (V9.2, SAS institute, Cary, NC) and Stata (V13.0, StataCorp, College Station, Texas). The University of Michigan Institutional Review Board reviewed the protocol for this study (University of Michigan Medical School Institutional Review Board, HUM00053488).

RESULTS

We identified 348,462 patients admitted with CHF, AMI, stroke, pneumonia, COPD exacerbation or hip fracture treated with arthroplasty to 1,120 acute-care hospitals. (Supplemental Figure 1; the most common reasons for a hospital to be excluded were having 3 or fewer ICU admissions for one of the diagnoses [n=1,394 excluded hospitals] and for missing data on ICU beds [n=518 excluded hospitals]). A majority of the hospitals were large, not-for-profit and lacked residency programs (Table 1). In-hospital mortality ranged from 1.6% for hip fracture to 7.3% for acute myocardial infarction, while 30-day mortality ranged from 4.4% for hip fracture to 11.6% for pneumonia (Table 2).

Hospitals that were not high-utilizers of the ICU for any condition admitted a median (IQR) of 27,434 (18,812 – 38,227) patients while those hospitals that were high-utilizers for five or all six conditions admitted 20,195 (12,464 – 30,786) patients. ICU admission rates varied widely across hospitals and conditions. The lowest median ICU admission rates were for hip fracture at 8.0% (6.4% – 9.9%) in lowest utilizing hospitals and 19.4% (14.5% – 25.1%) in highest utilizing hospitals. The highest ICU admission rates were for AMI at 52.6% (39.6% – 63.4%) in lowest utilizing hospitals and 82.8% (77.1% – 88.5%) in highest utilizing hospitals.

Rates of invasive mechanical ventilation did not differ significantly across conditions between low- and high-utilizing hospitals. Overall rates of mechanical ventilation were highest for patients with pneumonia at 7.0% (4.7% – 9.2%) in the lowest ICU utilizing hospitals and 5.6% (2.4% – 7.7%) in the highest utilizing hospitals ($p = 0.16$). When limited to the population of patients with ≥2 organ failures, there was no significant difference in invasive mechanical ventilation between low and high utilizing hospitals, with 34.9% (25.0% – 44.4%) receiving mechanical ventilation in low-utilizing hospitals and 31.2% (22.9% – 47.3%) in high-utilizing hospitals ($p = 0.18$) (Supplemental Table 1).

ICU admission rates were moderately-to-highly correlated within hospitals for all pairs of diagnoses (Table 3, all p-values <0.01). Spearman rank correlation coefficients ranged from high (0.59, COPD and pneumonia) to low (0.29, AMI and hip fracture). CHF was the most strongly and consistently correlated with other conditions (range 0.43 – 0.57) and hip fracture was the least correlated (0.29 – 0.43). When all conditions were combined into single model, the within-hospital intraclass correlation coefficient—the correlation in ICU admission rates within hospitals for all conditions—was high at 0.53(22).

Labeling a hospital in the top quartile of ICU admissions for CHF was specific for being in the top quartile of ICU admissions for all other conditions. Specificities (95% CI) ranged from 78.6% (75.5% – 81.4%) for hip fracture to 81.2% (78.3% – 83.9%) for both acute MI and pneumonia. Sensitivities were lower, ranging from 54.0% (48.6% – 59.2%) for hip fracture to 59.6% (54.3% – 64.8%) for AMI (Table 4).

ICU utilization for pneumonia was also predictive of risk-adjusted ICU utilization for other diagnoses. Hospitals ranked in the bottom 10% of ICU utilization for pneumonia used the ICU at a median rate of 5.1% (IQR 2.6% – 16.9%), while hospitals in the middle 80%

utilized the ICU at a rate of 11.1% (5.3% – 37.5%) and hospitals in the top 10% utilized the ICU at a rate of 48.8% (19.1% – 83.5%) for all other conditions (Figure 1).

Unadjusted ICCs were 7.4% (95% CI 6.5% – 8.4%) among hospitals and 31.5% (30.5% – 32.5%) among diagnoses, representing the fraction of total variability in ICU admission attributable to hospitals or patient diagnoses, respectively. These corresponded to median odds ratios of 1.77 and 3.23, respectively. After adjustment for patient and hospital factors, the ICC among hospitals was 17.6% (16.3% – 19.1%), and the ICC among diagnoses was 25.8% (24.5% – 27.1%). These corresponded to median odds ratios of 2.33 and 2.78, respectively (Table 5).

We also evaluated risk-adjusted 30-day mortality and length of stay among patients by diagnosis and usage groups. Mortality (95% CI) was highest for pneumonia at 11.7% (11.6% – 11.8%) in the lowest utilizing group and 11.6% (11.5% – 11.8%) in the highest utilizing group. Length-of-stay (Median, IQR) was also longest among patients with pneumonia at 6.2 (5.7–6.8) days in the lowest utilizing group and 5.8 (5.4 – 6.3) days in the highest utilizing groups. Though there were statistically significant differences between low- and high-utilizing groups for CHF and AMI with 30-day mortality and all conditions for length of stay, absolute differences were small in magnitude (Supplemental Table 2).

When we repeated analyses including only CHF, COPD, and pneumonia the total number of hospitals increased from 1120 to 1932. Hospitals in the three diagnosis sample, compared to the sample including six diagnoses, were more often small (18% vs 6.3% with < 100 beds) (Supplemental Table 3). Correlation coefficients between CHF, COPD and pneumonia were higher but not substantively different (Supplemental Table 4) as was the contribution made by hospitals to overall variability (Supplemental Table 5).

When we added three additional conditions (colectomy, trauma, and gastrointestinal bleeding) to the original six, the number of hospitals decreased from 1,120 to 495. Measured correlations between our original conditions were largely unchanged. Colectomy, trauma, and gastrointestinal bleeding were moderately correlated with all of the original conditions in the study with the exception of hip fracture (Table 6).

Next, we adjusted our exclusion criteria to sequentially hospitals that admitted fewer than six patients to the ICU for any one condition. This reduced the number of hospitals included in our sample from 1,120 to 588. Our measured correlations again did not change significantly (Supplemental Table 6).

We also performed a sensitivity analysis to examine the impact of differential transfer practices by excluding any patient who was admitted or discharged by transfer. Overall, this amounted to 1.6% of included patients. Excluding these patients had a negligible effect on our measured correlations (Supplemental Table 7).

Finally, in a separate analysis, rates of ICU utilization for NIV (among all patients) was positively correlated with ICU utilization for each of the six conditions (range 0.36 to 0.50) (Supplemental Table 8).

DISCUSSION

In this national sample of 348,462 Medicare patients admitted to 1,120 hospitals, we found that ICU utilization varied significantly across hospitals for six common conditions, and that rates of ICU use across medical conditions were correlated within hospitals. Although an individual's specific diagnosis accounted for a large proportion of variance in ICU admission rates, the hospital to which individuals were admitted was nearly as important. Identifying a hospital as one that admits a large proportion of patients with CHF to the ICU was specific for identifying that same hospital as a high utilizer for all of the other studied conditions. Similarly, high utilizers for pneumonia were significantly more likely to admit patients with the other four medical conditions and the included surgical condition to the ICU. Together, these findings reveal that higher-utilizing hospitals may be doing so for a broad range of medical diagnoses.

There are several possible interpretations of these results. First, differing ICU admission practices may be driven by differences in patient acuity across hospitals. Though our ability to control for differences in acuity that cluster at the level of the individual hospital is limited, prohibiting us from confidently ascribing differing use patterns to overuse and underuse, length of stay and 30-day mortality were similar across hospitals, and our results persisted despite adjustment for several administrative markers of severity. Meanwhile, it may be possible that hospitals are 'self-regulating,' and providing care in the setting most appropriate for the local institution. A sensitivity analysis did reveal that ICU utilization for NIV was correlated with high ICU utilization rates for each of the six conditions, potentially supporting this hypothesis. Despite this, it is unclear whether this represents differences in the ability to provide care (such as NIV) outside of the ICU or more aggressive use of NIV therapy among such hospitals. Moreover, our models were adjusted for hospital size, volume, nursing resources, and selected capabilities (such as intermediate care).

Instead, high or low ICU utilization that is consistent across medical conditions may suggest that organizational factors such as hospital-wide policies, practice norms, protocol use, or financial incentives contribute to the way in which a hospital utilizes the ICU. Though hospitals play an important role in driving ICU utilization, most efforts to guide ICU triage come in the form of practice guidelines that are designed by specialty groups and which are often diagnosis-specific. For example, the joint Infectious Diseases Society of America/ American Thoracic Society consensus guidelines for community acquired pneumonia provide several "moderate" and "strong" recommendations regarding triage of selected patients to outpatient treatment, ward care, and the ICU based on clinical factors and severity scores (25).

Efforts to address ICU utilization on the organization level may come in several forms. Should hospitals identify that high ICU use is attributed to inadequate nursing staffing on the floor, a more cost-effective solution may be to increase nursing care on general care floors rather than transferring patients to the ICU. The structure of care coordination present in rapid response teams might form the basis to implement such support. Alternatively, high ICU use in some hospitals and not others may be due to heterogeneity in the training and experience of providers making ICU triage decisions; equally, low ICU in some hospitals may be due to a failure to recognize patients who will benefit from ICU care, at least in some conditions(4) Educating these providers and hospital administrators about appropriate triage, or potentially centralizing triage decisions may better target ICU use to those with greatest ability to benefit. At a more upstream level, hospitals could be benchmarked against their peers by their ICU admission rates for selected conditions. If tied to financial incentives from payers, low-utilizing hospitals could potentially be rewarded. Of course, prior to widely implementing such programs, researchers and policy makers must ensure that incentivizing reduced ICU use does not result in unintended harm of floor patients.

These findings should be taken in context of several important limitations. The most threatening to our interpretation would be incomplete adjustment for patient differences across hospitals. Although we adjusted for several patient factors, residual confounding due to significant variability in average patient acuity across hospitals may contribute to differences in ICU use and may also limit the interpretation of the outcome data that we present. However, we demonstrated in prior work that better risk adjustment typically increases the hospitals' contribution to variation in ICU admission rates(5). This suggests that hospitals are more important contributors to variability in ICU use than what we describe. Second, as mentioned above, hospital capabilities to care for sicker patients outside of the ICU may also contribute to variation. To ensure we were comparing similar hospitals, we adjusted for between-hospital differences including size, teaching status, case-load, and certain capabilities such as organ transplantation and excluded smaller hospitals with fewer than three ICU patients for any condition. Still, the data we used was without detailed information on services available on the general care floor or in intermediate care units (i.e. step-down units), limiting our ability to accurately understand outcomes among high and low utilizers and therefore our ability to classify high ICU utilization as either excessive or appropriate for the local environment.

Further, because our diagnoses were based on administrative claims they are subject to misclassification. Specifically, differences in coding practices across hospitals may influence the denominator that is used to determine ICU admission rates and may explain some of our observed results, particularly with regards to hospital-level factors such as size or teaching status that may correlate with variations in coding practices. Where possible, however, we used standard methods for case definition required of Medicare's public reporting and pay for performance programs (16, 17). Our utilization of Medicare data also limits our ability to extrapolate the results to other payers and individuals that fall outside the typical ages of qualification for Medicare. Moreover, our definition of high- and low-utilizing was defined empirically, though is also subject to varying definitions that would impact classification of hospitals.

Finally, we ultimately included around one-third of all acute care hospitals and limited our study to five medical conditions and one surgical condition. This sample definition was selected after considering the balance between generalizability across a large range of conditions in similarly-sized hospitals versus inclusiveness of a broad group of hospitals. Because our aim was to draw conclusions on the roles of hospitals in contributing to variability at the level of the healthcare system, we sought to include the broadest possible group of hospitals by limiting our definition to six conditions and excluding only those hospitals with two or fewer admissions for each of the conditions over the study period. We acknowledge that this limits generalizability to other conditions, particularly other surgical conditions, and retains a broad group of hospitals for which residual confounding despite risk adjustment is a possibility.

Despite these limitations, our findings suggest that high ICU utilization at the hospital level may be consistent across medical conditions despite adjustment for several measured patient and hospital characteristics. This finding is consistent with a large body of literature supporting regional variations in the provision of a number of ambulatory, inpatient, and surgical services(26, 27). Our study should prompt further work evaluating the mechanisms underlying such variability and the implications of widely different rates of ICU use across hospitals. Specifically, further work may seek to study how ICU use is affected by of capacity constraints, presence or absence of intermediate care or stepdown units, and the availability of nursing care.

CONCLUSION

Utilizing a large, national cohort of patients admitted for several common conditions, we demonstrated that hospitals account for a significant proportion of variation. Though the dataset limited our ability to accurately detect over- and underuse, this finding persisted despite adjustment for several patient- and hospital-level factors that may otherwise explain this relationship. While current efforts aimed at improving efficiency in ICU triage are largely diagnosis-specific, our findings suggest a need for further work to evaluate the causes and consequence of variation at the hospital level.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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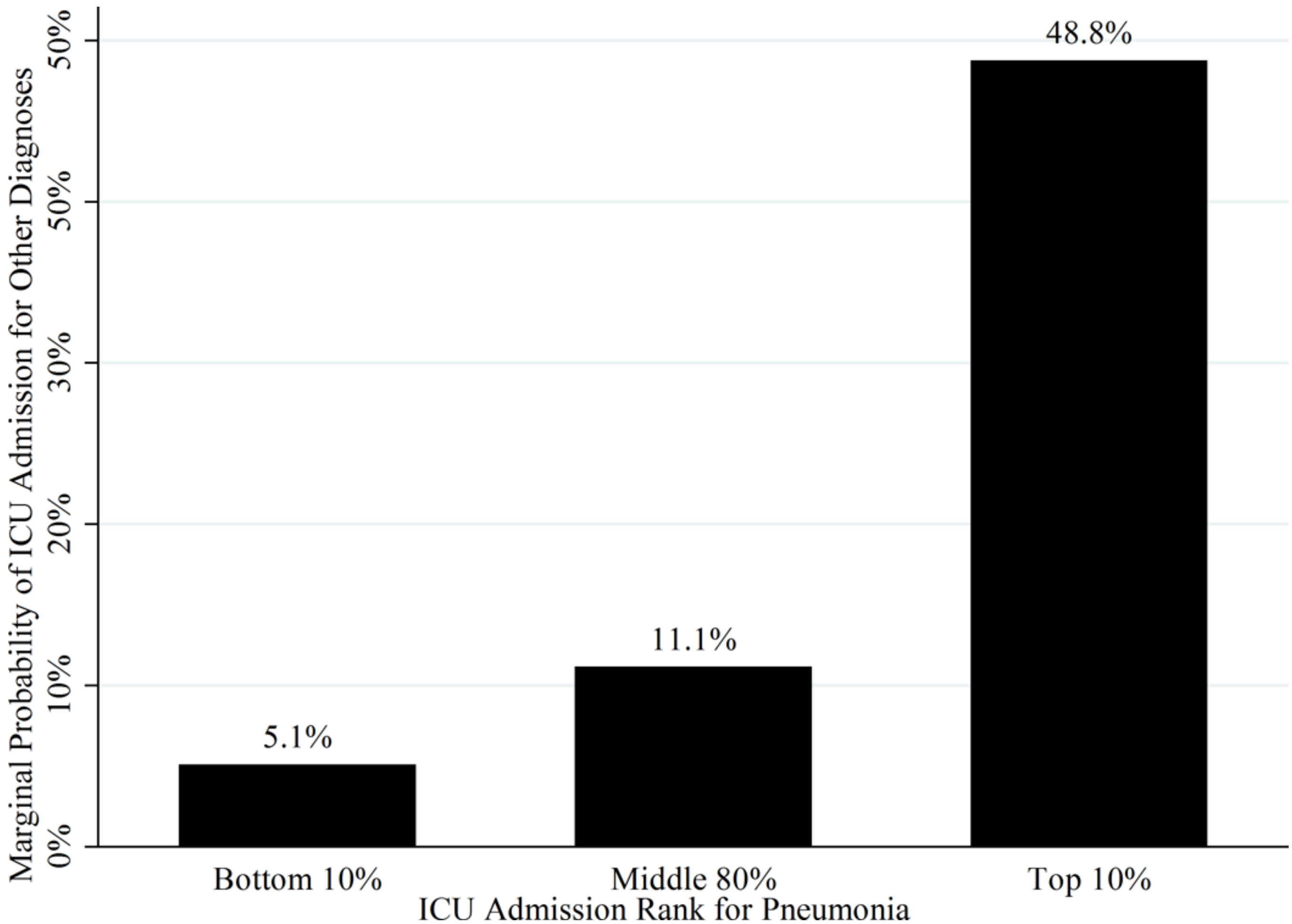

Figure 1.

Pneumonia Utilization Rate as a Predictor of ICU Utilization for Other Conditions.

Hospitals were grouped by ICU utilization rate for pneumonia: bottom decile (<11.1% ICU admission rate), middle 80% (11.1% – 28.1%), and top decile (>28.1%). Using hierarchical linear models with patients nested in diagnoses nested in hospitals and adjusting for risk, we generated predictive margins for ICU admissions among all patients in the sample without pneumonia.

Table 1

Characteristics of Hospitals Included in Analysis (n=1,120)

	Number of Conditions for which a hospital was in top quartile of ICU admission*				p**
	0	**1–2**	**3–4**	**5–6**	
Hospital Size in Beds (n, %)					
≤ 100	16 (22.9)	30 (42.9)	10 (14.3)	14 (20.0)	<0.01
101–200	76 (31.4)	89 (36.8)	42 (17.4)	35 (14.5)	
201–300	110 (41.5)	104 (39.3)	20 (7.6)	31 (11.7)	
301–400	103 (49.8)	74 (35.8)	21 (10.1)	9 (4.4)	
> 400	139 (41.4)	123 (36.6)	47 (14.0)	27 (8.0)	
ICU Beds as a Proportion of All Beds					
≤ 5%	18 (36.0)	19 (38.0)	4 (8.0)	9 (18.0)	<0.01
>5–7.5%	98 (50.0)	71 (36.2)	10 (5.1)	17 (8.7)	
>7.5–10%	145 (44.8)	121 (37.4)	29 (9.0)	29 (9.0)	
>10–12.5%	102 (41.0)	98 (39.4)	30 (12.1)	19 (7.7)	
>12.5–15%	32 (22.9)	60 (42.9)	34 (24.3)	14 (10.0)	
>15%	49 (30.4)	51 (31.7)	33 (20.5)	28 (17.4)	
Type of Hospital (n, %)					
Government	44 (31.4)	48 (34.3)	33 (23.6)	15 (10.7)	<0.01
Not-for-profit	354 (42.3)	307 (36.7)	88 (10.5)	88 (10.5)	
For-profit	46 (32.2)	65 (45.5)	19 (13.3)	13 (9.1)	
Nurse to Bed Ratios					
≤1.5	172 (38.3)	181 (40.3)	55 (12.3)	41 (9.1)	0.51
>1.5–2.5	239 (41.0)	207 (35.5)	70 (12.0)	67 (11.5)	
>2.5	33 (37.5)	32 (36.4)	15 (17.1)	8 (9.1)	
Medical School Affiliation (n, %)	210 (41.1)	195 (38.2)	62 (12.1)	44 (8.6)	0.32
Teaching Status					
No Residents	279 (38.2)	275 (37.7)	89 (12.2)	87 (11.9)	0.04
Minor Teaching Program (<0.25 residents/bed)	118 (45.6)	93 (35.9)	27 (10.4)	21 (8.1)	

	Number of Conditions for which a hospital was in top quartile of ICU admission*				p**
	0	**1–2**	**3–4**	**5–6**	
Major Teaching Program (>0.25 residents/bed)	47 (35.9)	52 (39.7)	24 (18.3)	8 (6.1)	
Admissions per Hospital By Diagnosis during Study Period (Median, IQR)					
CHF	176 (118–263)	128 (80–187)	95 (59.5–158)	103 (53–153)	<0.01
AMI	58 (31–102)	38 (18–76)	39 (16–60)	27 (13–53)	<0.01
Stroke	71 (43–108)	52 (32–86)	50.0 (28–83)	43 (24–72)	<0.01
Pneumonia	231 (160–320)	165 (109–233)	142 (86–214)	147 (100–198)	<0.01
COPD	124 (83–183)	87 (57–135)	70 (47–112)	73 (43–110)	<0.01
Hip Fracture	57 (60–118)	61 (40–94)	51 (35–78)	55 (36–82)	<0.01
Annual Condition-Specific Admissions (Median, IQR)	27,434 (18,812–38,227)	22,801 (15,583–34,624)	21,892 (14,085–37,928)	20,195 (12,464–30,786	<0.01
ICU Admission Rates per Hospital (Median Percent, IQR)					
CHF	9.7 (6.8–13.0)	14.5 (10.5–19.5)	24.6 (16.6–32.7)	71.4 (46.1–85.8)	<0.01
AMI	52.6 (39.6–63.4)	65.9 (53.3–75.9)	74.3 (65.0–81.2)	82.8 (77.1–88.5)	<0.01
Stroke	17.4 (13.2–22.7)	23.9 (16.7–31.6)	32.7 (23.0–41.7)	59.2 (45.1–73.3)	<0.01
Pneumonia	14.8 (12.2–17.6)	18.6 (15.2–21.8)	24.0 (20.4–28.6)	35.8 (27.8–46.6)	<0.01
COPD	12.7 (9.7–15.5)	16.3 (12.9–20.1)	23.1 (17.7–27.7)	39.9 (28.5–47.9)	<0.01
Hip Fracture	8.0 (6.4–9.9)	10.6 (8.3–14.5)	14.2 (10.8–18.6)	19.4 (14.5–25.1)	<0.01
Mechanical Ventilation Rates per Hospital (Median Percent, IQR)	4.6 (3.2–5.6)	5.0 (3.4–6.6)	5.6 (3.5–7.5)	4.5 (3.3–6.1)	<0.01

All percentages are row percentages

* Defined as in the top 25% of ICU admissions for a given condition.

** Using Chi-squared tests or non-parametric equality of medians test.

Table 2

Patient Characteristics by admission diagnosis (n=348,462)

	Clinical Condition					
	CHF n=68,393	**AMI n=31,050**	**Stroke n=43,109**	**Pneumonia n=98,782**	**COPD n=61,832**	**Hip Fracture n=45,296**
ICU Admission (%)	17.4	58.1	25.7	19.0	17.2	10.9
Age (Median, IQR)	79 (73 – 84)	76 (70 – 82)	78 (72 – 84)	78 (72 – 84)	75 (70 – 81)	82 (76 – 86)
Female (%)	49.6	44.6	53.9	51.3	57.5	72.3
Race/Ethnicity						
Black	13.6	8.4	12.9	7.7	8.7	3.7
Hispanic	1.9	1.5	1.6	1.9	1.3	1.3
White	82.0	87.2	82.5	87.4	88.1	92.9
Elixhauser Comorbidities (%)						
0	1.3	7.0	2.9	3.3	5.4	6.4
1	7.2	22.1	16.0	15.4	17.7	21.0
2	19.8	29.3	29.2	27.8	27.5	30.3
3	29.3	24.2	28.6	28.0	26.1	25.1
≥4	42.4	17.4	23.2	25.4	23.3	17.3
Mortality (%)						
In-hospital	2.9	7.3	4.6	6.1	2.7	1.6
30-day	7.3	11.1	10.6	11.6	6.9	4.4
Hospital Length of Stay (Median, 25%ile– 75%ile)	4 (3 – 7)	4 (2 – 6)	4 (2 – 6)	5 (3 – 7)	4 (3 – 7)	5 (4 – 6)
Mechanical Ventilation						
Non-invasive mechanical ventilation (%)	3.9	1.2	0.6	3.7	7.3	0.8
Invasive Mechanical Ventilation (%)	2.3	4.8	4.4	7.4	6.7	2.0

Table 3

Within-hospital Correlations* of ICU Admission Rate across Condition (n=1,120 hospitals)

	CHF	AMI	Stroke	Pneumonia	COPD	Hip Fracture
CHF	1.00	–	–	–	–	–
AMI	0.55	1.00	–	–	–	–
Stroke	0.46	0.39	1.00	–	–	–
Pneumonia	0.57	0.40	0.45	1.00	–	–
COPD	0.52	0.38	0.47	0.59	1.00	–
Hip Fracture	0.43	0.29	0.38	0.42	0.39	1.00

* Spearman's rank correlation p-value <0.001 for all comparisons (versus zero correlation)

Table 4

Characteristics of high CHF admission rate as a predictor of high admission rates for other conditions)

Condition	Percent Sensitivity (95% CI)	Percent Specificity (95% CI)	Positive Likelihood Ratio	Negative Likelihood Ratio
Acute MI	59.6 (54.2–64.8)	81.2 (78.3–83.9)	3.17	0.50
Stroke	55.8 (50.4–61.0)	79.5 (76.4–82.3)	2.46	0.62
Pneumonia	59.6 (54.3–64.8)	81.2 (78.3–83.9)	3.17	0.50
COPD	58.2 (52.9–63.4)	80.5 (77.6–83.3)	2.98	0.52
Hip Fracture	54.0 (48.6–59.2)	78.6 (75.5–81.4)	2.52	0.59

Table 5

Attributable variability using intraclass correlations coefficients (ICC) and median odds ratios (MOR).

	ICC % (95% CI)	Median Odds Ratio for differences
Unadjusted		
Between Hospitals	7.4 (6.5 – 8.4)	1.77
Between 1° Diagnoses	31.5 (30.5 – 32.5)	3.23
Adjusted*		
Between Hospitals	17.6 (16.3 – 19.1)	2.33
Between 1° Diagnoses	25.8 (24.5 – 27.1)	2.78

*Adjusted for age, gender, comorbidities, critical care procedure utilization, presence of organ system failures, hospital funding source, size, ICU capacity, teaching status, capabilities for cardiac catheterization, cardiac surgery, neurological care, organ transplantation and case-load

Table 6

Within-hospital Correlations of ICU Admission Rate across Condition. Sensitivity analysis with 9 conditions (n=495 hospitals)

	CHF	AMI	Stroke	Pneumonia	COPD	Hip Fracture	Colectomy	Trauma	GI Bleed
CHF	1.00 *	–	–	–	–	–	–	–	–
AMI	0.60 *	1.00 *	–	–	–	–	–	–	–
Stroke	0.49 *	0.42 *	1.00 *	–	–	–	–	–	–
Pneumonia	0.58 *	0.40 *	0.51 *	1.00 *	–	–	–	–	–
COPD	0.53 *	0.42 *	0.46 *	0.64 *	1.00 *	–	–	–	–
Hip Fracture	0.15 *	0.09	0.13 *	0.16 *	0.16 *	1.00 *	–	–	–
Colectomy	0.40 *	0.36 *	0.37 *	0.43 *	0.40 *	0.19 *	1.00 *	–	–
Trauma	0.34 *	0.27 *	0.46 *	0.40 *	0.44 *	0.15 *	0.34 *	1.00 *	–
GI Bleed	0.40 *	0.30 *	0.36 *	0.49 *	0.42 *	0.13 *	0.36 *	0.32 *	1.00 *

* Spearman's rank correlation p-value <0.001 (versus zero correlation)