ICU Use and Quality of Care for Patients With Myocardial Infarction and Heart Failure

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BACKGROUND: Quality of care for acute myocardial infarction (AMI) and heart failure (HF) varies across hospitals, but the factors driving variation are incompletely understood. We evaluated the relationship between a hospital's ICU or coronary care unit (CCU) admission rate and quality of care provided to patients with AMI or HF.

METHODS: A retrospective cohort study of Medicare beneficiaries hospitalized in 2010 with AMI or HF was performed. Hospitals were grouped into quintiles according to their risk- and reliability-adjusted ICU admission rates for AMI or HF. We examined the rates that hospitals failed to deliver standard AMI or HF processes of care (process measure failure rates), 30-day mortality, 30-day readmissions, and Medicare spending after adjusting for patient and hospital characteristics.

RESULTS: Hospitals in the lowest quintile had ICU admission rates < 29% for AMI or < 8% for HF. Hospitals in the top quintile had rates > 61% for AMI or > 24% for HF. Hospitals in the highest quintile had higher process measure failure rates for some but not all process measures. Hospitals in the top quintile had greater 30-day mortality (14.8% vs 14.0% [$P = .002$] for AMI; 11.4% vs 10.6% [$P < .001$] for HF), but no differences in 30-day readmissions or Medicare spending were seen compared with hospitals in the lowest quintile.

CONCLUSIONS: Hospitals with the highest rates of ICU admission for patients with AMI or HF delivered lower quality of care and had higher 30-day mortality for these conditions. Hospitals with high ICU use may be targets to improve care delivery.

CHEST 2016; 150(3):524-532

KEY WORDS: cardiology; health-care utilization; heart failure; intensive care; myocardial infarction

ABBREVIATIONS: ACE = angiotensin-converting enzyme; AMI = acute myocardial infarction; ARB = angiotensin receptor blocker; CCU = coronary care unit; HF = heart failure; LV = left ventricular

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FUNDING/SUPPORT: This research was supported by the National Institutes of Health [grant T32HL007749 to T. S. V. and M. W. S.] and the Agency for Healthcare Research and Quality [grant K08HS020672 to C. R. C.].

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DOI: <http://dx.doi.org/10.1016/j.chest.2016.05.034>

Cardiovascular conditions such as acute myocardial infarction (AMI) and heart failure (HF) accounted for 1.6 million hospitalizations and \$22 billion in health-care costs in 2011.¹ However, it has been suggested that approximately 20% of hospitalized patients with these conditions fail to receive standards of care, known as process measures, which are often used as surrogates for quality of care.²⁻⁵ The causes of the variation in quality of care between hospitals remain largely unexplained.²

One potential explanation for the variability in the quality of care for AMI or HF across hospitals could be the different locations in the hospital where patients receive care. Many patients with AMI or HF are admitted to the ICU or coronary care unit (CCU) (collectively referred to as ICU hereafter), while others are cared for on the general or telemetry ward, as universal guidelines for triage do not exist.^{6,7} Although

there are many reasons why some hospitals utilize the ICU more frequently than others,⁸⁻¹⁰ understanding the relationship between ICU use and overall quality of care may provide additional insights as to how hospitals can deliver optimal care for hospitalized patients.^{11,12}

The goal of the present study was to investigate the relationship between ICU admission rates for AMI or HF, process measure failure rates, and patient outcomes. Process measures for cardiovascular conditions include guideline-recommended administration of medications, counseling, heart function evaluation, and timely interventions. Given previous research in pneumonia processes of care, which showed that hospitals with higher ICU admission rates failed to provide appropriate processes of care and had higher 30-day mortality,¹¹ we hypothesized that similar findings would be present in AMI and HF.

Methods

We performed a retrospective cohort study of all acute care hospitalizations among fee-for-service Medicare beneficiaries aged ≥ 65 years by using the Medicare Provider Analysis and Review file from 2010 linked to mortality data in the Medicare Beneficiary Summary file. Hospital characteristics were obtained from the 2009 American Hospital Association's Annual Survey and the 2010 Healthcare Cost Reporting Information System. Income was defined according to the patient's ZIP code of residence by using 2010 US Census data.

All patients with an *International Classification of Diseases, Ninth Revision, Clinical Modification*, primary diagnosis code for AMI (410.XX, excluding 410.X2) or, in a separate analysis, primary diagnosis code for HF (402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, and 428.XX) were included.^{13,14} These methods of identifying patients with AMI or HF have been validated with high sensitivity and specificity.^{15,16} We excluded patients admitted to hospitals without ICU capabilities, with < 25 total AMI or HF admissions, transfers from another hospital, or those discharged against medical advice.^{11,17} ICU admission was identified by the presence of an ICU or CCU revenue center code in the administrative billing record, excluding intermediate or psychiatric care units.¹⁸

Each condition (AMI or HF) was analyzed separately. The study's primary exposure variable was the hospital-specific ICU admission rate for AMI or HF, defined as the proportion of patients admitted to the ICU of all hospitalized patients with AMI or HF. Hospitals were assigned to quintiles based on the distribution of ICU admission rates for each condition.

Process measure information for AMI and HF was obtained from Hospital Compare for 2010.¹⁹ For AMI, process measures included aspirin on arrival, aspirin on discharge, angiotensin-converting enzyme (ACE) inhibitors or angiotensin receptor blockers (ARBs) for left ventricular (LV) systolic dysfunction, smoking cessation counseling, beta-blocker at discharge, and percutaneous coronary intervention within 90 min for ST-segment elevation myocardial infarction. For HF, process measures included HF discharge instructions, LV systolic function evaluation, ACE inhibitors/ARBs for LV systolic dysfunction, and smoking cessation counseling. Some of these process measures have since been replaced, but they were

considered standards of care in 2010. We therefore used the processes that were in place in 2010 as surrogates for hospital quality of care at that time.

Mortality was defined as death within 30 days of hospital admission from any cause. Readmission was defined as hospitalization for any cause within 30 days of hospital discharge among survivors of AMI or HF. Payments were defined as the total amount reimbursed by Medicare to the hospital for a patient's care.

Statistical Analysis

Hospital-specific ICU admission rates were estimated by using methods similar to those the Centers for Medicare & Medicaid Services use to calculate risk- and reliability-adjusted hospital mortality and readmission rates.²⁰ This approach controls for any baseline patient differences between hospitals, and it accounts for the lower reliability of ICU admission rates for hospitals with few patients.²¹ Hospitals with many ICU admissions will have estimates approximating their actual rate, whereas hospitals with fewer ICU admissions will have their rates weighted toward the mean ICU admission rate.^{20,21}

Patient and hospital characteristics were compared across quintiles of risk- and reliability-adjusted ICU admission rates by using χ^2 tests or analyses of variance, as appropriate. To evaluate whether ICU admission rates were associated with process measure failure rates for AMI or HF at the hospital level, we used multivariable linear regression; ICU admission rate quintile was entered as the exposure variable and process measure failure rate as the outcome, with robust SEs. Comparisons across quintiles after model estimation were performed by using the Wald test. Process measure data were available only at the hospital level. To estimate the relationship between quintile of ICU admission rate and the patient-level outcomes of 30-day mortality, 30-day readmission, and Medicare spending, generalized estimating equations were used with robust SEs and a logit (30-day mortality and 30-day readmission) or identity (Medicare spending) link. Adjusted absolute rates were estimated by using predictive margins across quintiles of hospital ICU admission rate.

Models adjusted for patient characteristics, including age, sex, race, and preexisting comorbidities according to Elixhauser et al.²² Facility-level risk adjustment included hospital type (nonprofit, for-profit, or

government), hospital size according to number of beds, proportion of ICU beds according to total beds, teaching status (high, low, or none [defined by membership in the college of teaching hospitals]), proportion of Medicaid patients, hospital nursing ratio (number of full-time equivalent nurses divided by total patient-days in thousands), and proportion of nonwhite patients.^{23,24}

Data management and analysis were performed by using SAS version 9.3 (SAS Institute, Inc) and Stata 13.1 (Stata Corporation). All tests were two-sided, with a *P* value < .05 considered significant. The Institutional Review Board for the University of Michigan approved the study and provided a waiver of consent (HUM00053488).

Results

A total of 157,033 acute care hospitalizations for AMI were identified at 1,686 hospitals, of which 72,827 (46%)

received care in an ICU (e-Fig 1). We identified 421,165 acute care hospitalizations for HF at 2,199 hospitals, of whom 67,823 (16%) received care in an ICU. After risk and

TABLE 1 Selected Hospital and Patient Characteristics Across Quintiles of ICU Admission Rates for AMI

Characteristic	First Quintile (< 29%) ^a	Second Quintile (29%-39%)	Third Quintile (40%-48%)	Fourth Quintile (49%-61%)	Fifth Quintile (62%-100%)	<i>P</i> Value
Hospital characteristics^b						
Mean AMI admissions	107	103	94	86	76	< .001
Hospital type						< .001
Government	9.8	11.6	11.0	13.1	16.0	
Private nonprofit	82.8	75.7	74.8	68.6	66.8	
Private for-profit	7.4	12.8	14.2	18.4	17.2	
ICU beds ^c						< .001
< 8%	41.4	42.1	34.1	31.2	28.8	
8%-11%	29.3	31.5	31.5	33.2	28.2	
> 11%	29.3	26.4	34.4	35.6	43.0	
Percent Medicaid patients	9.7	9.8	10.4	10.5	11.3	< .001
Patient characteristics						
Age, y						< .001
65-74	35.1	36.1	36.8	36.9	37.0	
75-84	35.2	35.2	34.7	34.8	34.9	
> 84	29.6	28.7	28.5	28.4	28.2	
Male sex	50.6	51.2	51.3	50.9	51.1	.43
Nonwhite	11.1	13.7	13.6	13.2	14.7	< .001
Select comorbidities						
Congestive heart failure	38.9	39.8	38.6	38.4	38.2	.001
Chronic pulmonary disease	18.1	17.6	17.5	18.5	18.6	< .001
Income quartile^d						< .001
First (lowest)	20.8	22.9	24.6	28.0	30.9	
Second	26.2	22.9	25.0	24.4	27.1	
Third	27.1	25.6	25.3	23.5	22.5	
Fourth (highest)	25.9	28.7	25.1	24.1	19.5	

AMI = acute myocardial infarction.

^aICU admission rates are risk- and reliability-adjusted.

^bData are percentages unless otherwise indicated.

^cICU beds as a percentage of total hospital beds.

^dPatients were assigned the median household income of their ZIP code, which was then divided into quartiles.

TABLE 2] Hospital and Patient Characteristics Across Quintiles of ICU Admission Rates for HF

Characteristic	First Quintile ($< 8\%$) ^a	Second Quintile (8%-12%)	Third Quintile (13%-16%)	Fourth Quintile (17%-24%)	Fifth Quintile (25%-100%)	P Value
Hospital characteristics^b						
Mean HF admissions	276	232	180	146	123	$< .001$
Hospital type						$< .001$
Government	9.8	11.6	16.4	15.5	20.7	
Private nonprofit	80.5	73.9	69.1	65.9	62.0	
Private for-profit	9.8	14.6	14.6	18.6	17.3	
Total hospital beds						$< .001$
< 100	4.6	11.6	20.0	30.9	39.2	
100-399	68.0	65.7	62.7	54.8	50.8	
≥ 400	27.5	22.7	17.3	14.3	10.0	
Teaching status						$< .001$
None	61.1	62.3	68.2	73.0	80.9	
Low (any full-time equivalent residents)	24.1	24.1	19.3	17.5	13.4	
High (Council of Teaching Hospitals' member)	14.8	13.6	12.5	9.6	5.7	
ICU beds ^c						$< .001$
$< 8\%$	42.1	36.4	35.2	28.2	32.4	
8%-11%	30.9	34.3	32.5	28.2	27.6	
$> 11\%$	27.1	29.3	32.3	43.6	40.1	
Nurse staffing ratio ^d	4.1	3.8	3.7	3.6	3.5	.4
Percent Medicaid	10.0	9.6	10.6	10.5	9.8	$< .001$
Patient characteristics						
Age, y						$< .001$
65-74	27.7	28.0	28.6	28.7	27.6	
75-84	35.9	35.7	36.0	35.8	36.6	
> 84	36.5	36.3	35.4	35.5	35.9	
Male sex	45.4	45.4	45.1	45.1	44.4	$< .001$
Nonwhite	17.7	17.2	18.4	19.5	18.0	$< .001$
Select comorbidities						
Pulmonary circulatory disease	14.6	13.0	12.8	12.5	12.2	$< .001$
Chronic pulmonary disease	29.9	30.5	30.8	30.7	30.7	$< .001$
Renal failure	34.3	33.6	33.8	32.6	31.7	$< .001$
Metastatic cancer	1.1	1.1	1.1	1.0	1.0	.004
Income quartile ^e						$< .001$
First (lowest)	20.1	23.0	27.1	28.4	32.9	
Second	22.8	24.8	25.7	24.8	29.4	
Third	27.1	25.2	25.2	22.8	22.1	
Fourth (highest)	29.9	27.1	21.9	24.0	15.6	

HF = heart failure.

^aICU admission rates are risk- and reliability-adjusted.^bData are percentages unless otherwise indicated.^cICU beds as a percentage of total hospital beds.^dNumber of full-time equivalent nurses divided by number of patient-days in thousands.^ePatients were assigned a median household income of their ZIP code, which was then divided into quartiles.

TABLE 3] Hospital and Patient Factors Associated With ICU Admission for AMI and HF

Variable	AMI		HF	
	OR	95% CI	OR	95% CI
Hospital factors				
Profit status				
Government	Reference		Reference	
Private nonprofit	0.84	0.71-0.99	0.91	0.79-1.04
Private for-profit	1.02	0.83-1.25	0.88	0.73-1.04
Teaching status				
None	Reference		Reference	
Low ^a	0.96	0.84-1.09	0.85	0.75-0.96
High ^b	0.87	0.72-1.05	0.73	0.60-0.88
Volume of AMI/HF admissions				
Low (< 100)	Reference		Reference	
Moderate (100-200)	0.83	0.73-0.94	0.66	0.58-0.75
High (> 200)	0.65	0.52-0.81	0.48	0.41-0.55
ICU beds as percent total				
Low (< 8%)	Reference		Reference	
Moderate (8%-11%)	1.21	1.06-1.37	1.09	0.96-1.23
High (> 11%)	1.41	1.24-1.60	1.31	1.16-1.48
Proportion Medicaid patients				
Low (< 7%)	Reference		Reference	
Moderate (7%-11%)	1.02	0.90-1.16	0.98	0.87-1.10
High (> 11%)	1.04	0.90-1.21	1.01	0.89-1.16
Proportion nonwhite admits				
Low (< 7%)	Reference		Reference	
Moderate (7%-20%)	0.91	0.80-1.04	1.00	0.89-1.13
High (> 20%)	1.04	0.90-1.20	1.09	0.96-1.24
Nurse staffing ratio ^c				
Low	Reference		Reference	
Moderate	0.94	0.83-1.07	0.89	0.79-1.00
High	0.80	0.70-0.92	0.88	0.78-1.00
Patient factors				
Male sex	1.19	1.16-1.22	1.02	1.01-1.05
Age, y				
65-74	Reference		Reference	
75-84	0.80	0.78-0.83	0.78	0.76-0.80
>85	0.47	0.46-0.48	0.54	0.53-0.55
Nonwhite	0.91	0.87-0.94	0.99	0.96-1.02
Comorbidities				
Congestive heart failure	0.98	0.96-1.01	0.89	0.87-0.91
Chronic pulmonary disorders	0.79	0.77-0.82	0.89	0.87-0.92
Renal failure	0.79	0.76-0.82	0.81	0.74-0.89
Metastatic cancer	0.60	0.54-0.66	1.02	1.01-1.05

See Table 1 and 2 legends for expansion of abbreviations.

^aAny full-time equivalent residents.

^bCouncil of Teaching Hospitals' member.

^cNumber of full-time equivalent nurses divided by number of patient-days in thousands.

reliability adjustments, the median hospital ICU admission rate was 41.9% (range, 11.3%-90.9%; interquartile range, 29.9%-55.0%) for AMI and 11.3% (range, 2.8%-95.1%; interquartile range, 7.5%-17.1%) for HF.

Hospitals with the highest ICU admission rates on average had a lower volume of hospital admissions for AMI or HF. These hospitals were more often for-profit hospitals and had greater proportions of ICU beds to total hospital beds (e-Tables 1, 2, Tables 1, 2). There was no relationship between hospital size and ICU bed ratio ($r = -0.05$). Patients admitted to hospitals with high ICU use were more likely to reside in lower income ZIP codes.

After adjusting for patient and hospital characteristics, several factors were associated with greater odds of ICU admission (Table 3). Hospital factors associated with increased odds of ICU admission included admission to nonteaching hospitals, hospitals with a higher proportion of ICU beds, hospitals with more patients per nurse, and hospitals with lower volume for either condition. Patient characteristics associated with increased odds of ICU admission for both conditions included male sex and younger age, whereas white race increased the odds of ICU admission for AMI only.

In an adjusted analysis of the relationship between process measure failure rates for AMI and a hospital's ICU admission rate, hospitals with higher ICU admission rates more often failed to deliver aspirin on arrival ($P = .02$) and provide ACE inhibitors/ARBs for LV systolic dysfunction ($P = .004$) (e-Table 3, Fig 1A). For example, 1.7% of patients in the hospitals with the highest ICU use did not receive aspirin on arrival compared with 1.3% in the lowest ICU use hospitals, and 4.9% of patients in the highest ICU use hospitals failed to receive ACE inhibitors/ARBs compared with 3.0% in the lowest ICU use hospitals. At the highest quintile hospitals, 12.0% of patients did not receive percutaneous coronary intervention within 90 min for ST-segment elevation myocardial infarction compared with 9.9% of patients at the lowest quintile hospitals; this result was not statistically significant ($P = .06$). Quintile of ICU admission rate was not associated with failure to deliver aspirin on discharge ($P = .39$), smoking cessation counseling ($P = .73$), or beta-blockers on discharge ($P = .51$) (e-Fig 2).

Among the process measures for HF, hospitals in the highest ICU admission rate quintile more often failed to perform LV function evaluation (2.5% in highest ICU use hospitals vs 1.3% in lowest ICU use hospitals;

Figure 1 – Significant differences in process measure failure rates for (A) AMI and (B) HF. ^a $P < .05$. ACE = angiotensin-converting enzyme; AMI = acute myocardial infarction; ARB = angiotensin receptor blocker; HF = heart failure; LV = left ventricular; LVSD = left ventricular systolic dysfunction.

$P < .001$), to deliver ACE inhibitors/ARBs for treatment of LV systolic dysfunction (4.9% vs 3.0%; $P < .001$), and provide smoking cessation counseling (2.1% vs 1.1%; $P = .03$) (Fig 1B). Quintile of ICU admission rate was not associated with failure to deliver HF discharge instructions ($P = .13$) (e-Fig 2, e-Table 3).

After adjusting for patient and hospital characteristics, there was a statistically significant increase in 30-day mortality rates across the quintiles of ICU admission rate for AMI (14.0%-14.8%; P for trend = .002) and HF (10.6%-11.4%; P for trend < .001) (Table 4). There was no significant difference in 30-day readmission rates (AMI, 16.7%-17.0% [P for trend = .60]; HF, 22.8%-22.0% [P for trend = .16]) or Medicare spending across hospital quintiles (AMI, \$13,324-\$13,628 [P for trend = .08];

TABLE 4] Thirty-day Mortality Rate, 30-Day Hospital Readmission Rate, and Medicare Spending Across Hospital Quintiles of ICU Admission Rates for AMI and HF

Variable	First Quintile, % (< 29%)	Second Quintile, % (29%-39%)	Third Quintile, % (40%-48%)	Fourth Quintile, % (49%-61%)	Fifth Quintile, % (62%-100%)	P Value for Trend
AMI adjusted outcomes						
30-d mortality rate	14.0	14.0	14.1	14.8	14.8	.002
30-d readmission rate	16.7	16.9	17.1	16.8	17.0	.60
Spending, \$	13,324	13,362	13,470	13,802	13,638	.08
	First Quintile, % (< 8%)	Second Quintile, % (8%-12%)	Third Quintile, % (13%-16%)	Fourth Quintile, % (17%-24%)	Fifth Quintile, % (25%-100%)	P Value for Trend
HF adjusted outcomes						
30-d mortality rate	10.6	10.7	10.6	11.0	11.4	< .001
30-d readmission rate	22.8	22.7	23.3	22.9	22.0	.16
Spending, \$	8,598	8,617	8,703	8,425	8,389	.07

See Table 1 and 2 legends for expansion of abbreviations.

HF, \$8,598-\$8,389 [*P* for trend = .07]) for AMI and HF.

Discussion

The present study shows the wide variability across hospitals in the use of the ICU for elderly patients with AMI or HF. Hospitals with the highest ICU admission rates reported worse adherence to several process measures and higher 30-day mortality rates for both AMI and HF, with no significant differences in 30-day readmission rates or Medicare spending.

Our analysis builds on the findings of several previous studies assessing ICU utilization and outcomes for HF and AMI.^{14,25-27} Safavi et al¹⁴ assessed variation in ICU admission practices between hospitals for HF, assessing in-hospital mortality and interventions, and found that hospitals vary widely in ICU utilization with no differences in outcomes. The present study focused on an older population and evaluated associations between ICU admission rates and quality measures. Stolker et al²⁸ showed that ICUs with low annual AMI volume had higher mortality and provided less evidence-based therapies. Our study looked at a hospital's ICU admission rate and found that hospitals with the highest ICU admission rates had the lowest annual AMI volume. Similarly to Stolker et al, these low-volume, high ICU use hospitals had greater 30-day mortality and failed to provide guideline-based process measures for AMI.

A number of variables have been associated with ICU use and outcomes. Lower volume of AMI or HF admissions has previously been associated with worse

outcomes,^{28,29} and hospitals that used the ICU frequently in the present study tended to have lower annual AMI or HF volume, perhaps utilizing the ICU due to a lack of familiarity in caring for such patients. Furthermore, increased ICU bed availability has been associated with higher ICU admission rates.^{30,31} Hospitals in the present study with a greater proportion of ICU beds were more likely to admit patients with AMI or HF to the ICU. In addition, the presence of certain hospital characteristics such as intermediate care³² or cardiology specialty wards³³ may be more commonly found in larger teaching hospitals, which could also affect ICU admission rates.

Although many factors have previously been associated with ICU utilization,⁹ we showed that a hospital's quality of care for AMI or HF was also associated with ICU use. Further research is necessary to determine the mechanisms underlying this relationship. For example, hospital inexperience with a given condition may result in both poor overall quality of care and higher ICU admission rates for that condition.

The present study should be interpreted in the context of several limitations. First, although previously validated definitions were used, our approach may have improperly identified patients with AMI or HF.^{15,16} Second, risk adjustment was performed by using available administrative claims, which, if inadequate, may have introduced bias.³⁴ For instance, administrative claims may miss important clinical variables or imperfectly capture severity of illness; however, we used risk adjustment models similar to those used by the

Centers for Medicare & Medicaid Services. Third, we were unable to determine the time between admission to the hospital and to the ICU, a factor that may provide additional insight toward why the ICU is being utilized. Fourth, we assessed quality of care aggregated for the hospital and cannot differentiate between quality of care provided in various areas of the hospitals (eg, between the ICU, the CCU, and the general or telemetry ward). In addition, a previous study³⁵ showed that larger hospitals had greater proportions of ICU beds to total hospital beds. Our study failed to confirm this relationship, as there was no correlation between hospital size and ICU bed ratio. Finally, we assessed adherence to process measures that were recommended in 2010; however, since then, some of these process measures have been removed from guidelines while others have been added.¹⁹ The process measures studied were considered standards of care in 2010, however, and we therefore used them as surrogates of hospital quality at that time. The most common reason for removal was the lack of meaningful difference in performance between providers, suggesting little opportunity for improvement. In the present study, most quality measure adherence rates were > 95% at most hospitals. Thus, the quality measures we analyzed may not precisely capture variation in quality across hospitals.

However, these process measures were accepted as standards to measure hospital quality as they were endorsed by the National Quality Forum, were used in pay-for-performance programs, and were publicly reported.

The present study has important implications for clinicians and health policy makers. The association between higher ICU admission rates and worse quality of care for patients with AMI or HF suggests that additional research is needed to identify the mechanisms that link ICU admission with quality of care. By identifying hospitals that provide worse quality of care to patients, more resources may be devoted to recognizing gaps and enhancing care. This study underscores the need to understand the reasons why hospitals use the ICU, independent of a patient's severity of illness, to improve quality of care.

Conclusions

Our results suggest that, on average, hospitals with the highest ICU use for AMI or HF were less likely to provide accepted standards of care and had higher mortality rates than hospitals with the lowest ICU use. High ICU use hospitals may be targets to improve care delivery.

Acknowledgments

Author contributions: T. S. V. had full access to all of the data in the study and takes full responsibility for the integrity of the data and the accuracy of the data analysis. T. S. V., M. W. S., and C. R. C. contributed to study concept and design; T. S. V., M. W. S., and C. R. C. contributed to acquisition of data; T. S. V., M. W. S., Z. D. G., and C. R. C. contributed to analysis and interpretation of data; T. S. V. and C. R. C. contributed to drafting of the manuscript; T. S. V., M. W. S., Z. D. G., and C. R. C. contributed to critical revision of the manuscript for important intellectual content; T. S. V., M. W. S., and C. R. C. contributed to the statistical analysis; and C. R. C. obtained funding.

Financial/nonfinancial disclosure: None declared.

Role of sponsors: The sponsor had no role in the design of the study, the collection and analysis of the data, or the preparation of the manuscript.

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

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