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Hospital Variation In Admission To Intensive Care Units For Patients With Myocardial Infarction

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Hospital Variation in Admission to Intensive Care Units for Patients with Myocardial Infarction

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HOSPITAL VARIATION IN ADMISSION TO INTENSIVE CARE UNITS FOR PATIENTS WITH MYOCARDIAL INFARCTION. RuiJun Chen, Kelly M. Strait, Kumar Dharmarajan, Shu-Xia Li, Isuru Ranasinghe, John Martin, Reza Fazel, Frederick A. Masoudi, Colin R. Cooke, Brahmajee K. Nallamothu, and Harlan M. Krumholz. Section of Cardiovascular Medicine, Department of Internal Medicine, Yale University, School of Medicine, New Haven, CT.

The treatment of patients with myocardial infarction was transformed by the introduction of intensive care units (ICUs), but we know little about how contemporary hospitals employ this resource-intensive setting and whether higher use is associated with better outcomes. We sought to determine the variation in the rates of ICU admission across hospitals for patients with myocardial infarction and whether these rates were associated with mortality or usage of critical care therapies. We hypothesized that large variations exist in rates of ICU use for these patients across hospitals, but that these differences would not be associated with in-hospital mortality. We identified 114,980 adult hospitalizations for acute myocardial infarction from 311 hospitals in the 2009-10 Premier database using codes from the International Classification of Diseases, Ninth Revision, Clinical Modification. Hospitals were stratified into quartiles by rates of ICU admission for patients with myocardial infarction. Across quartiles, we examined in-hospital risk-standardized mortality rates and usage rates of critical care therapies for these patients. Rates of ICU admission for patients with myocardial infarction varied markedly among hospitals (median 48%, IQR 35%-61%, range 0%-98%) and there was no association with in-hospital risk-standardized mortality rates (6% all quartiles; p=0.7). However, hospitals admitting more patients to the ICU were more likely to use critical care therapies overall (mechanical ventilation [from Quartile 1 with lowest rate of ICU use to Quartile 4 with highest rate: 13% to 16%], vasopressors/inotropes [17% to 21%], intra-aortic balloon pumps [4% to 7%], and pulmonary artery catheters [4% to 5%]; p for trend<0.05 in all comparisons). Rates of ICU admission for myocardial infarction vary substantially across hospitals and were not associated with differences in mortality, but were associated with greater use of critical care therapies.

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Introduction

Contemporary intensive care units transformed the care of patients with myocardial infarction at a time when few effective therapies were available. The concept of the intensive observation of critically ill patients with readily available, specialized interventions is an idea deeply rooted in history, which has been referenced in writings throughout numerous civilizations dating back to ancient Egypt.[1] The modern implementation of intensive care in the United States began in the 1920s, with a 3 bed unit for postoperative neurosurgical patients at the Johns Hopkins Hospital. However, intensive care units gained little traction until this concept of a specialized unit for the critically ill and the development of novel life-sustaining technologies coalesced in the late 1950s.[2] This technological revolution included new machines capable of positive pressure ventilation, spurred by the polio epidemic, dialysis, external defibrillators, synchronized cardioversion, and even the less technologically advanced yet vital conception of external cardiopulmonary resuscitation techniques.[3]

Once hospitals began widely adopting intensive care units in the early 1960s and rapidly specialized into the development of coronary care units, patients with myocardial infarctions finally had readily available access to continuous electrocardiographic monitoring, invasive or resuscitative technologies, and higher nursing to patient ratios.[4,5] Their initial adoption improved outcomes for these patients in an era when short-term mortality rates were high and complications such as post-infarction ventricular arrhythmias were common. Several studies showed that patients with acute myocardial infarctions who were triaged to an intensive care unit had approximately 20% lower mortality, notably decreasing from 26% to 7% in the Killip's landmark study of 250 patients over 2 years.[6,7] As a result, approximately 60% of all hospitals in the United States had a coronary care unit within the next 10 years, and routine admission to an intensive care unit was quickly and widely accepted as the standard of care for most patients with myocardial infarction.[8] This standard has continued to be strongly endorsed by clinical practice guidelines into the modern era, as recent American College of Cardiology and American Heart Association guidelines prior to 2013 strongly recommended admission to a critical care unit for all patients with an ST-elevation myocardial infarction as well as those with a non ST-elevation myocardial infarction and "active, ongoing ischemia/injury or hemodynamic or electrical instability.[9,10] These represented Class I recommendations, the highest recommendation level possible, but held only a level of evidence C, indicating that they were based on expert opinion rather than modern supporting evidence.

Today, given the marked evolution in the clinical care and evidence base for myocardial infarction, the value of intensive care units for many of these patients in contemporary practice warrants closer scrutiny. Non-critical care wards now possess the capability to provide telemetry monitoring and advanced therapies previously limited to intensive care units, such as the administration of intravenous anti-arrhythmic agents.[2,11] Simultaneously, the prognosis of patients with myocardial infarction has substantially improved as ST-segment elevation myocardial infarctions, complications including shock and heart failure, and short-term mortality have all declined, raising questions about which contemporary patients truly benefit from being in an intensive care unit.[12-17] Finally, intensive care units are not only increasingly expensive, as they account for only 5-10% of total beds but 20-34% of nationwide hospital costs,[18,19] but also facilitate the implementation of resource-intensive strategies that, while essential for some patients, may be discretionary in others.[20-22] In part because of uncertainty about the marginal benefit of intensive care units for many patients, the most recent version of the American College of Cardiology and American Heart Association guidelines on myocardial infarction no longer contain specific recommendations on intensive care unit use.[23,24] Meanwhile, little is known about how hospitals use this resource and whether higher rates of intensive care unit use are associated with better outcomes.

Purpose, Hypothesis, and Aims

Accordingly, we sought to describe hospital variation in the use of intensive care units and associated outcomes for patients with myocardial infarction in a large contemporary sample of hospitals in the United States. We hypothesized that large variations would exist in the rates of intensive care unit use for these patients across hospitals, but that these differences in use would not be associated with any differences in in-hospital mortality. Further, we explored the relationship between hospital rates of intensive care unit use and the utilization of resource-intensive treatment strategies in the overall cohort of patients with myocardial infarction and the subset of these patients admitted to an intensive care unit.

Methods

Data Source

We conducted a retrospective cohort study using a voluntary, fee-supported database maintained by Premier, Inc. for measuring quality and healthcare utilization. Through 2010, the Premier database contained data on more than 325 million cumulative hospital discharges, with over 90 million discharges from 2009-2010 alone, representing approximately 1 out of every 5 hospital discharges nationwide. In addition to information available in standard hospital discharge files, this database contains a date-stamped log of all billed items at the patient level including diagnostic tests, medications, and therapeutic services. Patient data were de-identified in accordance with the Health Insurance Portability and Accountability Act and a random hospital identifier assigned by Premier was used to identify the hospitals. The Yale University Human Investigation Committee reviewed the protocol for this study and determined that it is not considered to be Human Subjects Research as defined by the Office of Human Research Protections.

Study Population

We included all hospitalizations from January 1, 2009 to December 31, 2010 for patients aged 18 years or older with a principal discharge diagnosis of acute myocardial infarction as defined by the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes 410.xx. We excluded ICD-9-CM codes representing subsequent episodes of care (410.x2) and all hospitalizations involving transfers, as we could not link hospitalizations across different institutions and would be unable to capture their full hospital course. Furthermore, we excluded hospitals with fewer than 25 admissions for myocardial infarction over the study period to decrease the likelihood of artifactual findings from small sample sizes. We also excluded hospitals with no intensive care unit hospitalizations for myocardial infarction to ensure that hospitals would not lack an intensive care unit as an option for hospitalized patients.

Study Variables

Intensive Care Unit Admission Rates. For each hospital, we identified the proportion of hospitalizations for acute myocardial infarction that were directly admitted to an intensive care unit. We defined direct admission to an intensive care unit as having a room and board charge for a medical, coronary, surgical, or general intensive care unit bed during the first hospital day. We did not include step-down units due to the lack of reliability in coding for these beds as well as the lack of availability of step-down units in a significant proportion of hospitals. We then assessed intensive care unit admission patterns among four distinct subgroups of hospitalizations for myocardial infarction: 1) patients with ST-segment elevation myocardial infarctions, 2) patients with non-ST-segment elevation myocardial infarctions, 3) patients receiving reperfusion therapy, and 4) patients not receiving reperfusion therapy. We chose to study variation further across these subgroups due to the possibility that these patients may differ in their acuity of illness and/or their monitoring needs. ST-segment elevation myocardial infarctions were identified using ICD-9-CM codes 410.0 through 410.8 (excluding 410.7).[12] Non-ST-segment elevation myocardial infarctions were identified using ICD-9-CM code 410.7.[25] Reperfusion therapy was defined as either thrombolysis or percutaneous coronary intervention provided at any time during hospitalization.

Mortality. For each hospital, we calculated in-hospital all-cause risk-standardized mortality rates for 1) all patients with myocardial infarction and 2) intensive care unit patients with myocardial infarction—defined as the subset of all patients with myocardial infarction who were directly admitted to an intensive care unit.

Use of Critical Care Therapy. For each hospital, we calculated the use of critical care therapies among 1) all patients with myocardial infarction and 2) intensive care unit patients with myocardial infarction. For these outcomes, we hypothesized that hospitals with higher rates of intensive care unit use would be more likely to use critical care therapies in their overall cohort of patients with myocardial infarction due to greater discretionary use and a gatekeeper effect granting more patients access to such therapies. In contrast, we postulated such therapies would be less likely to be used in their intensive care unit patient subgroups due to a higher proportion of low-risk patients in the intensive care unit. Critical care therapies were defined as therapies for myocardial infarction that are typically available only in an intensive care unit, including the use of mechanical ventilation, intravenous vasopressors or inotropes, intra-aortic balloon pumps, and/or pulmonary artery catheters.

Length of Stay. For each hospital, we calculated the length of stay for 1) all patients with myocardial infarction and 2) intensive care unit patients with myocardial infarction.

Statistical Analysis

Results for categorical variables are reported as percentages. Results for continuous variables are reported with medians and interquartile ranges. Hospitals were categorized into quartiles based on the proportion of all hospitalizations for myocardial infarction admitted to an intensive care unit, with the top quartile (quartile 4) having the highest rates of admission and the bottom quartile (quartile 1) having the lowest rates. Hospital characteristics, mortality, critical care therapies, and length of stay were assessed across quartiles.

For 1) all patients with myocardial infarction and 2) intensive care unit patients with myocardial infarction, we calculated in-hospital risk-standardized mortality rates for each hospital using hierarchical logistic regression, employing methods that are used in the outcomes measures publicly reported by the

Centers for Medicare & Medicaid Services.[26,27] We adjusted for patient characteristics including age and comorbidities (Table 1) classified using the software provided by the Healthcare Costs and Utilization Project of the Agency for Healthcare Research and Quality.[28] Variables were selected using a stepwise algorithm.

Table 1. Selected Comorbidities.

Covariates	**Used in ICU Patient Model**	**Used in Overall Patient Model**
Age (categorical)	X	X
Congestive heart failure	X	X
Pulmonary circulation disease	X	
Peripheral vascular disease	X	X
Paralysis		X
Other neurological disorders	X	X
Chronic pulmonary disease		X
Diabetes with or without chronic complications	X	X
Hypothyroidism	X	X
Renal failure	X	
Liver disease	X	X
Metastatic cancer	X	X

Solid tumor without metastasis	X	X
Coagulopathy	X	X
Obesity		X
Weight loss	X	X
Fluid and electrolyte disorders	X	X
Chronic blood loss anemia	X	X
Deficiency anemias	X	X
Drug abuse	X	X
Psychoses	X	
Depression	X	X
Hypertension	X	X

ICU, intensive care unit

We examined the relationship between intensive care unit admission rates and risk-standardized mortality rates using a scatterplot and also compared mortality rates across quartiles. Next, we compared the median length of stay across the four quartiles. A Kruskal-Wallis test was used to assess statistical significance in both the mortality rate and length of stay comparison. We then compared the rate of critical care therapy use across quartiles. A Cochran-Armitage Trend test was used to assess statistical differences in therapy use across quartiles. We considered p-values <0.05 as statistically significant.

Analyses were conducted with SAS version 9.3 (SAS Institute Inc., Cary, NC). The GLIMMIX procedure was used to estimate the hierarchical logistic models. We generated the figures with R version 2.9.1 (R Development Core Team, Vienna, Austria).[29] The statistical analysis on SAS as well as the acquisition of the Premier database was performed by other members of the research team. I was involved in the interpretation of the data and the design of the study, including decisions on aims, study variables, primary and secondary analyses, and statistical tests.

Results

Hospital Characteristics

We identified 114,136 hospitalizations for myocardial infarction in the 307 hospitals which admitted patients to an intensive care unit over the 2-year study period. Of these hospitalizations, 54,527 (48%) involved admission to an intensive care unit on the first hospital day. Among hospitals, the median bed size was 302 (interquartile range: 186,432), median 2-year volume of hospitalizations for myocardial infarction was 258 (interquartile range: 84,539), and median 2-year volume of intensive care unit hospitalizations for myocardial infarction was 112 (interquartile range: 34,265). Hospitals in our study tended to be located in the South (39%), serve an urban population (83%), and identify as non-teaching (71%; Table 2).

Following stratification into quartiles by intensive care unit admission rates for patients with myocardial infarction, quartile 1 included hospitals with intensive care unit admission rates ≤34%. Quartile 2 included hospitals with rates of 35%-48%. Quartile 3 included hospitals with rates of 49%-61%. Quartile 4 included hospitals with rates ≥ 62%. Across quartiles, hospitals had similar characteristics except that those with the lowest intensive care unit admission rates (quartile 1) were smaller (42% had ≤200 beds compared with 28%, 22%, and 20% in quartiles 2, 3, and 4, respectively) and had a lower 2-year case volume of myocardial infarctions (38% had <85 hospitalizations for AMI compared with 25%, 15% and 22% in quartiles 2, 3, and 4, respectively).

Table 2. Hospital Cohort Characteristics (N=307)

	All Hospitals (n=307) n(%)	**Quartile 1 (n=77) n(%)**	**Quartile 2 (n=76) n(%)**	**Quartile 3 (n=78) n(%)**	**Quartile 4 (n=76) n(%)**
Number of beds					
1 – 200	85 (28)	32 (42)	21 (28)	17 (22)	15 (20)
201 – 400	130 (42)	27 (35)	36 (47)	31 (40)	36 (47)
401 – 600	64 (21)	14 (18)	14 (18)	19 (24)	17 (22)
>600	28 (9)	4 (5)	5 (7)	11 (14)	8 (11)
Volume of hospitalizations for acute MI*					
25* – 84	77 (25)	29 (38)	19 (25)	12 (15)	17 (22)
85 – 258	77 (25)	17 (22)	21 (28)	18 (23)	21 (28)
259 – 539	77 (25)	15 (19)	19 (25)	21 (27)	22 (29)
>539	76 (25)	16 (21)	17 (22)	27 (35)	16 (21)
Volume of ICU hospitalizations for acute MI*					
1 – 34	79 (25)	43 (56)	18 (24)	9 (12)	9 (12)

35 – 112	75 (25)	17 (22)	23 (30)	16 (21)	19 (25)
113 – 265	77 (25)	16 (21)	22 (29)	21 (27)	19 (24)
>265	76 (25)	1 (1)	13 (17)	32 (41)	30 (39)
Geographic region					
Midwest	74 (24)	19 (25)	17 (22)	13 (17)	25 (33)
Northeast	49 (16)	17 (22)	12 (16)	13 (17)	7 (9)
South	119 (39)	27 (35)	32 (42)	30 (38)	30 (40)
West	65 (21)	14 (18)	15 (20)	22 (28)	14 (18)
Population served					
Urban	254 (83)	60 (78)	62 (82)	68 (87)	64 (84)
Rural	53 (17)	17 (22)	14 (18)	10 (13)	12 (16)
Teaching status					
Non-teaching	219 (71)	54 (70)	55 (72)	55 (71)	55 (72)
Teaching	88 (29)	23 (30)	21 (28)	23 (29)	21 (28)

MI, myocardial infarction; ICU, intensive care unit

*Categories were stratified by quartiles from the overall distribution of volume of hospitalizations for acute MI and ICU hospitalizations for MI. Volume was measured across the 2-year study period.

Among patients, the proportion of hospitalizations for ST-segment elevation myocardial infarction ranged from 32% to 39% from quartile 1 to 4, while the proportion of hospitalizations utilizing reperfusion therapy ranged from 44% to 51% (Table 3). Other patient characteristics, including age, gender, and comorbidities were largely similar across quartiles.

Table 3. Patient Characteristics (n=114,136).

	All Patients (n=114,136) (%)	Quartile 1 (n=24,576) (%)	Quartile 2 (n=25,904) (%)	Quartile 3 (n=38,121) (%)	Quartile 4 (n=25,535) (%)
Age					
18 – 54	21	18	21	22	24
55 – 64	23	20	22	23	24
65 – 74	21	21	21	22	20
75 – 84	20	22	21	20	19
≥85	15	18	16	14	13
Gender					
Male	60	59	60	61	61
Female	40	41	40	39	39
Type of Myocardial Infarction					
ST-Segment Elevation	37	32	36	38	39
Non-ST-Segment Elevation	63	68	64	62	61
Reperfusion					
Yes	47	44	47	46	51
No	53	56	53	54	49
Comorbidities					
Peripheral Vascular Disease	13	13	12	13	13
Other Neurological Disorders	7	7	7	7	6
Chronic Pulmonary Disease	21	21	21	21	20

Diabetes with and without Complications	36	36	36	35	35
Hypothyroidism	11	11	11	11	10
Renal Failure	20	21	20	19	19
Coagulopthy	5	5	5	5	6
Obesity	13	13	13	14	13
Fluid and Electrolyte Disorders	22	23	21	23	23
Deficiency Anemias	19	19	18	19	19
Depression	8	8	8	8	7
Hypertension	70	71	70	70	71

Intensive Care Unit Admission Rates

The intensive care unit admission rate for hospitalizations for myocardial infarction among hospitals varied markedly with a range from 0% to 98% (median: 48%; interquartile range: 35-61%; Figure 1). The hospital with the lowest admission rate did not have an absolute rate of 0% but rather, this figure was obtained due to rounding. The median intensive care unit admission rates across quartiles 1 through 4 were 20%, 41%, 55%, and 71%, respectively, and demonstrate a sizeable increase in median admission rates from quartile 1 to quartile 2.

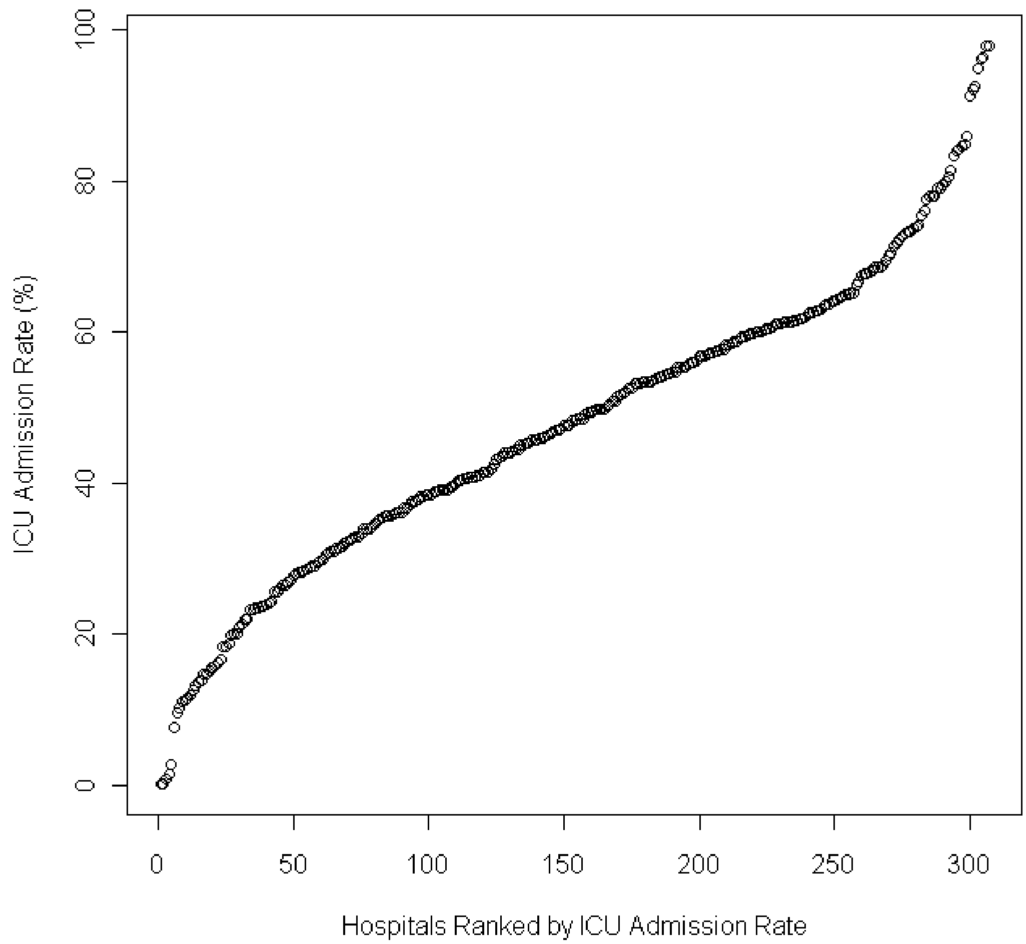

Figure 1. ICU Admission Rates across Hospitals for All Hospitalizations for Myocardial Infarction (N=307). Each data point represents a hospital; ICU, intensive care unit

Among the subgroups, intensive care unit admission rates across hospitals within each patient group also varied widely despite differences in median overall intensive care unit admission rates across patient groups. There were 302 out of the 307 total hospitals which had patients with an ST-segment elevation myocardial infarction admitted to an intensive care unit, while there were 306 out of the 307 total hospitals which had patients with a non ST-segment elevation myocardial infarction admitted to an intensive care unit. The median intensive care unit admission rate for patients with ST-segment elevation myocardial infarction was 75% (range 0-100%, Figure 2), higher than the median admission rate for all patients with myocardial infarction, while the median rate for non-ST-segment elevation myocardial infarctions was 35% (range 0-96%, Figure 3), lower than the median admission rate for all patients with myocardial infarction.

There were 221 out of the 307 total hospitals which admitted patients who underwent reperfusion therapy to an intensive care unit, while there were 306 out of the 307 total hospitals which admitted patients who did not undergo reperfusion therapy to an intensive care unit. The median intensive care unit admission rate for patients who received reperfusion therapy was 67% (range 0-100%, Figure 4), which was higher than the median admission rate for all patients with myocardial infarction. The median rate for patients who did not receive reperfusion therapy was 38% (range 0-97%, Figure 5), lower than the median admission rate for all patients with myocardial infarction. Again, rates of 0% were obtained due to rounding rather than a lack of patients admitted to an intensive care unit.

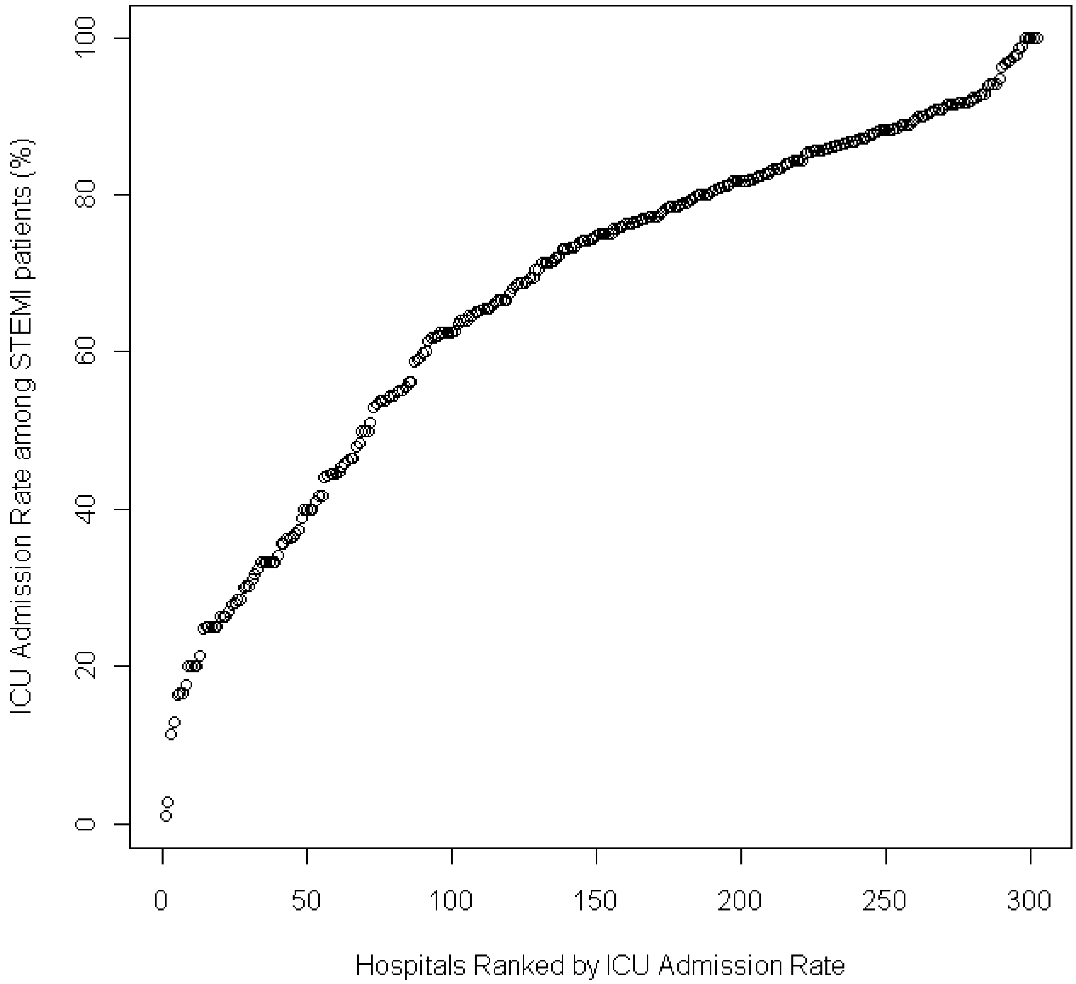

Figure 2. ICU Admission Rates across Hospitals for Patients with STEMI (N=302). Hospitals with no patients admitted to an ICU with a STEMI are not represented; ICU, intensive care unit; STEMI, ST-segment elevation myocardial infarction.

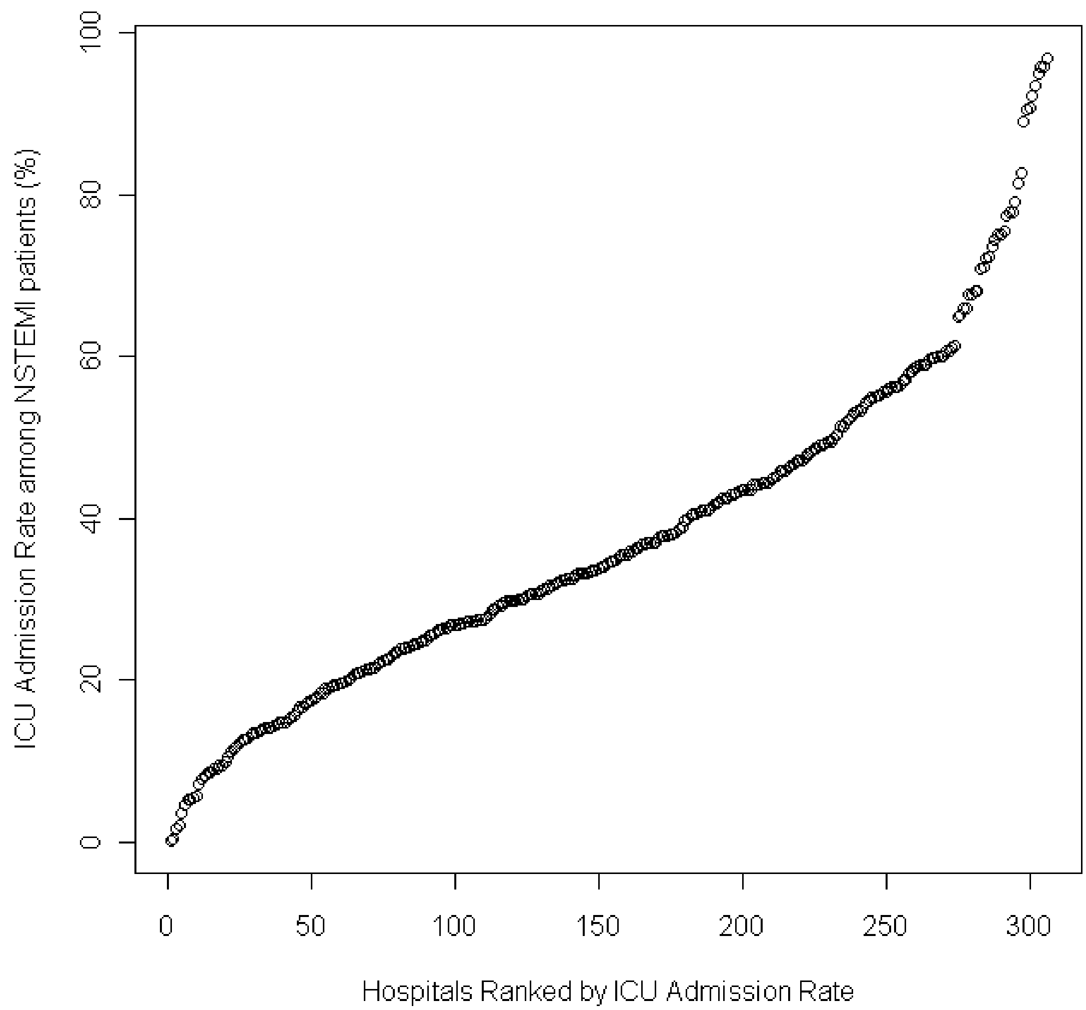

Figure 3. ICU Admission Rates across Hospitals for Patients with NSTEMI (N=306). Hospitals with no patients admitted to an ICU with a NSTEMI are not represented; ICU, intensive care unit; NSTEMI, non ST-segment elevation myocardial infarction.

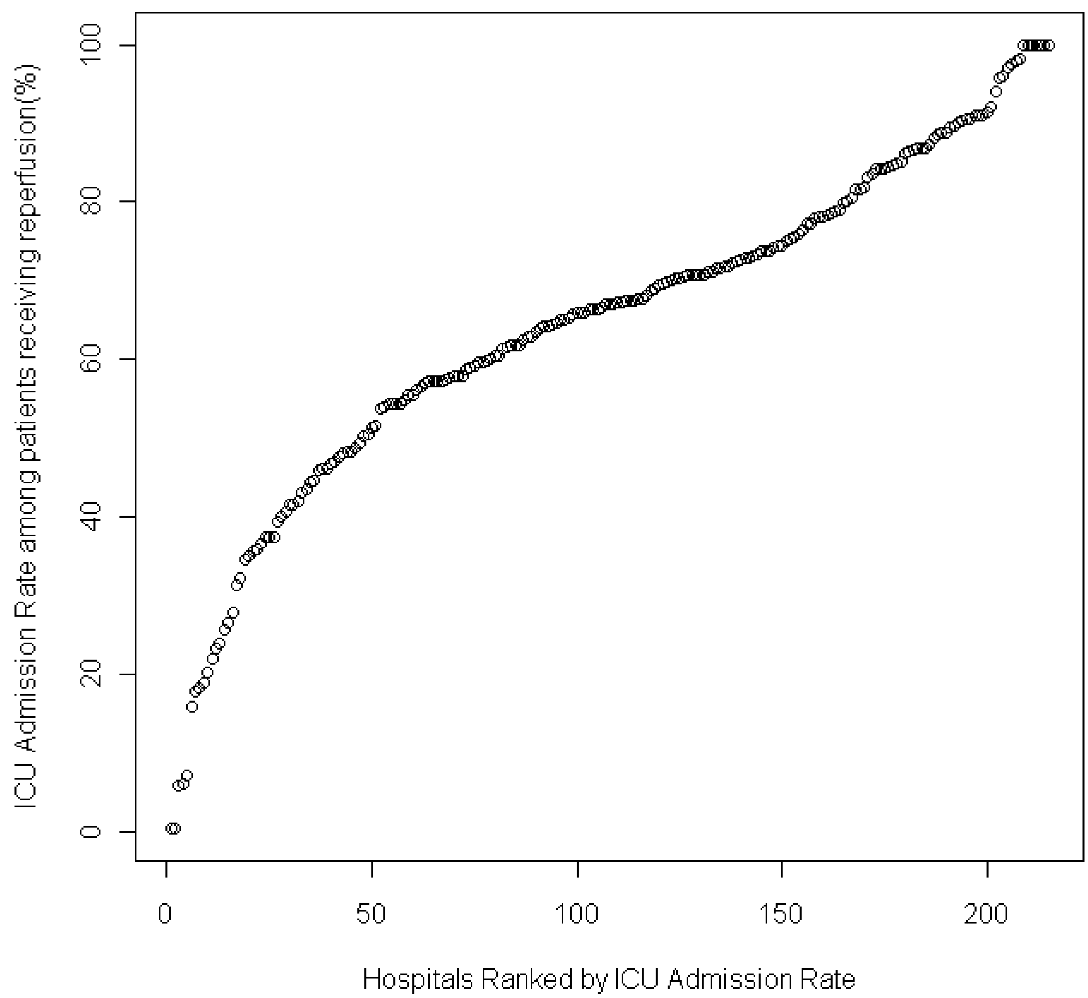

Figure 4. ICU Admission Rates across Hospitals for Patients with Myocardial Infarction Receiving Reperfusion Therapy (N=215). Hospitals with no patients admitted to an ICU with a myocardial infarction who received reperfusion therapy are not represented; ICU, intensive care unit.

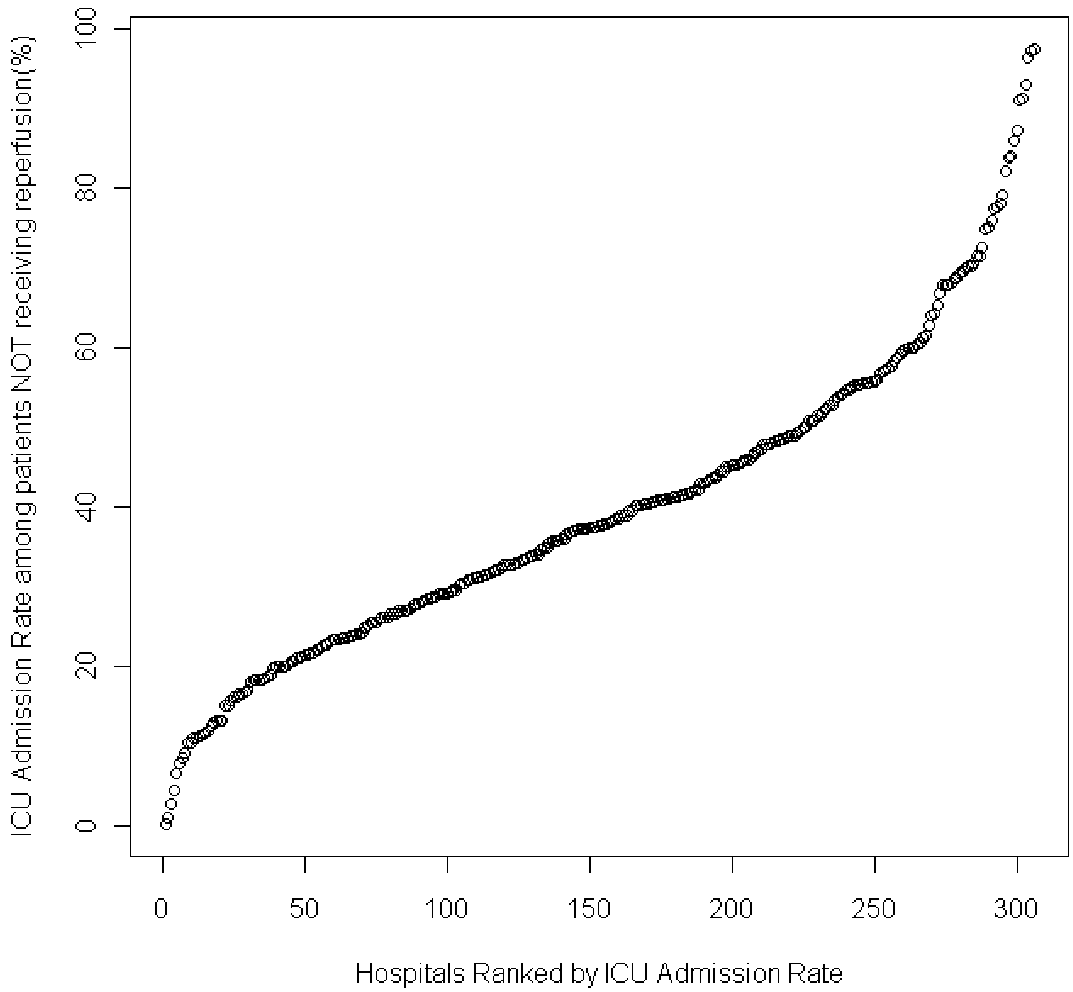

Figure 5. ICU Admission Rates across Hospitals for Patients with Myocardial Infarction Not Receiving Reperfusion Therapy (N=306). Hospitals with no patients admitted to an ICU with a myocardial infarction who did not receive reperfusion therapy are not represented; ICU, intensive care unit.

Mortality

There was no relationship between hospital intensive care unit admission rates and in-hospital risk-standardized mortality rates for all patients with myocardial infarction (Figure 6).

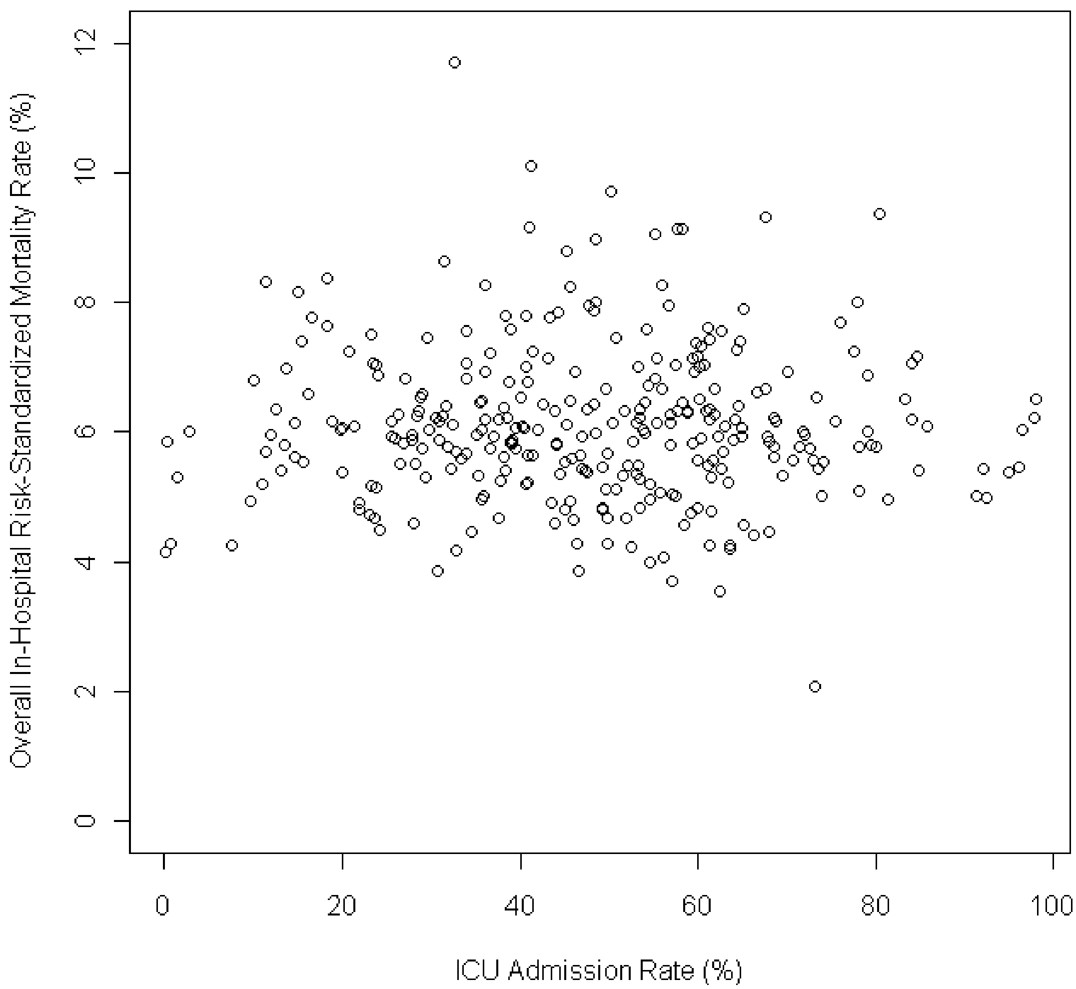

Figure 6. Overall In-Hospital Risk-Standardized Mortality Rates across Hospital ICU Admission Rates for Myocardial Infarction (N=307). Each data point represents a hospital; ICU, intensive care unit

When compared across quartiles of intensive care unit admission, there was no statistical difference in risk-standardized mortality rates. Quartile 1 hospitals had a collective mortality rate of 6.0% while hospitals in quartiles 2, 3, and 4 had collective mortality rates of 6.0%, 6.1%, and 5.9%, respectively (p=0.7; Table 4).

Table 4. Risk-Standardized In-Hospital Mortality across Hospitals for All Patients with Myocardial Infarction (N=307).

Outcome	Category	N	Mortality rate (%)	P-value
Risk-standardized in-hospital mortality	Quartile 1	77	6.0	0.73
	Quartile 2	76	6.0	
	Quartile 3	78	6.1	
	Quartile 4	76	5.9	

For the subgroup of intensive care unit patients with myocardial infarction, in-hospital risk-standardized mortality rates differed significantly among quartiles. The hospitals with the highest intensive care unit admission rates had the lowest mortality (6.5% in quartile 4) while lower intensive care unit admission rates were associated with higher mortality (7.1%, 7.9%, and 8.7% in quartiles 3, 2, and 1, respectively; p<0.0001; Table 5).

Table 5. Risk-Standardized In-Hospital Mortality across Hospitals for ICU Patients with Myocardial Infarction (N=307).

Outcome	Category	N	Mortality rate (%)	P-value
Risk-standardized in-hospital mortality	Quartile 1	77	8.7	<0.01
	Quartile 2	76	7.9	
	Quartile 3	78	7.1	
	Quartile 4	76	6.5	

ICU, intensive care unit

Use of Critical Care Therapy

All Patients with Myocardial Infarction

The proportion of all patients with myocardial infarction utilizing critical care therapies increased across quartiles of increasing hospital intensive care unit admission rates. From quartile 1 to 4, there was a significantly increasing trend in the use of mechanical ventilation from 13% to 16% ($p<0.01$), vasopressors or inotropes from 17% to 21% ($p<0.01$), intra-aortic balloon pumps from 4% to 7% ($p<0.01$), and pulmonary artery catheters from 4% to %5 ($p=0.04$; Table 6).

Table 6. Critical Care Therapy Utilization across Hospitals for All Patients with Myocardial Infarction (N=114,136)

	Usage of therapy (Proportion of hospitalizations utilizing therapy; %)				
Therapy	**Quartile 1 (n=**24,576**)**	**Quartile 2 (n=**25,904**)**	**Quartile 3 (n=**38,121**)**	**Quartile 4 (n=**25,535**)**	**P-value for Trend**
Mechanical ventilation	13	15	15	16	<0.01
Vasopressors and/or inotropes	17	18	20	21	<0.01
Intra-aortic balloon pump	4	5	5	7	<0.01
Pulmonary artery catheter	4	6	5	5	0.04

Intensive Care Unit Patients with Myocardial Infarction

Among the subgroup of intensive care unit patients with myocardial infarction, there was a significantly decreasing trend in the proportion of patients receiving critical care therapies across quartiles of increasing intensive care unit admission rates. From quartile 1 to 4, there was a decrease in the use of mechanical ventilation from 28% to 18%, vasopressors or inotropes from 35% to 24%, intra-aortic balloon pumps from 12% to 9%, and pulmonary artery catheters from 6% to 5% (p<0.01 for all therapies; Table 7).

Table 7. Critical Care Therapy Utilization across Hospitals for ICU Patients with Myocardial Infarction (N=54,527)

	Usage of therapy (Proportion of hospitalizations utilizing therapy; %)				
Therapy	**Quartile 1 (n=**4,860**)**	**Quartile 2 (n=**10,537**)**	**Quartile 3 (n=**20,940**)**	**Quartile 4 (n=**18,190**)**	**P-value for Trend**
Mechanical ventilation	28	22	19	18	<0.01
Vasopressors and/or inotropes	35	26	25	24	<0.01
Intra-aortic balloon pump	12	9	8	9	<0.01
Pulmonary artery catheter	6	6	5	5	<0.01

ICU, intensive care unit

Length of Stay

All Patients with Myocardial Infarction

The median length of stay for all patients with myocardial infraction was largely similar across quartiles. Quartiles 1, 2, and 4 all had a median length of stay of 3 days, with an interquartile range of 2 to 6 days. Quartile 3 hospitals had the longest length of stay at 4 days but similarly had an interquartile range of 2 to 6 days (p<0.0001; Table 8).

Table 8. Length of Stay across Hospitals for All Patients with Myocardial Infarction (N=114,980).

Outcome	Category	N	Length of Stay in days Median (IQR)	P-value
Length of Stay	Quartile 1	24,576	3 (2, 6)	<0.0001*
	Quartile 2	25,904	3 (2, 6)	
	Quartile 3	38,121	4 (2, 6)	
	Quartile 4	25,535	3 (2, 6)	

*****Global test

Intensive Care Unit Patients with Myocardial Infarction

Among the subgroup of intensive care unit patients with myocardial infarction, there was a slight difference in length of stay across quartiles. Patients admitted to the intensive care unit with myocardial infarctions at quartile 4 hospitals, those with the highest admission rates, had the shortest median length of stay at 3 days (interquartile range: 2, 6). Quartile 3 hospitals had a median length of 4 days (interquartile range: 2, 7), while quartile 2 hospitals had a median length of stay of 4 days (interquartile range: 2, 6). Quartile 1 hospitals, those with the lowest intensive care unit admission rates, had the longest median length of stay of 4 days (interquartile range: 3, 7; p<0.0001; Table 9).

Table 9. Length of Stay across Hospitals for ICU Patients with Myocardial Infarction (N=54,527).

Outcome	Category	N	Length of Stay in days Median (IQR)	P-value
Length of Stay	Quartile 1	4,860	4 (3, 7)	<0.0001*
	Quartile 2	10,537	4 (2, 6)	
	Quartile 3	20,940	4 (2, 7)	
	Quartile 4	18,190	3 (2, 6)	

*Global test; ICU, intensive care unit

Discussion

We found that intensive care unit admission rates for myocardial infarction varied substantially across hospitals but were not associated with differences in mortality after accounting for case mix. There was also little absolute difference in overall length of stay. Hospitals admitting a greater percentage of patients to the intensive care unit were more likely to perform invasive critical care interventions overall. However, the use of these interventions and length of stay was lower in these high-admitting hospitals among the subset of patients with myocardial infarction admitted directly to the intensive care unit, suggesting that at the margin, hospitals admitting a larger proportion of patients to the intensive care unit were admitting a group of lower risk patients with weaker indications for these therapies.

To our knowledge, this is the first study to examine hospital-level variation in intensive care unit utilization for myocardial infarction and its association with outcomes in such large sample of hospitals. Although intensive care may be providing lifesaving interventions for the appropriate patients, it may not be providing value for all patients admitted to an intensive care unit. The decision to use an intensive care unit is important not only because intensive care units are resource intensive settings,[18] but also because these hospitalizations potentially pose numerous inherent risks for patients including but not limited to various sources of infection, venous thromboembolic disease, and delirium.[30,31] Our findings suggest that we may not be optimally utilizing these highly specialized resources.

These findings highlight the decision to use an intensive care unit for patients with a myocardial infarction as a potential target for improvement. As early as 1987, Wagner noted a significant portion of the general intensive care unit population in hospitals were low-risk patients admitted for monitoring, of which only 4.3% received any critical care treatments, and called for a reassessment of contemporary intensive care unit utilization to guide optimization of use.[32] More recent studies have shown little improvement in the landscape of intensive care utilization today, as more than half of patients directly admitted to intensive care units have a 30-day mortality of 2% or less.[33] Furthermore, hospitals demonstrate significant variation in their utilization of intensive care unit care for both all patients and patients with specific conditions such as acute decompensated heart failure and diabetic ketoacidosis.[33-36] We extend this work to patients with myocardial infarction in a contemporary patient population. Compared with previous work on heart failure patients and the overall patient population, patients with myocardial infarction have a higher median hospital intensive care unit admission rate and wider variation across hospitals (interquartile range of 35-61% for patients with myocardial infarction versus 6-16% for heart failure patients and 4.7-10% or 9-17% for all patients).[33-35] Such differences suggest that patients with myocardial infarction account for a relatively higher cost and resource burden on the healthcare system overall and high-admitting hospitals in particular, making this population a potentially high yield target for optimization.

Our results suggest that variation across hospitals in intensive care unit triage may be more due to hospital factors rather than patient characteristics. For example, we found that patient demographics and comorbidities were comparable across the four quartiles of hospitals. Wide variations in rates of intensive care unit admission across hospitals were identified in all patient subgroups. This includes patients with ST-segment and non- ST-segment elevation myocardial infarctions, and patients who did and did not undergo reperfusion therapy, suggesting that no particular group was responsible for this overall hospital-level variation. Our findings are consistent with previous literature for other conditions suggesting that patient characteristics explain only a modest proportion of the variation in intensive care unit use.[33] Despite efforts to standardize patient care through published algorithms and guidelines, the lack of consistency in intensive care unit use likely still reflects a large discretionary component that includes consideration of bed availability, patients' wishes, physician incentives, and differing beliefs about best practices, particularly across different institutions.[34,37,38]

There are several possible explanations for our findings. First, hospitals admitting a large proportion of patients with myocardial infarction to the intensive care unit may have lower thresholds for intensive care unit admission, thereby using intensive care for lower-risk patients who are less likely to have adverse outcomes or need critical care therapies. Consistent with this hypothesis, we found a trend that intensive care unit patients with myocardial infarction were less likely to receive critical care interventions and had lower mortality at higher-admitting hospitals. Also supporting this hypothesis, these intensive care unit patients at the highest-admitting hospitals also had the shortest median length of stay while the lowest-admitting hospitals had the longest length of stay. When considered in combination with the overall lack of difference in mortality, this further suggests that hospital patient-risk thresholds for admission to an intensive care unit may be very different between high- and low-admitting hospitals. An alternative explanation for this trend may be that high-admitting hospitals are improving patient outcomes with intensive care unit admission. However, this seems unlikely given that across quartiles, patient characteristics were similar and overall mortality rates for myocardial infarction did not differ despite such widely varying rates of intensive care unit and critical care therapy use.

Our results have important implications for health system leaders and policymakers seeking to improve the efficiency of inpatient care. This pattern of care for myocardial infarction in high-admitting hospitals—higher overall use of intensive care units and critical care therapies across all patients combined with the lower use of critical care therapies per intensive care unit patient—suggests an opportunity where improving triage could enhance resource utilization without undermining outcomes.

Several strategies may provide practical approaches to improve use of the intensive care unit for patients with a myocardial infarction. At the provider level, a renewed emphasis may need to be placed on the use of appropriate risk stratification for patients with myocardial infarction at presentation. Well-validated risk prediction models exist to accurately predict in-hospital adverse cardiac outcomes, such as the well-known Global Registry of Acute Coronary Events (GRACE) and the Thrombolysis in Myocardial Infarction (TIMI) scores.[39,40] Other studies have specifically identified clinical features and risk factors that predict complications and critical care needs.[41] Low-risk patients identified with these tools have excellent in-hospital and long-term outcomes and therefore may not routinely require intensive care unit admission. Furthermore, for many patients admitted to intensive care units for monitoring and prevention of complications, intermediate care units such as step-down units or general telemetry units may provide an equally safe yet more cost-effective alternative. Finally, risk prediction models can also effectively guide admission to these units in an effort to optimize utilization and cost through a more gradated system of care.[42]

In addition to these strategies, future investigation should focus on better understanding the drivers of these hospital-level variations or phenotypes, the population of patients with myocardial infarction who most benefit from intensive care unit admission, and the point at which marginal benefit from intensive care unit admission ceases. A few studies have demonstrated that certain subsets of patients with acute myocardial infarction, such as low-risk patients who underwent successful reperfusion through percutaneous coronary intervention, have similar outcomes whether they are admitted to a general medicine ward or to an intensive care unit.[10,20,22] However, more of these studies are needed in order to determine all of the patient subgroups, patient characteristics, and clinical markers which may influence whether or not intensive care admission can influence outcomes. Additional research utilizing clinical databases or registry may be the next steps in better understanding this distinction. In addition, detailed investigations utilizing both quantitative and qualitative methods to analyze various samples of hospitals from each of these quartiles of intensive care unit utilization may elucidate which hospital factors have the largest effect on dictating patient triage and allow us to better understand the discretionary components of use.

Such investigations and future studies of these resource-intensive settings are particularly relevant as healthcare spending in the United States continues to escalate, gaining attention and notoriety in both the political arena and the public eye. Even as the economy has slowed in recent years, healthcare expenditures continued to grow each year, reaching $2.7 trillion in 2011.[43] Intensive care accounts for a substantial proportion of these expenditures, with costs exceeding $80 billion as of 2005 and growing.[19] Recently, a significant amount of literature has focused on the need for effective and efficient use of critical care in order to maximize its value. Articles in prominent, high-impact journals have promoted the use of several multidisciplinary strategies to improve critical care utilization, including health information technology capitalizing on integrated health systems and electronic health records,[44] as well as the economic concept of demand elasticity and the need to understand or control the influence of intensive care unit bed availability on utilization.[45] These multidisciplinary, high-level approaches should go hand in hand with our suggested need to understand the hospital-level influences on discretionary use and varying institutional cultures, and complement potentially more granular approaches to optimizing critical care for high-value diseases such as myocardial infarction.

Several factors should be considered in interpreting our results. Our study focused on hospital patterns so we cannot make an inference about the utility of admission to an intensive care unit for any particular patient. We performed hospital risk adjustment using age, sex, and comorbidities derived from administrative data. Although clinical data are typically superior to claims data for patient-level risk adjustment, claims-based hospital-level risk adjustment has been shown to produce similar results at the hospital level, particularly for myocardial infarctions.[26,27] Our study also depended on the reliability of the administrative and billing data to distinguish between intensive care unit and non-intensive care unit beds. However, due to the large discrepancy in billing costs between these bed types, we feel confident that hospitals would ensure these billing codes are accurate as they potentially represent a significant difference in compensation. In addition, we were unable to apply a clinical risk score to assess the extent to which intensive care unit use was calibrated to patients' underlying clinical risk. We were also unable to track patients after hospital discharge so longer-term outcomes could not be evaluated. Finally, our hospital cohort may not be representative of general intensive care unit triage patterns nationwide; however, the Premier network covers much of the United States.

In conclusion, we revealed marked variation in intensive care unit admission across hospitals for patients admitted with myocardial infarction. We failed to find any relationship between more intensive use of intensive care units and better outcomes, even though aggressive intensive care unit use was associated with greater use of critical care resources. The pattern among those patients admitted to the intensive care unit suggests that hospitals with higher utilization may have a lower threshold for admitting patients. These findings identify an opportunity to improve intensive care unit use through optimizing triage decisions and determining which patients truly derive benefit from the intensive care setting.

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