Original Investigation

Transfer Rates From Nonprocedure Hospitals After Initial Admission and Outcomes Among Elderly Patients With Acute Myocardial Infarction

José Augusto Barreto-Filho, MD, PhD; Yongfei Wang, MS; Saif S. Rathore, MD, PhD; Erica S. Spatz, MD, MHS; Joseph S. Ross, MD, MHS; Jeptha P. Curtis, MD; Brahmajee K. Nallamothu, MD, MPH; Sharon-Lise T. Normand, PhD; Harlan M. Krumholz, MD, SM

IMPORTANCE It is unknown whether hospital transfer rates for patients with acute myocardial infarction admitted to nonprocedure hospitals (facilities that do not provide catheterization) vary and whether these rates further influence revascularization rates, length of stay, and mortality.

OBJECTIVES To examine hospital differences in transfer rates for elderly patients with acute myocardial infarction across nonprocedure hospitals and to determine whether these rates are associated with revascularization rates, length of stay, and mortality.

DESIGN, SETTING, AND PARTICIPANTS We used Medicare claims data from January 1, 2006, to December 31, 2008, to assess transfer rates in nonprocedure hospitals, stratified according to transfer rates as low (≤20%), mid-low (>20%-30%), mid-high (>30%-40%), or high (>40%). Data were analyzed for 55 962 Medicare fee-for-service patients admitted to 901 nonprocedure US hospitals with more than 25 admissions per year for acute myocardial infarction.

MAIN OUTCOMES AND MEASURES We compared rates of catheterization, percutaneous coronary intervention, and coronary artery bypass graft surgery during hospitalization and within 60 days, as well as hospital total length of stay, across groups. We measured risk-standardized mortality rates at 30 days and 1 year.

RESULTS The median transfer rate was 29.4% (interquartile range [25th-75th percentile], 21.8%-37.8%). Higher transfer rates were associated with higher rates of catheterization ($P < .001$), percutaneous coronary intervention ($P < .001$), and coronary artery bypass graft surgery ($P < .001$). Median length of stay was not meaningfully different across the groups. There was no meaningful evidence of associations between transfer rates and risk-standardized mortality at 30 days (mean [SD], 22.3% [2.6%], 22.1% [2.3%], 22.3% [2.4%], and 21.7% [2.1%], respectively; $P = .054$) or 1 year (43.9% [2.3%], 43.6% [2.2%], 43.5% [2.4%], and 42.8% [2.2%], respectively; $P < .001$) for low, mid-low, mid-high, and high transfer groups.

CONCLUSIONS AND RELEVANCE Nonprocedure hospitals vary substantially in their use of the transfer process for elderly patients admitted with acute myocardial infarction. High-transfer hospitals had greater use of invasive cardiac procedures after admission compared with low-transfer hospitals. However, higher transfer rates were not associated with a significantly lower risk-standardized mortality rate at 30 days. Moreover, at 1 year there was only a 1.1% difference (42.8% vs 43.9%) between hospitals with higher and lower transfer rates. These findings suggest that, as a single intervention, promoting the transfer of patients admitted with acute myocardial infarction may not improve hospital outcomes.

JAMA Intern Med. 2014;174(2):213-222. doi:10.1001/jamainternmed.2013.11944
Published online December 2, 2013.

Author Affiliations: Author affiliations are listed at the end of this article.

Corresponding Author: Harlan M. Krumholz, MD, SM, Yale Center for Outcomes Research and Evaluation, 1 Church St, Ste 200, New Haven, CT 06510 (harlan.krumholz@yale.edu).

According to the American Heart Association/American College of Cardiology guidelines[1-5] for the management of ST- and non–ST-elevation acute myocardial infarction, the selection of patients for invasive cardiac procedures (ie, cardiac catheterization and coronary revascularization) requires judicious evaluation of their risk profile, a decision that influences short- and long-term outcomes. An interventional strategy for patients who are admitted to hospitals that lack onsite cardiac catheterization and coronary revascularization facilities (ie, nonprocedure hospitals) requires transfer to hospitals with such capacities (ie, procedure hospitals).

Less than half of patients with acute myocardial infarction who are admitted to nonprocedure hospitals are transferred,[6,7] and in contrast to guideline recommendations, patients at lower risk are more likely to be transferred to procedure facilities to receive cardiac invasive treatment.[8,9] Additionally, the likelihood that a patient will be transferred by a nonprocedure hospital may depend on nonclinical factors, such as proximity to procedure hospitals and staff capacity, as well as institutional policies at the nonprocedure hospital. This hospital-level variation in the transfer process for patients with acute myocardial infarction may have profound implications for patients and hospital performance for this condition. We know little, however, about hospital variation in the use of the transfer process to procedure hospitals for patients with acute myocardial infarction. Moreover, if there is substantial variation across hospitals, it is unknown whether the variation has led to differences in the use of hospital resources, length of stay, and outcomes.

Therefore, we examined hospital variation in transfer rates among patients with acute myocardial infarction who were initially admitted to nonprocedure hospitals in the United States. We sought to determine whether differences in patient characteristics could explain these variations and to evaluate the association of transfer rates with total length of stay, use of invasive cardiac procedures, and short- and long-term mortality rates.

Methods

Source of Data

We used Medicare claims records as the data source. Part A claims contain data on each hospitalization for Medicare fee-for-service enrollees and include demographic information, principal and secondary *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) diagnosis codes, and procedure codes. Part B physician carrier claims contain data on each visit to a physician's office and include diagnosis and procedure codes. Hospitals with the capacity to perform cardiac catheterization were those that had performed at least 1 cardiac catheterization during the study period. The Yale University institutional review board approved this study.

Patient Sample

We selected patients aged 65 years or older who were discharged between January 1, 2006, and December 31, 2008, with a principal diagnosis of acute myocardial infarction. The diagnosis was determined by *ICD-9-CM* codes 410.xx except for 410.x2 (N = 685 980).

We excluded patients who were admitted to procedure hospitals (n = 503 556), those who left the hospital against medical advice (n = 2548), and those who were discharged alive with a total length of stay of 1 day (n = 29 354) because these individuals would be unlikely to have had an acute myocardial infarction. For patients with multiple admissions for acute myocardial infarction (n = 27 751), we randomly selected 1 admission per calendar year to avoid survival bias. The same approach is used by the Centers for Medicare & Medicaid Services to determine 30-day risk-standardized mortality rate.[10] To avoid double-counting mortality, we excluded admissions that were not the first admission within 30 days before the date of death (n = 75). We excluded patients who had invalid death data (n = 57) and those admitted to hospitals that had 25 or fewer cases of acute myocardial infarction during the 3-year period (n = 15 965). In addition, we excluded patients who were admitted to hospice within 1 year of the index admission (n = 5025) because survival was not the goal of their treatment. We excluded patients who were transferred from another hospital (n = 53 932) because we were evaluating the episode of care and attributing the admission to the initial hospital. Finally, we excluded hospitals located in territories of the United States (n = 561).[11] There were 630 018 cases that met 1 or more of our exclusion criteria, leaving a final cohort of 55 962 cases at 901 hospitals in the 50 states and District of Columbia.

Transfer Rate

Transfer status was assigned to hospitalizations in which the discharge date from the nonprocedure hospital was the same as or 1 day less than the admitting date at the receiving hospital. We calculated the distance traveled by the patient during the transfer process as the difference between the 5-digit zip code centroids of the admitting and receiving hospitals.

Outcomes Measures

Length of Stay

Length of stay was defined as the total period of hospitalization. For transferred patients, length of stay represented the time, in days, from the date of admission to the first hospital to the date of discharge from the transfer hospital.

Cardiac Procedures

We evaluated the rates of use of coronary catheterization, percutaneous coronary intervention, and coronary artery bypass graft surgery during 3 time periods: the index hospitalization, which encompasses the length of stay at both hospitals in cases of transfer; within 60 days after the index admission date; and from hospital discharge to 60 days after the index admission date. We identified coronary catheterization (*ICD-9-CM* procedure codes 88.55-88.57), percutaneous coronary intervention (*ICD-9-CM* procedure codes 36.01-36.07, 36.09, or 00.66), and coronary artery bypass graft surgery (*ICD-9-CM* procedure code 36.1x).

Mortality

We linked data from Medicare Provider Analysis and Review files with the Medicare enrollment database using unique patient identifiers. Mortality outcomes were defined using the admission date and death date.

Hospital Characteristics

We obtained hospital characteristics from 870 hospitals that participated in the 2008 American Hospital Association Survey (http://www.opeiu391.org/pdf/american-hospital-association-survey-2008/). For categorization, we defined safety-net hospitals as described elsewhere.[12] We classified hospitals according to census regions and core-based statistical areas, which use level of urbanization (metropolitan, micropolitan, and rural) to define the categories.

Statistical Analysis

We categorized hospitals into approximate quartiles according to the level of the observed proportion of patients transferred during the 3-year study period (transfer rate): low (≤20%), mid-low (>20%-30%), mid-high (>30%-40%), and high (>40%). Transfer rates were subsequently risk standardized to account for variation in patient characteristics across hospitals. We developed and calculated the hospital risk-standardized transfer rates using 2-level hierarchical logistic regression models that account for patient age, sex, and 25 clinical characteristics.

A risk-standardized transfer rate represents the ratio of a hospital's predicted transfer rate to the expected transfer rate of an average hospital that cares for patients with similar clinical risk profiles, multiplied by the mean transfer rate of the study cohort. Thus, we calculated the risk-standardized transfer rate using the analytical approach and variables used in the risk-standardized 30-day mortality measure developed for the Centers for Medicare & Medicaid Services.[10]

We compared hospital characteristics across the 4 transfer groups, including bed size, location, ownership (government, private not-for-profit, and nonprivate for-profit), teaching status, core-based statistical area, and safety-net status. We used χ^2 tests for categorical variables and analysis of variance for continuous variables. We used analysis of variance and weights to compare total length of stay and rates of procedure use (cardiac catheterization, percutaneous coronary intervention, and coronary artery bypass graft surgery) and to compare 30-day and 1-year risk-standardized mortality rates across the 4 transfer groups. Because risk-standardized mortality rates are estimates rather than observable measurements, we weighted each rate by the inverse of its standard error. Finally, we assessed the correlation of hospital transfer rate with the 30-day and 1-year risk-standardized mortality rates. We calculated the risk models using a hierarchical logistic regression model adjusted for age, sex, and clinical characteristics using the same variables included in the risk-standardization measures developed for the Centers for Medicare & Medicaid Services.[10] Using the regression coefficients from these risk models, we calculated the risk-standardized mortality rates for each hospital. The risk-standardized mortality rate accounts for differences in case mix across hospitals and enables performance comparison between hospitals. Given that patient characteristics could explain the variation in transfer rates from nonprocedure hospitals, we performed a secondary analysis using the risk-standardized transfer rates to account for differences in case mix that could have influenced the hospitals' propensity to transfer patients.

All statistical testing was 2-sided at a significance level of .05. The study statistician (Y.W.) conducted the analyses using commercial software (SAS, version 9.2; SAS Institute Inc; and Stata, version 10.0; Stata Corp Inc).

Results

Patient and Hospital Characteristics

We evaluated 55 962 patients admitted to 901 nonprocedure hospitals. Of these, 10 767 patients were admitted to 189 low-transfer hospitals, 18 870 were admitted to 277 mid-low-transfer hospitals, 16 829 were admitted to 263 mid-high-transfer hospitals, and 9496 were admitted to 172 high-transfer hospitals. Patients initially admitted to the nonprocedure hospitals with higher transfer rates were younger, more likely to be male, and less likely than those admitted to low-transfer hospitals to have had conditions such as previous acute myocardial infarction, valvular or rheumatic heart disease, heart failure, stroke, renal failure, dementia/senility, and chronic obstructive pulmonary disease (**Table 1**).

The mean (SD) number of beds in our sample was 99.6 (77.7); 22.2% of the institutions were public and 95.7% were nonteaching. Low-transfer hospitals were smaller than high-transfer hospitals. Although hospitals with the highest propensity to transfer were located in the South Atlantic and Mountain regions, we found no specific geographic pattern (**Table 2** and **Figure 1**).

Transfer Process, Transfer Rates, and Risk-Standardized Transfer Rates

The median hospital transfer rate was 29.4% (interquartile range [IQR] [25th-75th percentile], 21.8%-37.8%), ranging from zero to 81.3%. The median risk-standardized transfer rate was 29.8% (IQR, 25.9%-33.9%), ranging from 9.0% to 59.8% (**Figure 2**). The median interhospital transfer distance traveled by patients was 33.4 miles (IQR, 17.9-53.1 miles) and was longer for higher-transfer hospitals (**Table 3**).

Length of Stay

The median hospital length of stay, including the days in the receiving hospital for transferred patients, was 5.0 days (IQR, 4.0-5.0 days). This variable was similar across the nonprocedure hospitals' categories of transfer rates (Table 3).

Invasive Cardiac Procedures

The mean rates of cardiac catheterization, percutaneous coronary intervention, and coronary artery bypass graft surgery during the index hospitalization were 25.2% [11.3%], 13.2% [7.4%], and 4.8% [4.0%], respectively. Higher transfer

Table 1. Characteristics of Patients Admitted to Nonprocedure Hospitals According to Transfer Rates

Characteristic	Mean (SD)					P Value
		Transfer Rates				
	Overall	Low (≤20%)	Mid-Low (>20%-30%)	Mid-High (>30%-40%)	High (>40%)	
No. of patients	55 962	10 767	18 870	16 829	9496	
No. of hospitals	901	189	277	263	172	
Demographics						
Age, y	81.9 (2.1)	83.5 (2.1)	82.3 (1.9)	81.5 (1.7)	80.4 (1.8)	<.001
Male sex, %	42.3 (8.9)	40.0 (8.9)	40.8 (7.7)	43.5 (8.5)	45.4 (9.9)	<.001
Cardiovascular conditions and risk factors, %						
Hypertension	83.1 (7.0)	82.9 (7.7)	83.5 (6.6)	82.8 (7.0)	83.1 (7.0)	.71
Diabetes mellitus	43.0 (9.2)	42.2 (10.1)	43.6 (8.9)	43.1 (8.8)	42.9 (9.3)	.42
Chronic atherosclerosis	59.7 (10.0)	61.1 (9.6)	60.7 (10.1)	58.0 (10.3)	59.1 (9.8)	.002
Unstable angina	13.8 (6.4)	15.0 (7.2)	13.8 (6.1)	13.4 (5.8)	13.1 (6.7)	.02
Acute myocardial infarction	15.5 (7.6)	16.6 (7.7)	16.7 (8.2)	14.5 (7.0)	14.2 (6.7)	<.001
Anterior myocardial infarction	7.8 (6.0)	8.2 (6.4)	7.5 (5.6)	7.9 (5.7)	7.9 (6.6)	.63
Other location of myocardial infarction	8.0 (6.0)	7.3 (5.7)	7.4 (5.3)	7.9 (5.8)	9.6 (7.1)	<.001
Heart failure	41.1 (10.0)	46.0 (10.3)	42.2 (9.4)	39.6 (9.3)	36.2 (8.9)	<.001
Cardiorespiratory failure and shock	9.7 (5.4)	10.6 (5.8)	9.5 (5.3)	9.6 (5.0)	9.2 (5.5)	.047
PCI	4.8 (3.9)	3.6 (3.5)	4.4 (3.4)	5.1 (3.8)	6.3 (4.6)	<.001
CABG surgery	7.1 (5.4)	5.6 (4.7)	6.5 (4.8)	7.6 (5.5)	9.1 (6.0)	<.001
Valvular or rheumatic heart disease	27.6 (11.6)	28.1 (11.5)	29.7 (12.1)	26.4 (10.7)	25.5 (11.5)	<.001
Stroke	9.9 (5.4)	10.9 (5.8)	10.5 (5.5)	9.3 (5.0)	8.8 (5.1)	<.001
Cerebrovascular disease other than stroke	20.4 (7.5)	21.2 (7.2)	20.9 (7.7)	19.6 (7.1)	19.7 (7.9)	.053
Geriatric conditions, %						
Dementia/senility	26.0 (9.5)	32.0 (10.5)	26.8 (8.7)	24.0 (8.1)	21.3 (7.9)	<.001
Motor deficit/functional disability	7.1 (4.3)	8.3 (5.1)	7.1 (4.0)	6.8 (4.1)	6.3 (4.1)	<.001
Protein-calorie malnutrition	4.7 (5.1)	5.7 (6.8)	4.7 (4.7)	4.9 (4.9)	3.4 (3.4)	<.001
Other conditions, %						
Renal failure	20.3 (7.7)	21.6 (8.3)	21.5 (7.1)	19.7 (7.3)	17.9 (7.8)	<.001
COPD	34.6 (11.4)	35.8 (12.1)	35.6 (11.1)	33.1 (10.3)	34.1 (12.5)	.03
Pneumonia	31.4 (10.3)	35.8 (10.2)	32.5 (10.2)	30.1 (9.3)	26.9 (9.7)	<.001
Peripheral vascular disease	26.0 (9.8)	26.9 (10.0)	27.6 (10.4)	24.8 (9.2)	24.2 (9.2)	<.001
Metastatic cancer/leukemia	3.8 (3.0)	3.7 (2.8)	4.0 (3.0)	3.6 (2.9)	3.8 (3.0)	.39
Trauma	32.2 (8.1)	34.8 (8.3)	32.7 (7.6)	31.7 (8.2)	29.2 (7.8)	<.001
Major psychiatric disorder	9.4 (6.7)	12.2 (9.2)	9.8 (6.3)	8.5 (5.1)	7.1 (4.8)	<.001
Liver disease	1.0 (1.5)	1.0 (1.6)	1.0 (1.5)	1.0 (1.4)	0.7 (1.2)	.15
Predicted mortality, %						
30 d	22.6 (3.7)	25.2 (4.0)	23.0 (3.4)	22.1 (3.0)	20.2 (2.9)	<.001
1 y	43.8 (5.5)	48.5 (4.9)	44.9 (4.7)	42.5 (4.3)	39.0 (4.2)	<.001

Abbreviations: CABG, coronary artery bypass graft; COPD, chronic obstructive pulmonary disease; PCI, percutaneous coronary intervention.

rates were associated with higher rates of procedures within the following 60 days including cardiac catheterization (14.7% [6.1%], 25.0% [6.2%], 32.6% [6.2%], and 43.9% [8.0%] for low-, mid-low-, mid-high-, and high-transfer groups, respectively; $P < .001$), percutaneous coronary intervention (7.5% [4.0%], 12.3% [4.7%], 16.3% [5.7%], and 23.0% [8.2%]; $P < .001$), and coronary artery bypass graft surgery (2.4% [2.2%], 4.8% [3.3%], 6.5% [4.0%], and 8.4% [5.1%]; $P < .001$). Most of these procedures were performed at the receiving hospital during the index episode of hospital care (Table 3).

Risk-Standardized Mortality Rates

The mean hospital 30-day and 1-year risk-standardized mortality rates were 22.1% (2.4%) and 43.5% (2.3%), respectively. There was no evidence of association between rates of transfer and 30-day risk-standardized mortality (22.3% [2.6%], 22.1% [2.3%], 22.3% [2.4%], and 21.7% [2.1%] for low-, mid-low-, mid-high-, and high-transfer groups, respectively; $P = .054$) and only a modest association with 1-year risk-standardized mortality (43.9% [2.3%], 43.6% [2.2%], 43.5% [2.4%], and 42.8% [2.2%]; $P < .001$) (Table 3). There was no linear correlation between the rates of transfer and 30-day

Table 2. Characteristics of Nonprocedure Hospitals Categorized by Transfer Rates

Characteristic	No. (%) Overall	Transfer Rates[a] Low (≤20%)	Mid-Low (>20%-30%)	Mid-High (>30%-40%)	High (>40%)	*P* Value
Beds						
<50	239 (27.5)	74 (40.7)	62 (23.2)	66 (26.1)	37 (22.0)	<.001
51-99	290 (33.3)	44 (24.2)	92 (34.5)	90 (35.6)	64 (38.1)	
100-149	177 (20.3)	41 (22.5)	56 (21.0)	41 (16.2)	39 (23.2)	
≥150	164 (18.9)	23 (12.6)	57 (21.3)	56 (22.1)	28 (16.7)	
Mean (SD)	99.6 (77.7)	92.2 (101.4)	104.3 (71.6)	99.6 (69.9)	100.1 (67.8)	.45
Ownership						
Government	193 (22.2)	43 (23.6)	58 (21.7)	48 (19.0)	44 (26.2)	.51
Not-for-profit	563 (64.7)	119 (65.4)	168 (62.9)	171 (67.6)	105 (62.5)	
For-profit	114 (13.1)	20 (11.0)	41 (15.4)	34 (13.4)	19 (11.3)	
Teaching status						
Council of Teaching Hospitals	7 (0.8)	2 (1.1)	1 (0.4)	2 (0.8)	2 (1.2)	.76
Teaching	30 (3.4)	4 (2.2)	9 (3.4)	12 (4.7)	5 (3.0)	
Nonteaching	833 (95.7)	176 (96.7)	257 (96.3)	239 (94.5)	161 (95.8)	
Safety-net hospital						
Yes	267 (30.7)	57 (31.3)	75 (28.1)	76 (30.0)	59 (35.1)	.48
No	603 (69.3)	125 (68.7)	192 (71.9)	177 (70.0)	109 (64.9)	
Region						
New England	71 (7.9)	10 (5.3)	28 (10.1)	20 (7.6)	13 (7.6)	<.001
Middle Atlantic	138 (15.3)	23 (12.2)	50 (18.1)	41 (15.6)	24 (14.0)	
South Atlantic	152 (16.9)	18 (9.5)	42 (15.2)	45 (17.1)	47 (27.3)	
East North Central	146 (16.2)	40 (21.2)	56 (20.2)	32 (12.2)	18 (10.5)	
East South Central	82 (9.1)	19 (10.1)	25 (9.0)	29 (11.0)	9 (5.2)	
West North Central	93 (10.3)	25 (13.2)	19 (6.9)	28 (10.6)	21 (12.2)	
West South Central	94 (10.4)	24 (12.7)	24 (8.7)	26 (9.9)	20 (11.6)	
Mountain	18 (2.0)	2 (1.1)	4 (1.4)	4 (1.5)	8 (4.7)	
Pacific	107 (11.9)	28 (14.8)	29 (10.5)	38 (14.4)	12 (7.0)	
Core-based statistical area						
Metropolitan area	229 (26.3)	46 (25.3)	86 (32.2)	61 (24.1)	36 (21.4)	.08
Metropolitan divisions	115 (13.2)	22 (12.1)	39 (14.6)	33 (13.0)	21 (12.5)	
Micropolitan area	291 (33.4)	58 (31.9)	91 (34.1)	83 (32.8)	59 (35.1)	
Rural area	235 (27.0)	56 (30.8)	51 (19.1)	76 (30.0)	52 (31.0)	

[a] Some hospital characteristics were available for 870 hospitals: low, 182; mid-low, 267; mid-high, 253; and high, 168.

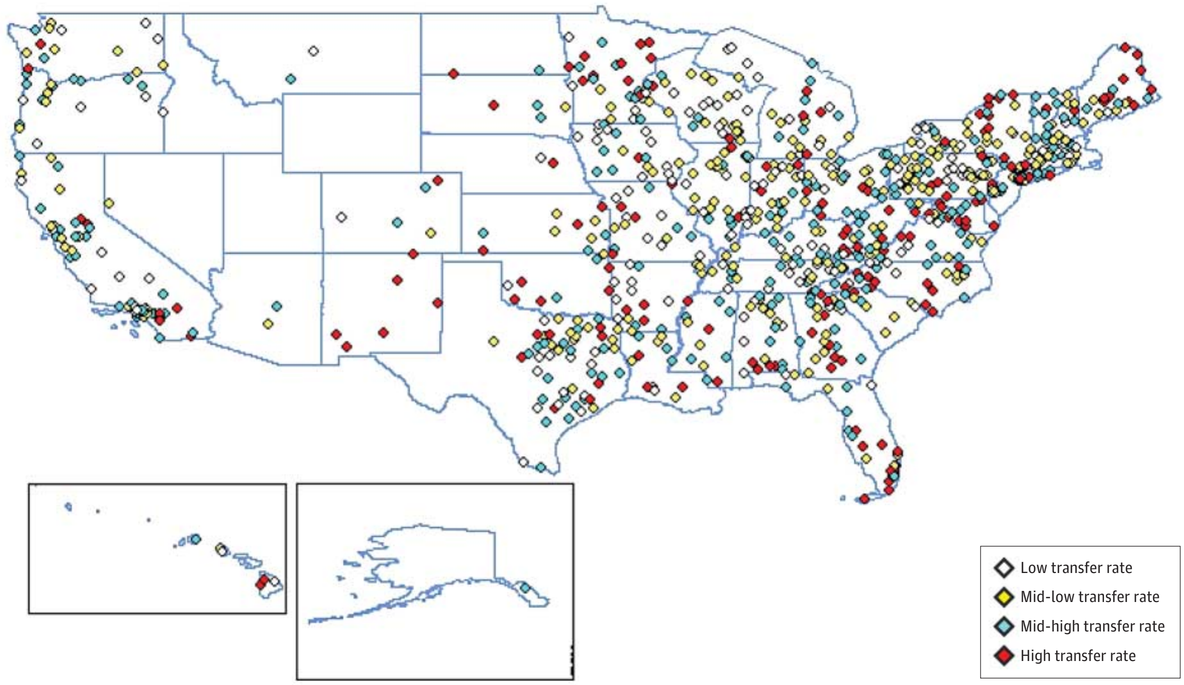
risk-standardized mortality rates (coefficient = −0.009; $R = -0.045$; $P = .18$) (**Figure 3**) and no meaningful correlation between rates of transfer and 1-year risk-standardized mortality rates (coefficient = −0.024; $R = -0.128$; $P < .001$) (Figure 3). We obtained the same level of results when we evaluated the relationship between the risk-standardized mortality rates and the risk-standardized transfer rates.

Discussion

We found marked variations in transfer rates after admission to nonprocedure hospitals for acute myocardial infarction. Patients admitted to hospitals with higher transfer rates had substantially higher rates of cardiac catheterization, percutaneous coronary intervention, and coronary artery bypass graft surgery. However, compared with hospitals with low transfer rates, those with higher transfer rates had risk-standardized mortality rates that were not significantly different at 30 days, the period during which a difference would be most expected. There was a small difference at 1 year, which is a measure that may be influenced by many factors beyond the hospitalization. Overall, these findings fail to provide strong evidence that hospitals with high transfer rates achieve better clinical outcomes.

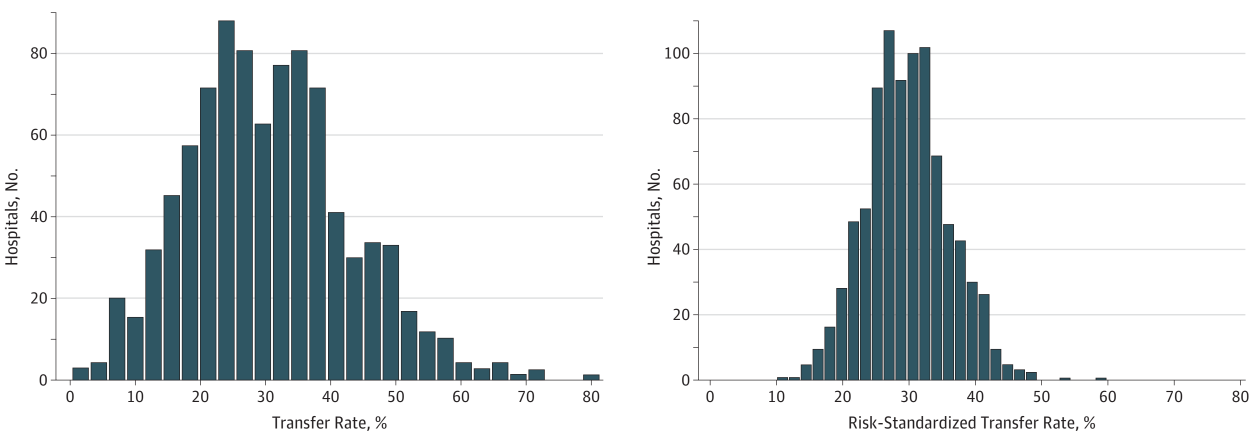
The extensive variability among transfer rates suggests that clinical needs have not been a primary driver of this process of care. In general, among patients admitted to nonprocedure hospitals, mortality rates are higher for patients who are not transferred compared with patients who are transferred,[7] and nonprocedure hospitals have the poorest performance for acute myocardial infarction.[13] As a result, in an attempt to fa-

Figure 1. Geographic Distribution of Hospitals by Transfer Rates



Geographic distribution of hospitals according to transfer rates for patients with acute myocardial infarction admitted to nonprocedure hospitals.

Figure 2. Distribution of Unadjusted and Risk-Standardized Transfer Rates



Distribution of transfer rates and risk-standardized transfer rates for patients with acute myocardial infarction admitted to nonprocedure hospitals.

cilitate more invasive treatment and improve outcomes, it has been recommended[1-5] to transfer patients admitted to nonprocedure hospitals. Although this strategy may be effective for some patients, prior studies[8,9] indicate that patient selection for transfer suggests a risk paradox practice. Moreover, little is known about the implications of rates of transfer practiced by nonprocedure hospitals for their performance. We anticipated that hospitals with higher rates of both transfer and invasive procedures should have notably better risk-standardized mortality rates. However, this was not the case. It may be that interhospital transfer of patients with acute myocardial infarction is a complex process that depends on other key processes, including the proper selection of patients at the right time, to be translated into a net benefit.[14] We did not study transfers from the emergency department, which involves different issues.

Several reasons may be hypothesized to explain the lack of meaningful association between transfer rates and mortal-

Table 3. Transfer Process, Invasive Strategy at the Receiving Hospital, and Hospital Outcomes Categorized by Transfer Rates

Characteristic	Mean (SD) Overall	Transfer Rates Low (≤20%)	Mid-Low (>20%-30%)	Mid-High (>30%-40%)	High (>40%)	*P* Value
No. of hospitals	901	189	277	263	172	
Transfer process						
Transfer rates, %	30.3 (12.4)	14.4 (4.5)	25.1 (2.7)	35.0 (2.8)	49.0 (7.1)	<.001
No. of days to transfer for transferred patients[a]	1.2 (0.7)	1.4 (1.0)	1.3 (0.6)	1.2 (0.6)	1.1 (0.5)	<.001
Patients transferred on day 1, %	7.1 (6.2)	3.6 (3.6)	5.3 (4.1)	8.3 (5.6)	12.2 (8.1)	<.001
Patients transferred on day 2, %	12.9 (7.7)	5.5 (3.7)	10.4 (4.0)	14.8 (5.5)	22.0 (7.9)	<.001
Patients transferred on day 3 or later, %	10.3 (7.2)	5.3 (4.2)	9.4 (5.0)	11.8 (6.9)	14.8 (9.1)	<.001
Interhospital distance for transfer, miles[b]	39.9 (34.7)	36.5 (29.4)	33.4 (22.5)	41.8 (43.1)	50.7 (39.0)	<.001
Median (IQR), miles[b]	33.4 (17.9-53.1)	29.2 (16.3-51.4)	29.0 (15.9-45.5)	35.6 (19.4-55.4)	41.7 (23.3-65.4)	<.001
Cardiac catheterization rate, %						
During the episode of hospitalization	25.2 (11.3)	11.4 (4.7)	20.9 (4.3)	29.2 (4.8)	41.3 (7.8)	<.001
After discharge and within 60 d of admission	3.5 (3.6)	3.3 (3.5)	4.1 (4.2)	3.5 (3.4)	2.7 (2.9)	.001
Within 60 d of admission[c]	28.7 (11.7)	14.7 (6.1)	25.0 (6.2)	32.6 (6.2)	43.9 (8.0)	<.001
PCI rate, %						
During episode of hospitalization	13.2 (7.4)	6.2 (3.8)	10.8 (4.2)	15.0 (5.2)	21.8 (7.9)	<.001
After discharge and within 60 d of admission	1.3 (1.8)	1.2 (1.6)	1.5 (2.1)	1.2 (1.7)	1.2 (1.9)	.30
PCI within 60 d of admission[c]	14.5 (7.7)	7.5 (4.0)	12.3 (4.7)	16.3 (5.7)	23.0 (8.2)	<.001
CABG surgery rate, %						
During episode of hospitalization	4.8 (4.0)	1.8 (1.9)	4.1 (3.0)	5.8 (3.8)	7.6 (4.9)	<.0001
After discharge and within 60 d of admission	0.7 (1.3)	0.6 (1.1)	0.7 (1.3)	0.7 (1.4)	0.8 (1.3)	.30
Within 60 d of admission[c]	5.5 (4.3)	2.4 (2.2)	4.8 (3.3)	6.5 (4.0)	8.4 (5.1)	<.0001
Total length of stay, d	4.8 (1.2)	4.6 (1.3)	4.9 (1.1)	4.8 (1.1)	4.9 (1.0)	.02
Median (IQR), d	5.0 (4.0-5.0)	4.0 (4.0-5.0)	5.0 (4.0-5.0)	5.0 (4.0-5.0)	5.0 (4.0-5.0)	.005
Risk-standardized mortality rate, %						
30 d	22.1 (2.4)	22.3 (2.6)	22.1 (2.3)	22.3 (2.4)	21.7 (2.1)	.054
1 y	43.5 (2.3)	43.9 (2.3)	43.6 (2.2)	43.5 (2.4)	42.8 (2.2)	<.001

Abbreviations: CABG, coronary artery bypass graft; IQR, interquartile range (25th-75th percentile); PCI, percutaneous coronary intervention.

[a] Days to transfer were calculated in 899 hospitals (2 hospitals had unverified transfer of patients with acute myocardial infarction).

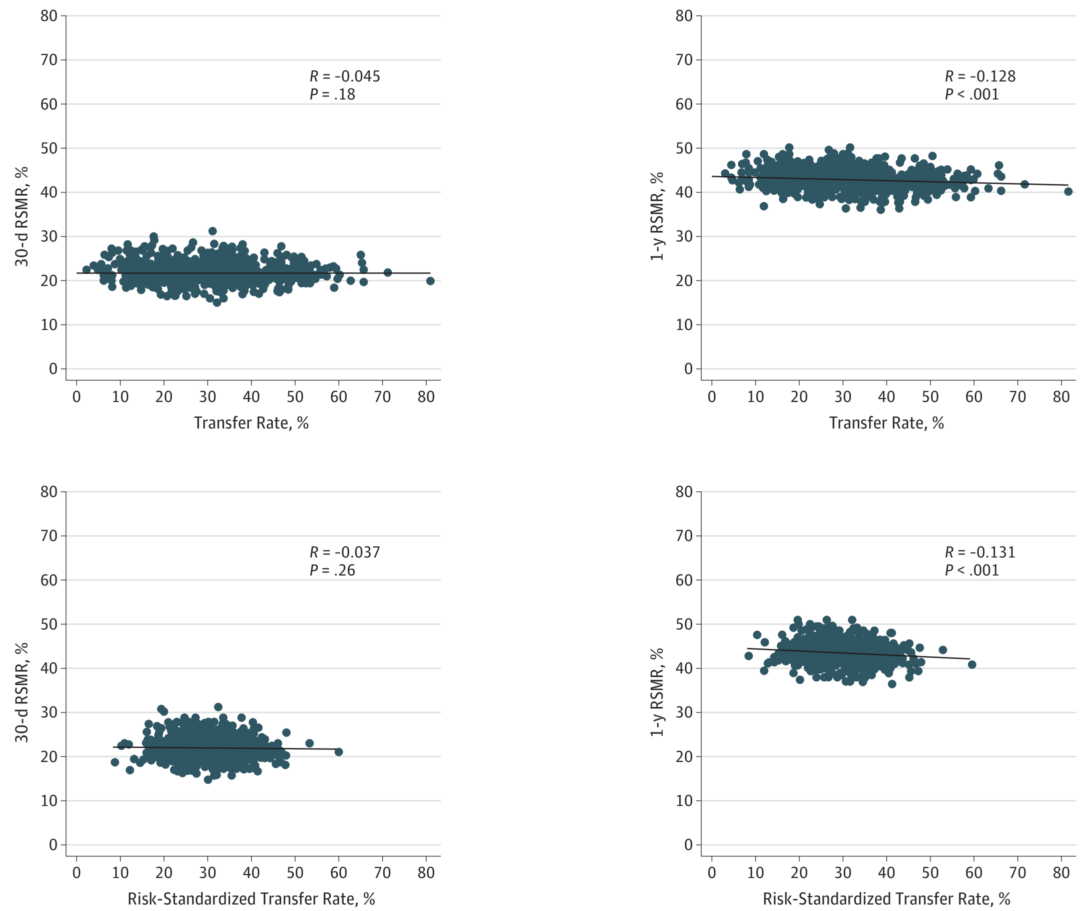
[b] Interhospital distance calculation was estimated using data from 864 hospitals.

[c] Catheterization, PCI, and CABG within 60 days of admission indicates the number of procedures performed within 60 days of the index admission (first hospital).

ity despite higher transfer rates being associated with more revascularization procedures. First, the evidence of superiority of a more intensive strategy for high-risk patients with acute myocardial infarction was documented in clinical trials, and the efficacy of this strategy for mortality rates has not been definitively confirmed outside the setting of ST-elevation myocardial infarction.[15-20] Additionally, although it is generally accepted that the higher the risk, the greater the benefit, this has not been tested in the very elderly population. Nevertheless, assuming that the higher risk of adverse outcomes results in greater benefit, patients with the highest risk would be more likely to benefit from invasive therapies. However, they are not the most likely to be referred for cardiac catheterization in the real-world setting.[7-9,21,22] Moreover, it has been shown[9,23] that patients with less likelihood of benefitting from transfer and revascularization are more likely to be transferred. In our study, patients with acute myocardial infarction who were admitted to high-transfer hospitals had lower expected 30-day and 1-year mortality rates than did patients admitted to low-transfer hospitals, further suggesting a risk paradox practice.

Second, the median hospital transfer rate in our study was 29.4%. It is possible that a higher transfer rate is necessary to realize better results for patients. Our data were limited with regard to testing this hypothesis, as less than 10% of the hospitals had transfer rates above 50%. Considering the high risk of our patient population and the rates of cardiac catheterization for these patients when invasive procedures are available,[24,25] it may be posited that an early invasive strategy for patients with acute myocardial infarction was underused even in high-transfer nonprocedure hospitals. How-

Figure 3. Relationship Between Transfer Rate and Risk-Standardized Mortality Rate (RSMR) at 30 Days and 1 Year for Patients with Acute Myocardial Infarction Admitted to Nonprocedure Hospitals



These figures show the association between transfer rate and 30-day or 1-year risk-standardized mortality rate. The line indicates the linear association and the black points show the scatter plot. No linear association was observed for 30-day RSMR and only a modest linear association was found for the 1-year RSMR.

ever, the effect of the intensity of use of invasive procedures after acute myocardial infarction on mortality rates remains debatable.[20,25-29]

Third, some procedure hospitals perform worse with respect to 30-day risk-standardized mortality compared with some nonprocedure hospitals.[13] Therefore, transferring patients from nonprocedure to procedure hospitals does not guarantee that they will receive better health care or achieve better outcomes.[13,30]

Our results offer important insights for policymakers and researchers. Our data and those from other studies[6,31] illustrate the complexity surrounding the standardization of transfer practice at the hospital level, further suggesting the importance of scrutinizing the effectiveness of this process to improve institutional outcomes.[32] The absence of a meaningful benefit of high hospital transfer rates to hospital risk-standardized mortality rates does not necessarily imply that transfer is ineffective for any particular patients. At the margin, higher transfer rates in this study were not associated with substantially better outcomes.[33] We observed that hospitals that tend to transfer more patients do not achieve better outcomes. We interpret this finding as suggesting that as currently implemented, at the margin, more transfers are not producing substantially more benefit.

Some limitations must be highlighted in the interpretation of our study. The study did not focus on patients who were transferred directly from the emergency department, so we cannot comment on the association of that practice with outcomes. All patients in this study were initially admitted to a nonprocedure hospital, and most were transferred after the second day of admission. Moreover, by using Medicare claims data, we were not able to evaluate these associations according to myocardial infarction subtype, severity of acute myocardial infarction, or physical and cognitive function, which may influence outcomes. Nevertheless, the administrative claims risk model produces estimates of hospital risk-standardized mortality that are reasonable surrogates for models using clinical data.[10,34,35] Also, potential benefits promoted by higher use of revascularization procedures for quality of life and on recurrent acute myocardial infarction, which could be particularly relevant to elderly patients, were not measured. Finally, these data reflect outcomes among elderly patients with acute myocardial infarction; generalizability to younger populations is therefore unknown.

The large variation in transfer rates across hospitals in the United States suggests a highly discretionary process that appears to take into account many patient factors, including frailty and comorbidity. The likelihood that a patient admitted to a nonprocedure hospital will be transferred depends to a large extent on the hospital to which the patient is admitted. Moreover, admission to hospitals that have higher rates of transfer is associated with a much greater likelihood of a revascularization procedure, especially during the hospitalization, with risk-standardized mortality rates that are not meaningfully better. In the absence of better empirical data and practical limitations to conducting experimental studies addressing this topic, given current levels of performance, our observational study suggests that promoting late transfer of patients admitted with acute myocardial infarction as a single intervention is unlikely to improve hospital outcomes. The implementation of this strategy may be creating the difference between the expected result and what is being achieved. More research is needed to understand how to optimize decisions about transfer and the ensuing outcomes.

ARTICLE INFORMATION

Accepted for Publication: August 17, 2013.

Published Online: December 2, 2013. doi:10.1001/jamainternmed.2013.11944.

Author Affiliations: Division of Cardiology, Federal University of Sergipe, Aracaju, Sergipe, Brazil (Barreto-Filho); Section of Cardiovascular Medicine, Department of Internal Medicine, School of Medicine, Yale University, New Haven, Connecticut (Wang, Spatz, Curtis, Krumholz); Center for Outcomes Research and Evaluation, Yale-New Haven Hospital, New Haven, Connecticut (Wang, Curtis, Krumholz); Department of Medicine, Massachusetts General Hospital, Boston (Rathore); Robert Wood Johnson Clinical Scholars Program, Department of Internal Medicine, School of Medicine, Yale University, New Haven, Connecticut (Ross, Krumholz); Section of General Internal Medicine, Department of Internal Medicine, School of Medicine, Yale University, New Haven, Connecticut (Ross); Veterans Affairs Ann Arbor Health Services Research and Development Service Center for Clinical Management Research, Ann Arbor, Michigan (Nallamothu); Division of Cardiovascular Medicine, Department of Internal Medicine and Center for Healthcare Outcomes and Policy, Institute for Healthcare Policy and Innovation, University of Michigan Medical School, Ann Arbor, Michigan (Nallamothu); Department of Health Care Policy, Harvard Medical School, Harvard University, Boston, Massachusetts (Normand); Department of Biostatistics, Harvard School of Public Health, Harvard University, Boston, Massachusetts (Normand); Department of Health Policy and Management, School of Public Health, Yale University, New Haven, Connecticut (Krumholz).

Author Contributions: Dr Wang had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Barreto-Filho, Krumholz.
Acquisition of data: Krumholz.
Analysis and interpretation of data: All authors.
Drafting of the manuscript: Barreto-Filho, Krumholz.
Critical revision of the manuscript for important intellectual content: Wang, Rathore, Spatz, Ross, Curtis, Nallamothu, Normand, Krumholz.
Statistical analysis: Wang, Spatz, Normand.
Obtained funding: Krumholz.
Administrative, technical, and material support: Krumholz.
Study supervision: Krumholz.

Conflict of Interest Disclosures: Drs Ross and Krumholz work under contract with the Centers for Medicare & Medicaid Services to develop and maintain performance measures. Dr Ross is a member of a scientific advisory board for FAIR Health, and Dr Krumholz is chair of a cardiac scientific advisory board for UnitedHealth. Drs Ross and Krumholz are the recipients of a research grant from Medtronic, through Yale University, to develop methods of clinical trial data sharing. No other disclosures were reported.

Funding/Support: This study was funded by grant 1U01HL105270-04 (Center for Cardiovascular Outcomes Research at Yale University) from the National Heart, Lung, and Blood Institute. Dr Barreto-Filho is supported by grant 3436-10-1 from the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, Ministry of Education, Brazil, and the Federal University of Sergipe, Sergipe, Brazil. Dr Ross is supported by grants K08 AG032886 and K08 AG038336 from the National Institute on Aging and by the American Federation for Aging Research through the Paul B. Beeson Career Development Award Program, respectively.

Role of the Sponsors: The sponsors had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

REFERENCES

1. Anderson JL, Adams CD, Antman EM, et al; 2011 Writing Group members; ACCF/AHA Task Force members. 2011 ACCF/AHA focused update incorporated into the ACC/AHA 2007 guidelines for the management of patients with unstable angina/non–ST-elevation myocardial infarction: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. *Circulation*. 2011;123(18):e426-e579. doi:10.1161/CIR.0b013e318212bb8b.

2. Anderson JL, Adams CD, Antman EM, et al; American College of Cardiology; American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 2002 Guidelines for the Management of Patients With Unstable Angina/Non–ST-Elevation Myocardial Infarction); American College of Emergency Physicians; Society for Cardiovascular Angiography and Interventions; Society of Thoracic Surgeons; American Association of Cardiovascular and Pulmonary Rehabilitation; Society for Academic Emergency Medicine. ACC/AHA 2007 guidelines for the management of patients with unstable angina/non–ST-elevation myocardial infarction: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 2002 Guidelines for the Management of Patients With Unstable Angina/Non–ST-Elevation Myocardial Infarction) developed in collaboration with the American College of Emergency Physicians, the Society for Cardiovascular Angiography and Interventions, and the Society of Thoracic Surgeons endorsed by the American Association of Cardiovascular and Pulmonary Rehabilitation and the Society for Academic Emergency Medicine. *J Am Coll Cardiol*. 2007;50(7):e1-e157. doi:10.1016/jacc.2007.02.013.

3. Antman EM, Anbe DT, Armstrong PW, et al; American College of Cardiology; American Heart Association; Canadian Cardiovascular Society. ACC/AHA guidelines for the management of patients with ST-elevation myocardial infarction—executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 1999 Guidelines for the Management of Patients With Acute Myocardial Infarction). *J Am Coll Cardiol*. 2004;44(3):671-719.

4. Kushner FG, Hand M, Smith SC Jr, et al; American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. 2009 Focused updates: ACC/AHA guidelines for the management of patients with ST-elevation myocardial infarction (updating the 2004 guideline and 2007 focused update) and ACC/AHA/SCAI guidelines on percutaneous coronary intervention (updating the 2005 guideline and 2007 focused update): a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines [published correction appears in *Circulation*. 2010;121(12):e57]. *Circulation*. 2009;120(22):2271-2306.

5. American College of Emergency Physicians; Society for Cardiovascular Angiography and Interventions; O'Gara PT, Kushner FG, Ascheim DD, et al. 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. *J Am Coll Cardiol*. 2013;61(4):e78-e140. doi:10.1016/j.jacc.2012.11.019.

6. Iwashyna TJ, Kahn JM, Hayward RA, Nallamothu BK. Interhospital transfers among Medicare beneficiaries admitted for acute myocardial infarction at nonrevascularization hospitals. *Circ Cardiovasc Qual Outcomes*. 2010;3(5):468-475.

7. Westfall JM, Kiefe CI, Weissman NW, et al. Does interhospital transfer improve outcome of acute myocardial infarction? a propensity score analysis from the Cardiovascular Cooperative Project. *BMC Cardiovasc Disord*. 2008;8:22. doi:10.1186/1471-2261-8-22.

8. Gurwitz JH, Goldberg RJ, Malmgren JA, et al. Hospital transfer of patients with acute myocardial infarction: the effects of age, race, and insurance type. *Am J Med*. 2002;112(7):528-534.

9. Mehta RH, Stalhandske EJ, McCargar PA, Ruane TJ, Eagle KA. Elderly patients at highest risk with acute myocardial infarction are more frequently transferred from community hospitals to tertiary centers: reality or myth? *Am Heart J*. 1999;138(4, pt 1):688-695.

10. Krumholz HM, Wang Y, Mattera JA, et al. An administrative claims model suitable for profiling hospital performance based on 30-day mortality rates among patients with an acute myocardial infarction. *Circulation*. 2006;113(13):1683-1692.

11. Nunez-Smith M, Bradley EH, Herrin J, et al. Quality of care in the US territories. *Arch Intern Med*. 2011;171(17):1528-1540.

12. Ross JS, Cha SS, Epstein AJ, et al. Quality of care for acute myocardial infarction at urban safety-net hospitals. *Health Aff (Millwood)*. 2007;26(1):238-248.

13. Chen J, Krumholz HM, Wang Y, et al. Differences in patient survival after acute myocardial infarction by hospital capability of performing percutaneous coronary intervention: implications for regionalization. *Arch Intern Med*. 2010;170(5):433-439.

14. Craig P, Dieppe P, Macintyre S, Michie S, Nazareth I, Petticrew M. Developing and evaluating complex interventions: the new Medical Research Council guidance. *BMJ*. 2008;337:a1655. doi:10.1136/bmj.a1655.

15. Cannon CP, Weintraub WS, Demopoulos LA, et al; TACTICS (Treat Angina with Aggrastat and Determine Cost of Therapy with an Invasive or Conservative Strategy)–Thrombolysis in Myocardial Infarction 18 Investigators. Comparison of early invasive and conservative strategies in patients with unstable coronary syndromes treated with the glycoprotein IIb/IIIa inhibitor tirofiban. *N Engl J Med*. 2001;344(25):1879-1887.

16. Cantor WJ, Fitchett D, Borgundvaag B, et al; TRANSFER-AMI Trial Investigators. Routine early angioplasty after fibrinolysis for acute myocardial infarction. *N Engl J Med*. 2009;360(26):2705-2718.

17. Dalby M, Bouzamondo A, Lechat P, Montalescot G. Transfer for primary angioplasty versus immediate thrombolysis in acute myocardial infarction: a meta-analysis. *Circulation*. 2003;108(15):1809-1814.

18. De Luca G, Biondi-Zoccai G, Marino P. Transferring patients with ST-segment elevation myocardial infarction for mechanical reperfusion: a meta-regression analysis of randomized trials. *Ann Emerg Med*. 2008;52(6):665-676.

19. de Winter RJ, Windhausen F, Cornel JH, et al; Invasive versus Conservative Treatment in Unstable Coronary Syndromes (ICTUS) Investigators. Early invasive versus selectively invasive management for acute coronary syndromes. *N Engl J Med*. 2005;353(11):1095-1104.

20. Mehta SR, Cannon CP, Fox KA, et al. Routine vs selective invasive strategies in patients with acute coronary syndromes: a collaborative meta-analysis of randomized trials. *JAMA*. 2005;293(23):2908-2917.

21. Ko DT, Ross JS, Wang Y, Krumholz HM. Determinants of cardiac catheterization use in older Medicare patients with acute myocardial infarction. *Circ Cardiovasc Qual Outcomes*. 2010;3(1):54-62.

22. Spertus JA, Weiss NS, Every NR, Weaver WD; Myocardial Infarction Triage and Intervention Project Investigators. The influence of clinical risk factors on the use of angiography and revascularization after acute myocardial infarction. *Arch Intern Med*. 1995;155(21):2309-2316.

23. Roe MT, Chen AY, Delong ER, et al. Patterns of transfer for patients with non–ST-segment elevation acute coronary syndrome from community to tertiary care hospitals. *Am Heart J*. 2008;156(1):185-192.

24. Tu JV, Ko DT. Ecological studies and cardiovascular outcomes research. *Circulation*. 2008;118(24):2588-2593.

25. Tu JV, Pashos CL, Naylor CD, et al. Use of cardiac procedures and outcomes in elderly patients with myocardial infarction in the United States and Canada. *N Engl J Med*. 1997;336(21):1500-1505.

26. Guadagnoli E, Hauptman PJ, Ayanian JZ, Pashos CL, McNeil BJ, Cleary PD. Variation in the use of cardiac procedures after acute myocardial infarction. *N Engl J Med*. 1995;333(9):573-578.

27. Krumholz HM. Cardiac procedures, outcomes, and accountability. *N Engl J Med*. 1997;336(21):1522-1523.

28. O'Donoghue M, Boden WE, Braunwald E, et al. Early invasive vs conservative treatment strategies in women and men with unstable angina and non–ST-segment elevation myocardial infarction: a meta-analysis. *JAMA*. 2008;300(1):71-80.

29. Selby JV, Fireman BH, Lundstrom RJ, et al. Variation among hospitals in coronary-angiography practices and outcomes after myocardial infarction in a large health maintenance organization. *N Engl J Med*. 1996;335(25):1888-1896.

30. Krumholz HM, Chen J, Murillo JE, Cohen DJ, Radford MJ. Admission to hospitals with on-site cardiac catheterization facilities: impact on long-term costs and outcomes. *Circulation*. 1998;98(19):2010-2016.

31. Nallamothu BK, Bates ER, Wang Y, Bradley EH, Krumholz HM. Driving times and distances to hospitals with percutaneous coronary intervention in the United States: implications for prehospital triage of patients with ST-elevation myocardial infarction. *Circulation*. 2006;113(9):1189-1195.

32. Ellrodt G, Sadwin LB, Aversano T, et al. Development of systems of care for ST-elevation myocardial infarction patients: the non-percutaneous coronary intervention–capable (ST-elevation myocardial infarction referral) hospital perspective. *Circulation*. 2007;116(2):e49-e54. doi:10.1161/circulationaha.107.184048.

33. Schwartz S. The fallacy of the ecological fallacy: the potential misuse of a concept and the consequences. *Am J Public Health*. 1994;84(5):819-824.

34. Antman EM, Cohen M, Bernink PJ, et al. The TIMI risk score for unstable angina/non-ST elevation MI: a method for prognostication and therapeutic decision making. *JAMA*. 2000;284(7):835-842.

35. Eagle KA, Lim MJ, Dabbous OH, et al; GRACE Investigators. A validated prediction model for all forms of acute coronary syndrome: estimating the risk of 6-month postdischarge death in an international registry. *JAMA*. 2004;291(22):2727-2733.