

# Interhospital Transfers Among Medicare Beneficiaries Admitted for Acute Myocardial Infarction at Nonrevascularization Hospitals

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**Background**—Patients with acute myocardial infarction (AMI) who are admitted to hospitals without coronary revascularization are frequently transferred to hospitals with this capability, yet we know little about the basis for how such revascularization hospitals are selected.

**Methods and Results**—We examined interhospital transfer patterns in 71 336 AMI patients admitted to hospitals without revascularization capabilities in the 2006 Medicare claims using network analysis and regression models. A total of 31 607 (44.3%) AMI patients were transferred from 1684 nonrevascularization hospitals to 1104 revascularization hospitals. Median time to transfer was 2 days. Median transfer distance was 26.7 miles, with 96.1% within 100 miles. In 45.8% of cases, patients bypassed a closer hospital to go to a farther hospital that had a better 30-day risk standardized mortality rates. However, in 36.8% of cases, another revascularization hospital with lower 30-day risk-standardized mortality was actually closer to the original admitting nonrevascularization hospital than the observed transfer destination. Adjusted regression models demonstrated that shorter transfer distances were more common than transfers to the hospitals with lowest 30-day mortality rates. Simulations suggest that an optimized system that prioritized the transfer of AMI patients to a nearby hospital with the lowest 30-day mortality rate might produce clinically meaningful reductions in mortality.

**Conclusions**—More than 40% of AMI patients admitted to nonrevascularization hospitals are transferred to revascularization hospitals. Many patients are not directed to nearby hospitals with the lowest 30-day risk-standardized mortality, and this may represent an opportunity for improvement. (*Circ Cardiovasc Qual Outcomes*. 2010;3:468-475.)

**Key Words:** patient transfers ■ revascularization ■ networks ■ Medicare ■ mortality

Most acute-care hospitals in the United States are unable to provide coronary revascularization to patients with acute myocardial infarction (AMI).<sup>1</sup> Many AMI patients who are admitted to nonrevascularization hospitals are therefore transferred to revascularization hospitals during the same admission.<sup>2</sup> Yet, we know little of the basis for how revascularization hospitals are selected during this process. In particular, it is unclear the extent to which AMI patients are transferred preferentially toward “higher-quality” revascularization hospitals and the role that geographic distances play in such decisions. If transfers between hospitals fail to concentrate AMI patients at the best-performing hospitals within a region, opportunities would exist for improving care in this high-risk group.

## Editorial see p 441

As evidence continues to support early cardiac catheterization and revascularization in both ST-segment-elevation

MI<sup>3,4</sup> and high-risk non-ST-segment-elevation MI patients,<sup>5,6</sup> it is increasingly important to understand the ways in which transfers to revascularization hospitals occur in the real world. Although who is transferred has been examined in the past, there has been no previous work examining where patients are transferred.<sup>2</sup> Because outcomes across all revascularization hospitals are not uniform,<sup>7</sup> examining the organizational structure of transfers may provide an empirical basis to assess interventions to optimize the use of transfer in AMI.

Accordingly, we used network analysis to better understand patterns of interhospital transfer among elderly Medicare beneficiaries with AMI who were initially admitted to nonrevascularization hospitals in the United States. Our analyses set out to examine (1) the proportion of AMI patients admitted to hospitals without revascularization capabilities transferred to revascularization hospitals, (2) the frequency with which patients were transferred to a nearby

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hospital with the lowest 30-day risk-standardized mortality rate (RSMR) for AMI, and (3) the relationship between a hospital's likelihood as a transfer destination and its 30-day risk-standardized mortality rate for AMI after accounting for geographic distances traveled.

### WHAT IS KNOWN

- Patients with acute myocardial infarction are frequently admitted to hospitals that lack the capacity for coronary revascularization, but little is known about the patterns of transfer.

### WHAT THE STUDY ADDS

- We examined nationwide Medicare data from 2006 and found that 44% of AMI patients admitted to nonrevascularization hospitals were transferred to a revascularization hospital.
- We found evidence of inefficiencies in the transfer system. For example, although patients were generally transferred to hospitals that had better 30-day risk-standardized mortality, for 36.8% of transfers another revascularization hospital with lower 30-day risk-standardized mortality was actually closer than the observed transfer destination.
- Our findings suggest that improving decision-making on transfers has the potential to substantially improve patient outcomes; focusing on where to transfer a patient may complement current efforts to optimize which patients with acute myocardial infarction should be transferred and when.

## Methods

### Data Sources and Study Population

In this retrospective cohort analysis, we analyzed all fee-for-service Medicare beneficiaries in the 2006 Medicare Provider Analysis and Review (MedPAR) files admitted with a primary diagnosis of AMI, as defined by an *International Classification of Diseases, 9th Revision—Clinical Modification* (ICD-9-CM) diagnostic code of 410.xx (excluding 410.x2). We excluded cases with a length of stay less than or equal to 1 day—unless that patient died, left against medical advice, or was transferred to another hospital—because such a short length of stay was likely to represent “rule-out” admissions and not true AMI.<sup>8</sup>

We empirically defined revascularization hospitals, as have others, as those that performed at least 5 coronary bypass grafting and percutaneous coronary intervention (PCI) procedures during the year; all others were considered nonrevascularization hospitals.<sup>9,10</sup> For this analysis, we included only patients initially admitted to nonrevascularization hospitals with at least 10 AMI admissions during the calendar year to allow more reliable estimates of our outcomes of interest. We specifically excluded patients from hospitals that performed PCI in Medicare patients but did not perform coronary bypass grafting because such facilities receive very few transfers from nonrevascularization hospitals and have distinct rationales for transferring out patients (eg, emergent coronary bypass grafting after PCI).

We obtained 30-day RSMRs and volume for AMI from each revascularization hospital using publicly-available data from 2006 on the Hospital Compare website.<sup>11,12</sup> The approach for calculating these rates and their validation (as compared with clinical chart abstraction) has been described elsewhere.<sup>13,14</sup> Briefly, the rates are

calculated from extensive Medicare inpatient and outpatient claims data using hierarchical regression models. Of relevance for this analysis, the approach used by Hospital Compare assigns AMI patients to the first hospital where they received care when calculating these rates, so as not to bias facilities accepting patients in transfer.<sup>15</sup> To ensure that our results were not susceptible to year-to-year fluctuations in 30-day risk-standardized mortality rates across hospitals, we also examined the use of rates from a 3-year period between July 2005 and June 2008 during sensitivity analysis.

We defined interhospital transfers as temporally adjacent hospitalizations in the same patient at 2 different facilities; the discharge day for the nonrevascularization hospital had to be the same or 1 day less than the admitting date of the revascularization hospital.<sup>16,17</sup> For each transfer, straight-line distances between the hospitals involved were calculated.<sup>18</sup> Additional data on geographic location and academic affiliation were obtained from the 2005 American Hospital Association Annual Survey.<sup>19</sup> For subgroup analyses, we defined hospitals as being an urban or rural facility using metropolitan statistical areas.

We limited our analyses to AMI patients at hospitals in the 50 states and the District of Columbia. We also excluded those patients treated at nonrevascularization hospitals with incomplete data on facility characteristics (n=18) and at revascularization hospitals with insufficient geographical information (n=8).

### Statistical Analysis

We graphed the nationwide interhospital network of transfers for AMI patients between nonrevascularization and revascularization hospitals in the United States during 2006 using ArcGIS software. In the network representation, hospitals are nodes, and the transfer of a patient from a nonrevascularization hospital to a revascularization hospital forms an edge.

To determine the relative importance of 30-day risk-standardized mortality rates and geographical proximity for a hospital, we used the McFadden discrete choice framework with a logistic regression implementation.<sup>20,21</sup> This model quantifies tradeoffs that are made between several competing alternatives, each of which has several measurable characteristics of value. In a general sense, it quantitatively asks the question: What characteristics of hospital A made it more likely to be chosen as a transfer destination than other nearby hospitals? For each patient, we compared the 30-day risk-standardized mortality of and distance to the revascularization hospital that was the final transfer destination with the outcomes of and distance to other revascularization hospitals that were competing alternatives for that transfer. Both distance and RSMR were continuous variables. This approach only compares characteristics of competing alternatives; as such, it takes into account the number of alternatives available from any given nonrevascularization hospital. We separately defined this set of competing alternatives to include all other revascularization hospitals within 25 and 100 miles of the nonrevascularization hospitals, as both are plausible distances over which transfers might be considered.

During sensitivity analyses, we replicated this last analysis in several important subgroups. First, we considered only patients with a primary diagnosis of AMI at both the nonrevascularization and revascularization hospitals. Second, we replicated the analysis separately for nonrevascularization hospitals located in urban and rural areas. Third, we evaluated several different radii within 25 miles and 100 miles of the nonrevascularization hospital to define our set of alternative revascularization hospitals. Further, we also controlled for the designation as better or worse than the national average in Hospital Compare, as well as hospital AMI volume and teaching status. Finally, we also evaluated the impact of using distance traveled from the patient's home (based on the centroid of his or her ZIP code) to the transfer destination to define the set of alternative revascularization hospitals.

We assessed the network's overall tendency to favor transfers to revascularization hospitals with lower 30-day risk-standardized mortality for AMI. To do so, we tested for a bivariate association between outcomes at a revascularization hospital and the number of nonrevascularization hospitals sending patients to that facility, after

dividing hospitals into quintiles based on the number of sending hospitals and using the Cuzick Wilcoxon-type nonparametric test for trend.<sup>22</sup> Using negative binomial regression, we asked whether revascularization hospitals with lower RSMR tended to receive more transfers, after adjusting for academic affiliation, urban/rural location, and region of the country defined by US Census division.<sup>23</sup> These analyses were conducted at the hospital level for all revascularization hospitals. For the negative binomial regression, we conducted and report parallel analyses with 2 dependent variables: the number of hospitals from which patients are transferred and the number of patients transferred in. This form of regression was used because the dependent variables were counts, as in Poisson regression; however, negative binomial regression allows for overdispersion in the counts.

To estimate the potential population impact of an optimized transfer system, we performed a Monte Carlo simulation in which each patient was transferred to the hospital with the lowest published RSMR within a given radius. The aggregate potential reduction in mortality was calculated as the sum, across all patients, of the difference between the RSMRs for the observed transfer destination and that of an optimized transfer destination. To incorporate the uncertainty in the actual RSMRs, we repeated each simulation after sampling the RSMR for both the observed and optimized destination from a probability distribution based on its 95% confidence intervals (CI). The differences in sampled RSMRs were then summed across all patients, and compared with the expected mortality (based on a mean 30-day risk-standardized mortality rate among all revascularization hospitals in the sample of 0.162, applied to the same population). The simulations were repeated 1000 times and the resultant numeric 95% CIs were reported. (A worked example with greater detail and sensitivity analyses is available from the authors on request.) This analysis assumes that the average mortality risk of transferred patients was the same as patients who were directly admitted; that no transfers were refused or provided lower-quality care due to capacity constraints<sup>24</sup>; that transfers were accomplished with the high level of safety currently observed<sup>25,26</sup>; and that revascularization hospitals provided the same outcomes of care to transferred patients as to directly admitted patients.

All analyses were conducted in Stata 10.<sup>27</sup> All regression standard errors were adjusted for potential clustering of AMI patients within a nonrevascularization hospital using Huber and White robust standard errors.

This research was reviewed and approved by the University of Michigan Institutional Review Board.

## Results

We identified 71 336 Medicare beneficiaries admitted with AMI at 1684 nonrevascularization hospitals in 2006. Of these, 31 607 (44.3%) were transferred to another hospital, with 30 875 (97.7% of transfers) directed to revascularization hospitals. The mean age of AMI Medicare beneficiaries who were transferred was 74.2 years; 87.6% were white, and 52.8% were men. The mean length of stay at the nonrevascularization hospital before transfer was 2.5 days (standard deviation: 3.0) with a median of 2 days. Nonrevascularization hospitals transferred AMI patients to a median of 3 different revascularization hospitals (interquartile range, 2 to 4), although 72.2% of patients were transferred to its most common destination facility. After arrival at the revascularization hospital, 19 513 (61.7%) patients underwent coronary revascularization with 14 452 (45.7%) receiving PCI.

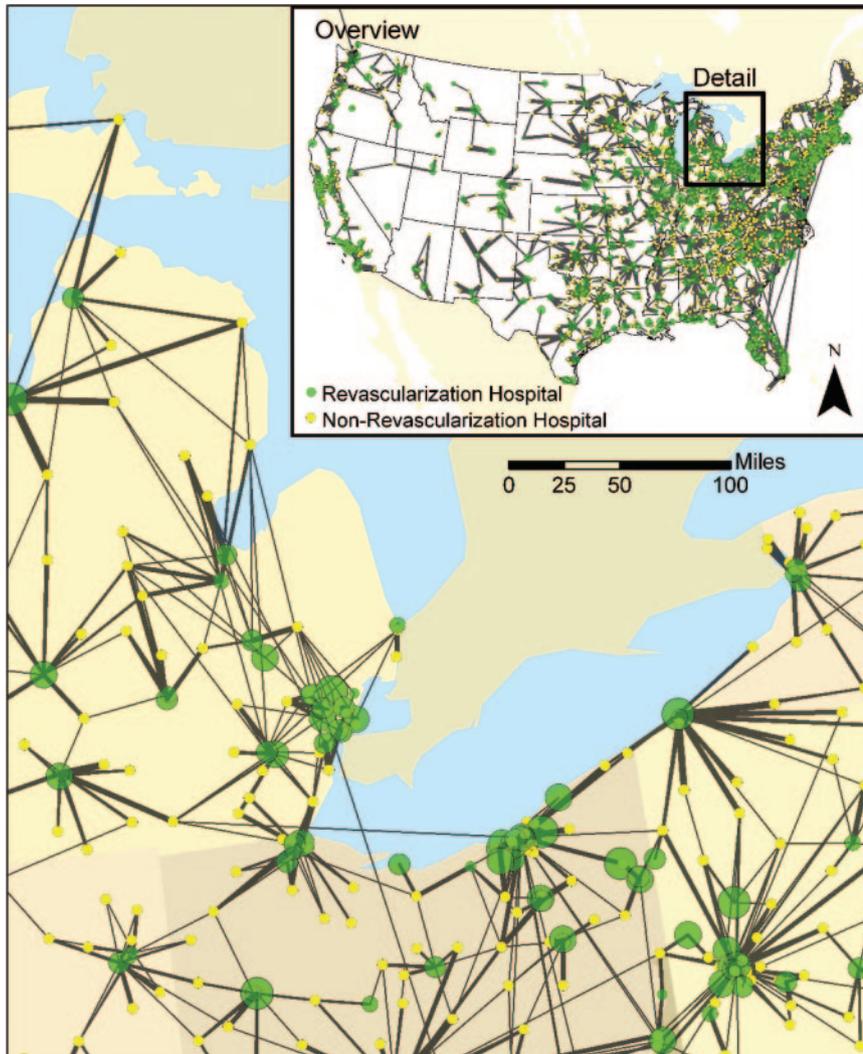
We constructed the 2006 nationwide interhospital network of transfers for AMI patients between nonrevascularization and the 1104 revascularization hospitals (Figure). The median distance patients traveled to a revascularization hospital was 26.7 miles (interquartile range, 11.6 to 46.7 miles). Overall,

48.2% of transfers were within 25 miles and 96.1% of transfers were within 100 miles. Transfers originating in rural areas traveled a median of 47.3 miles (interquartile range, 32.8 to 69.2 miles), whereas those originating in urban settings traveled a median of 13.9 miles (interquartile range, 6.6 to 25.0 miles). The median number of revascularization hospitals within 25 and 100 miles of each nonrevascularization hospital was 3 and 18, respectively.

When a patient is to be transferred, a potential destination hospital's proximity and 30-day risk-standardized mortality rates might both be taken into consideration. In 6.0% of cases, patients went to the nearest revascularization hospital, and that hospital also had the best 30-day risk-standardized mortality of all revascularization hospitals within 100 miles. In 45.8% of cases, patients bypassed a closer hospital to go to farther hospital that had a better 30-day risk standardized mortality rates. However, patients also frequently bypassed hospitals with better mortality outcomes to go to hospitals farther away. In 36.8% of cases, another revascularization hospital with lower 30-day risk-standardized mortality was actually closer to the original admitting nonrevascularization hospital than the observed transfer destination. In 27.2% of cases, another revascularization hospital was closer and had a 30-day risk-standardized mortality rate more than 1 percentage point better than the observed transfer destination. As Table 1 shows, patients were infrequently transferred to the hospital with the lowest 30-day risk-standardized mortality rate within any given radius.

Patients were transferred farther to go to a revascularization hospital with improved 30-day risk-standardized mortality when such an option was available. However, there appeared to be a trade-off between these 2 factors, and the additional distances traveled were small on average. In rural settings, each 1 percentage point improvement in 30-day risk-standardized mortality rate increased a revascularization hospital's odds of being the destination by 19% (95% CI, 13% to 26%), whereas being 10 miles closer doubled the odds of being chosen (odds ratio, 2.05; 95% CI, 1.94 to 2.18). In urban settings, proximity was even more important: Although each 1 percentage point improvement in its 30-day risk-standardized mortality rate increased its odds of being the destination by 16% (95% CI, 10% to 21%), being 10 miles closer nearly quadrupled the odds of being chosen (odds ratio, 3.87; 95% CI, 3.41 to 4.38).

The high value of proximity relative to observed 30-day risk-standardized mortality persisted when controlling for other characteristics of the revascularization hospital that have been associated with improved outcomes, such as total volume of AMI patients and teaching status (Table 2). Still, high-volume hospitals and teaching hospitals (particularly in rural areas) were more likely to be destinations than other equally close hospitals, showing that these factors were not ignored. In sensitivity analyses, very similar results were obtained when considering distance traveled from the patient's home ZIP code rather than from the nonrevascularization hospital initiating the transfer. Likewise, substantively identical results were obtained when using the 30-day risk standardized mortality rates for 2005 to 2008, or when



**Figure.** Transfers of AMI patients from nonrevascularization hospitals. This map shows transfers of patients from nonrevascularization hospitals (yellow) to revascularization hospitals (green). The thickness of the lines is proportional to the number of transfers between the hospitals. The diameter of the markers for revascularization hospitals is inversely proportional to their 30-day risk-standardized mortality, with hospitals with better outcomes having larger diameters.

controlling for a hospital's designation as better or worse than the national average in Hospital Compare.

Despite the apparent high value placed on proximity, revascularization hospitals with lower 30-day mortality measures received more transfers. Revascularization hospitals varied substantially in the number of nonrevascularization hospitals that sent them transfers (Table 3): 147 (13.3% of 1104) received no transfers, whereas 49 (4.4%) hospitals received transfers from 15 or more other hospitals. Revascularization hospitals with lower 30-day risk-standardized

mortality rates, in general, received transfers from more hospitals. After adjusting for academic affiliation, urban/rural location and region of the country, a 1% lower 30-day risk-standardized mortality rate was associated with a 6.5% increase in the number of hospitals from which transfers were received ( $P < 0.001$ ). Similarly, revascularization hospitals with better outcomes also received more total AMI patients in transfer.

To contextualize these results, we simulated the potential impact of a system that optimized patient transfers exclu-

**Table 1. Fraction of Transfers That Are to the Revascularization Hospital With Best Outcomes Within Different Radii Around Non-PCI Admitting Hospital: Unadjusted Counts and Fractions Are Presented**

Radius (Miles)	Observed Transfers	Percent of All Transfers That Were Within Radius	Percent to Best	Percent to Within 0.5 Percentage Points of Best*	Percent to Within 1.0 Percentage Points of Best*
100	29 654	93.8%	13.1%	15.5%	20.0%
75	28 264	89.4%	17.7%	21.1%	28.3%
50	24 029	76.0%	24.9%	30.3%	38.9%
25	14 883	47.1%	41.1%	44.1%	51.4%

\*The 0.5 refers to a one-half percentage point of the best 30-day risk-adjusted mortality rate of any revascularization hospital within the given radius, and 1.0 refers to within 1 percentage point of the best. These columns are not exclusive; all patients transferred to the best were, by definition, also transferred to a hospital within 1.0 of best.

**Table 2. Association Between Destination Hospital Characteristics and Their Odds of Being a Transfer Destination**

	Odds Ratio	95% CI		Odds Ratio	95% CI	
<b>Urban hospitals</b>						
Proximity (per 10 miles closer to nonrevascularization hospital)	3.87	3.41	4.38	3.94	3.48	4.46
30-Day risk-standardized mortality (per 1% absolute improvement)	1.16	1.10	1.21	1.07	1.02	1.12
AMI volume (per 100 patients)				1.67	1.55	1.80
Hospital residency program (vs not)				1.10	0.88	1.37
Affiliated with medical school				1.18	0.93	1.51
Member of the Council of Teaching Hospitals				1.20	1.00	1.43
<b>Rural hospitals</b>						
Proximity (per 10 miles closer to nonrevascularization hospital)	2.05	1.94	2.18	2.22	2.09	2.36
30-Day risk-standardized mortality (per 1% absolute improvement)	1.19	1.13	1.26	1.05	0.99	1.11
AMI volume (per 100 patients)				2.11	1.91	2.32
Hospital residency program (vs not)				1.60	1.23	2.09
Affiliated with medical school				0.96	0.73	1.25
Member of the Council of Teaching Hospitals				1.85	1.51	2.25

These odds ratios are from a McFadden discrete choice model, implemented with conditional logistic regression. Characteristics of the revascularization hospital that received each transfer are compared with those of all other revascularization hospitals within 100 miles of the sending nonrevascularization hospital.

sively on the basis of 30-day risk-standardized mortality rates (Table 4). In the baseline case, an optimized system that always transferred patients to the lowest 30-day mortality hospital within 100 miles might reduce absolute mortality 2.7 percentage points (95% CI, 2.6 to 2.7 percentage points), a relative reduction of 16.5% at 30 days after AMI (95% CI, 16.3% to 16.8%). An optimized system that never transferred patients farther than they were currently transferred and never more than 100 miles might reduce absolute mortality by 0.78 percentage points (95% CI, 0.77 to 0.80 percentage points), a relative reduction of 4.8% (95% CI, 4.7% to 5.0%) while also reducing travel time. Table 4 shows the extent to which an optimized transfer system might offer meaningful reductions in 30-day AMI mortality as the maximum transfer distance is varied.

**Table 3. Association Between Number of Hospitals From Which Transfers Are Received and 30-Day Risk-Standardized Mortality Rate Across Quintiles of Revascularization Hospitals**

No. of Hospitals From Which Transfers Are Received	No. of Revascularization Hospitals	30-Day Mortality Rate	Standard Deviation of Mortality Rate
0 to 1	309	16.39	1.57
2	155	16.51	1.65
3 to 4	257	16.22	1.64
5 to 7	188	16.01	1.55
8 to 39	195	15.67	1.84

For ease of display, hospitals are divided into quintiles based on the number of hospitals from which transfers were received. Groups are divided as evenly as possible given the clumping of hospitals receiving few transfers. The Cuzick Wilcoxon-type nonparametric test for trend was  $P < 0.001$  across groups.

## Discussion

More than 40% of elderly Medicare beneficiaries with AMI who are admitted at hospitals without revascularization are ultimately transferred to revascularization hospitals during their hospitalization. We find evidence that these patients are preferentially transferred toward hospitals with lower 30-day risk-standardized mortality rates, but that this pattern of movement between facilities with different levels of services provided may be suboptimal. For example, only a minority of patients are transferred and of those transferred, many are transferred to revascularization hospitals with higher mortality rates than other revascularization hospitals within similar distances. Indeed, more than one third of patients had a revascularization hospital that was both closer and with better outcomes than the observed destination. This suggests that in general, optimizing the transfer process might result in clinically meaningful improvements in patient outcomes.

Past work has examined the characteristics of patients most likely to be transferred; ours is the first study to examine the system-level patterning of those transfers.<sup>16,17</sup> For example, an analysis of the CRUSADE initiative showed that 46.1% of patients with non-ST elevation acute coronary syndromes were transferred to revascularization centers from community hospitals.<sup>28</sup> Further, lower-risk patients appear to be preferentially transferred early in their hospital course. These findings reinforce the pattern noted in 1994 to 1995 data on Medicare beneficiaries from the Cooperative Cardiovascular Project within Michigan.<sup>2</sup> Claims data lack the clinical granularity to reexamine the appropriateness of any given decision to transfer or not. Instead, our data raise the

**Table 4. Potential Impact of Optimized Transfer on 30-Day Mortality**

Radius (Miles)	Observed Transfers	Percent of All Transfers That Were Within Radius	Optimized Transfer Potential Reduction in Mortality (95% CI)	
			Relative	Absolute
100	29 654	93.8%	16.5% (16.3–16.7)	2.7% (2.6–2.7)
75	28 264	89.4%	14.4% (14.2–14.6)	2.3% (2.3–2.4)
50	24 029	76.0%	11.9% (11.7–12.1)	1.9% (1.9–2.0)
25	14 883	47.1%	9.4% (9.2–9.6)	1.5% (1.5–1.6)
No further than observed and within 100 miles*	29 654	93.8%	4.8% (4.7–5.0)	0.78% (0.77–0.80)

The potential reductions in mortality are the summed differences between risk-standardized mortality rate of the observed transfer destination and a system that always transferred a patient to the revascularization hospital with the lowest 30-day risk-standardized mortality. Please see text for a discussion of the important simplifying assumptions used to generate these estimates. 95% CIs take into account the uncertainty about actual RSMRs of observed and optimized transfer hospitals, using 1000 Monte Carlo simulations.

\*The restriction to within 100 miles is based on the assumption that longer range transfers may occur for idiosyncratic reasons; the inclusion of such transfers might inappropriately bias the potential benefits upward.

possibility that patients often bypass nearby revascularization hospitals with better outcomes, once the decision to transfer has been made. Future studies will need to evaluate how the decision to transfer is initiated, how patients are selected, and what processes are in place for determining the destination.

There are several potential reasons why patients may not be transferred to nearby revascularization hospitals with the best outcomes. First, logistical barriers as the result of bed occupancy or physician availability may prevent a revascularization hospital from accepting patients at the moment a transfer is needed. Timeliness of revascularization is an essential part of the care of AMI patients, and, theoretically, better hospitals must be available when transfers are required. Second, the choice of transfer destination may be a routine rather than conscious decision for any particular patient. More than 70% of transfers from nonrevascularization hospitals went to a single revascularization hospital, suggesting well-established relationships between facilities. These relationships may be driven by the presence of supplemental insurance or by corporate relationships between hospitals that send and receive patients; however, our evidence emphasizes that such nonclinical issues may have clinical consequences for patients, who may not be sent to the best available facility.

Third, publicly available information on hospital performance in AMI patients may not have been available for a sufficient time to patients and providers. Data from Hospital Compare used in this analysis have only recently become available and may not have become incorporated into these decisions by 2006. However, the impact of public information about the quality of healthcare providers has not been substantial to date.<sup>29–31</sup> Fourth, it is possible that providers and patients considered the individual “rankings” of hospital performance in Hospital Compare unreliable even when they were familiar with the information. Finer grain information that allows individuals to make reliable decisions is urgently needed to change these population-level outcomes.

Finally, another important possibility is that patients might highly value proximity of care relative to outcomes even if these other challenges were resolved.<sup>32</sup> In a recent survey of AMI patients who had been transferred for primary PCI in the

setting of ST elevation, more than 15% of respondents responded that they would have preferred receiving care locally despite the potential mortality benefits associated with transfer.<sup>33</sup> Efforts to optimize the care of patients need to consider strategies to minimize the psychological distress associated with transfer while achieving the best outcomes possible.<sup>34</sup>

Despite these multiple barriers, there is evidence that current patterns of transfer at least partially consider hospital performance. We observe that on average hospitals with better outcomes received more patients from more hospitals. More reliable and accessible information might take advantage of these decentralized mechanisms, potentially if coupled to incentives to optimize outcomes. Linking accountability for transfers back to the nonrevascularization hospital could also be helpful, a practice that is already in place through the publicly reported data from Hospital Compare, in which 30-day AMI mortality rates for nonrevascularization hospitals include patients who were ultimately transferred to a revascularization hospital. There may be a role for individual physicians and hospitals to view their own referral practices through a quality-improvement lens, independent of any system-level reform to improve transfers.

This empirical work has several limitations that should be kept in mind. First, we studied transfer patterns within Medicare and after hospital admission. Other insurers may actively shape transfers to meet different clinical or economic objectives. Similarly, our analyses do not address transfers that occur between emergency departments before hospital admission. Second, we lacked detailed clinical information to evaluate whether the decision to transfer was “right” or “optimal” for particular patients. Medicare claims did not allow for us to reliably determine why more than 50% of AMI patients were not transferred, nor to distinguish ST-segment-elevation MI and non-ST-segment-elevation MI. For some patients, this may be due to patient and family preference to undergo noninvasive stress testing or advanced comorbidities or other relative contraindications to cardiac catheterization or revascularization. Some have even suggested that sicker patients may be less likely to be transferred from community

hospitals to academic centers.<sup>2,28</sup> However, these issues are beyond the scope of our work. Our primary goal was to evaluate where patients were directed after the decision for transfer had been made. Third, the 30-day risk-standardized mortality for a specific hospital is a point estimate with a 95% CI. Comparing the decision to transfer a given patient between 2 specific hospitals is not possible from this analysis. Instead, we focused on the patterns of transfer from a population-level perspective, which is more critical for policymakers. We also accounted for uncertainty in estimates of a hospital's 30-day risk-standardized mortality in our Monte Carlo simulations. Finally, we assumed that revascularization hospitals perform as well for transferred patients as they do for patients directly admitted with AMI; in theory, some hospitals might perform disproportionately better in one or the other population. Indeed, some decision-makers may prefer to focus on outcomes other than mortality, such as a risk-stratified readmission rate or other process measures; it would be valuable if our work were replicated with other measures. Future work explicitly measuring the care provided to transfer patients may be of substantial benefit in guiding policy and clinical decision-making on this important issue.

### Conclusion

The transfer of patients to revascularization hospitals is a frequent part of the care of AMI patients at nonrevascularization hospitals. Although revascularization hospitals with lower 30-day risk-standardized mortality rates receive more of these transfers, many patients are not directed toward local hospitals with the best outcome rates. Consequently, efforts to systematically improve these transfer decisions, both at the level of the health systems and individual referring physicians, may represent an important opportunity to positively affect outcomes for patients with AMI.

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### Disclosures

None.

### References

- Keeley EC, Grines CL. Primary percutaneous coronary intervention for every patient with ST-segment elevation myocardial infarction: what stands in the way? *Ann Intern Med.* 2004;141:298–304.
- 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;138:688–695.
- Grines CL, Westerhausen DR Jr, Grines LL, Hanlon JT, Logemann TL, Niemela M, Weaver WD, Graham M, Boura J, O'Neill WW, Balestrini C. A randomized trial of transfer for primary angioplasty versus on-site thrombolysis in patients with high-risk myocardial infarction: the Air Primary Angioplasty in Myocardial Infarction study. *J Am Coll Cardiol.* 2002;39:1713–1719.
- Cantor WJ, Fitchett D, Borgundvaag B, Ducas J, Heffernan M, Cohen EA, Morrison LJ, Langer A, Dzavik V, Mehta SR, Lazzam C, Schwartz B, Casanova A, Goodman SG. Routine early angioplasty after fibrinolysis for acute myocardial infarction. *N Engl J Med.* 2009;360:2705–2718.
- Cannon CP, Weintraub WS, Demopoulos LA, Vicari R, Frey MJ, Lakkis N, Neumann FJ, Robertson DH, DeLuca PT, DiBattiste PM, Gibson CM, Braunwald E. 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;344:1879–1887.
- Anderson JL, Adams CD, Antman EM, Bridges CR, Califf RM, Casey DE, Chavey WE II, Fesmire FM, Hochman JS, Levin TN, Lincoff AM, Peterson ED, Theroux P, Wenger NK, Wright RS, Smith SC Jr, Jacobs AK, Adams CD, Anderson JL, Antman EM, Halperin JL, Hunt SA, Krumholz HM, Kushner FG, Lytle BW, Nishimura R, Ornato JP, Page RL, Riegel B. 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. *J Am Coll Cardiol.* 2007;50:e1–e157.
- Krumholz HM, Normand S-LT, Spertus JA, Shahian DM, Bradley EH. Measuring performance for treating heart attacks and heart failure: the case for outcomes measurement. *Health Affairs.* 2007;26:75–85.
- Epstein AJ, Rathore SS, Krumholz HM, Volpp KG. Volume-based referral for cardiovascular procedures in the United States: a cross-sectional regression analysis. *BMC Health Serv Res.* 2005;5:42.
- Magid DJ, Calonge BN, Rumsfeld JS, Canto JG, Frederick PD, Every NR, Barron HV, for the National Registry of Myocardial Infarction 2 and 3 Investigators. Relation between hospital primary angioplasty volume and mortality for patients with acute MI treated with primary angioplasty vs thrombolytic therapy. *JAMA.* 2000;284:3131–3138.
- Nallamothu BK, Young J, Gurm HS, Pickens G, Safavi K. Recent trends in hospital utilization for acute myocardial infarction and coronary revascularization in the United States. *Am J Cardiol.* 2007;99:749–753.
- U.S. Department of Health and Human Services. Hospital Compare. *Centers for Medicare and Medicaid Services.* Available at: www.hospitalcompare.hhs.gov.
- Ross JS, Normand SL, Wang Y, Ko DT, Chen J, Drye EE, Keenan PS, Lichtman JH, Bueno H, Schreiner GC, Krumholz HM. Hospital volume and 30-day mortality for three common medical conditions. *N Engl J Med.* 2010;362:1110–1118.
- Krumholz HM, Normand S-LT. Public reporting of 30-day mortality for patients hospitalized with acute myocardial infarction and heart failure. *Circulation.* 2008;118:1394–1397.
- Krumholz HM, Wang Y, Matterna JA, Wang Y, Han LF, Ingber MJ, Roman S, Normand S-LT. An administrative claims model suitable for profiling hospital performance based on 30-day mortality rates among patients with an acute myocardial infarction. *Circulation.* 2006;113:1683–1692.
- Rosenberg AL, Hofer TP, Strachan C, Watts CM, Hayward RA. Accepting critically ill transfer patients: adverse effect on a referral center's outcome and benchmark measures. *Ann Intern Med.* 2003;138:882–890.
- Iwashyna TJ, Christie JD, Kahn JM, Asch DA. Uncharted paths: hospital networks in critical care. *Chest.* 2009;135:827–833.
- Iwashyna TJ, Christie JD, Moody J, Kahn JM, Asch DA. The structure of critical care transfer networks. *Med Care.* 2009;47:787–793.
- Sinnott RW. Virtues of the Haversine. *Sky Telescope.* 1984;68:159.
- American Hospital Association. *American Hospital Association Annual Survey Database for Fiscal Year 2005.* Chicago: American Hospital Association; 2005.
- Allison PD. *Logistic Regression Using the SAS System: Theory and Applications.* Cary, NC: SAS Institute; 1999.
- Hoffman SD, Duncan GJ. Multinomial and conditional logit discrete-choice models in demography. *Demography.* 1988;25:415–427.
- Cuzick J. A Wilcoxon-type test for trend. *Stat Med.* 1985;4:87–90.
- Gelman A, Hill J. *Data Analysis Using Regression and Multi-level/Hierarchical Models.* New York: Cambridge University Press; 2007.

24. Iwashyna TJ, Kramer AA, Kahn JM. Intensive care unit occupancy and patient outcomes. *Crit Care Med*. 2009;37:1545–1557.
25. Singh JM, MacDonald RD, Bronskill SE, Schull MJ. Incidence and predictors of critical events during urgent air–medical transport. *CMAJ*. 2009;181:579–584.
26. Fan E, McDonald RD, Adhikari NKJ, Scales DC, Wax RS, Stewart TE, Ferguson ND. Outcomes of interfacility critical care adult patient transport: a systematic review *Crit Care*. 2006;10:R6.
27. StataCorp. *Stata Statistical Software: Release 10.1*. College Station, Tex: Stata Corporation; 2009.
28. Roe MT, Chen AY, DeLong ER, Boden WE, Calvin JE Jr, Cairns CB, Smith SC Jr, Pollack CV Jr, Brindis RG, Califf RM, Gibler WB, Ohman EM, Peterson ED. Patterns of transfer for patients with non-ST-segment elevation acute coronary syndrome from community to tertiary care hospitals. *Am Heart J*. 2008;156:185–192.
29. Schneider EC, Epstein AM. Use of public performance reports: a survey of patients undergoing cardiac surgery. *JAMA*. 1998;279:1638–1642.
30. Schwartz LM, Woloshin S, Birkmeyer JD. How do elderly patients decide where to go for major surgery? Telephone interview survey. *BMJ*. 2005; 331:821.
31. Schoenberg NE, Amey CH, Stoller EP, Muldoon SB. Lay referral patterns involved in cardiac treatment decision making among middle-aged and older adults. *Gerontologist*. 2003;43:493–502.
32. Finlayson SR, Birkmeyer JD, Tosteson AN, Nease RF Jr. Patient preferences for location of care: implications for regionalization. *Med Care*. 1999;37:204–209.
33. Henry J, Lindsay B, Menssen K, Christiansen E, Unger B, Larson D, Henry T. Impact of emergent transfer for percutaneous coronary intervention on ST-elevation myocardial infarction patients and their families. *J Am Coll Cardiol*. 2009;53:A374.
34. Tel H, Tel H. The effect of individualized education on the transfer anxiety of patients with myocardial infarction and their families. *Heart Lung*. 2006;35:101–107.

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