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Differences in hospital risk-standardized mortality rates for acute myocardial infarction when assessed using transferred and non-transferred patients

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Abstract

Background—One in five patients with acute myocardial infarction (AMI) are transferred between hospitals. However, current hospital performance measures based on AMI mortality exclude these patients from the evaluation of referral hospitals.

Objective—To determine the relationship between risk-standardized mortality for transferred and non-transferred patients at referral hospitals.

Research Design—Retrospective cohort study

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Subjects—Fee-for-service Medicare claims from 2011 for patients hospitalized with a primary diagnosis of AMI, at hospitals admitting at least 15 patients in transfer

Measures—Hospital-specific risk-standardized 30-day mortality rates (RSMRs) for two groups of patients: those admitted via transfer from another hospital, and those natively admitted without a preceding or subsequent inter-hospital transfer

Results—There were 304 hospitals admitting at least 15 patients in transfer. These hospitals cared for 77,711 natively admitted patients (median 254, IQR [162–321]), and 11,829 patients admitted in transfer (median 26, IQR [19–46]). Risk-standardized mortality rates were higher for natively admitted patients than for those admitted in transfer (mean $11.5\% \pm 1.2\%$ vs. $7.2\% \pm 1.1\%$). There was weak correlation between hospital performance as assessed by RSMR for patients natively admitted vs. those admitted in transfer (Pearson's $r=0.24$, $p<0.001$); **when performance was arrayed by quartile**, 102 hospitals (33.6%) **differed** at least two quartiles of performance across the two patient groups.

Conclusions—For Medicare patients with AMI, hospital-specific RSMRs for natively admitted patients are only weakly associated with RSMRs for patients transferred in from another hospital. Current AMI performance metrics may fail to provide guidance about hospital quality for transferred patients.

Keywords

Acute MI; Health Services; Hospital Quality; Mortality; Performance Measurement

INTRODUCTION

Hospital performance on publicly reported quality measures is of increasing importance to clinicians, health care administrators, and health policy makers. Most current hospital-based performance metrics, including Centers for Medicare and Medicaid Services (CMS) metrics for patients with acute myocardial infarction (AMI), attribute outcomes for patients who undergo interhospital transfer to the transferring hospital; these patients are excluded from the performance metrics of the referral hospital that receives the patient.^{1–3} As a consequence, current benchmarking approaches do not provide insight into the quality of care that a hospital provides to patients admitted in transfer, particularly given the evidence for differences in time to reperfusion⁴ and mortality between directly admitted and transferred patients.⁵ Understanding hospital performance for transferred patients is important because they represent up to 18% of all AMI patients, a proportion that is increasing over time.⁶ Hospital performance for these patients is also important for public reporting programs, since publicly reported quality data are meant, in part, to steer transfers to high quality referral hospitals and incentivize internal quality improvement efforts.^{7–10}

To the extent that performance is different for patients admitted natively and patients admitted in transfer, current metrics may therefore fail to provide adequate information to patients, clinicians and policy makers seeking to identify referral hospitals providing high quality tertiary care to patients with AMI. Indeed, despite early evidence that different methods of accounting for hospital transfers yields different conclusions about hospital performance rankings,¹¹ the choice to assign outcomes to pre-transfer hospitals rather than

referral hospitals remains an under-studied aspect of health policy. To better understand this issue, we examined the relationship between referral hospital performance as assessed by risk-standardized 30-day mortality for two groups of patients with AMI: those natively admitted to referral hospitals and those admitted to referral hospitals in transfer from another acute care hospital.

METHODS

Study Design and Data Sources

We conducted a retrospective comparative cohort study using patient-level claims data from the 2011 Medicare Provider Analysis and Review (MedPAR) file. MedPAR contains detailed demographic and billing information for individual hospitalizations for Medicare fee-for-service beneficiaries. Using unique Medicare provider identifiers, we linked patient-level data from MedPAR to hospital-level data from Medicare's Healthcare Cost Reporting Information System (HCRIS) to obtain hospital-level characteristics.

Patients

We identified all hospitalizations for patients age 65 or older discharged between January 1, 2011 and December 31, 2011 with a principal diagnosis of AMI using previously validated International Classification of Diseases, Ninth Edition, Clinical Modification (ICD-9-CM) diagnosis codes.¹ Among these hospitalizations we defined interhospital transfers as instances when a patient was discharged from one hospital on a given day and admitted to a different hospital on the same day or the subsequent day, and for which both hospitalizations were for AMI, as previously performed.^{12,13} We defined "natively admitted" patients as those that were not admitted in transfer from another institution. These patients are currently the subject of existing CMS performance measures. We defined "admitted in transfer" patients as those admitted in transfer from another institution. These patients are currently excluded from existing CMS performance measures in the evaluation of referral hospitals.

We included only short-stay hospitals, which could either be general hospitals or specialty hospitals, because short-stay cardiology specialty hospitals were likely to care for a significant number of patients transferred with AMI. We excluded hospitals with fewer than 15 hospitalizations for patients admitted in transfer, in order to restrict our analysis to the referral hospitals for which this research question primarily applies and to reduce random variation from unreliably small sample sizes. In practice this also restricted our analysis to those hospitals with at least 15 natively admitted patients, as there were not any hospitals with more than 15 transferred patients and fewer than 15 natively admitted patients. In the event of multiple episodes of care for a given patient, we selected the first episode, to reduce the influence of **observed prior** hospitalizations for AMI on the transfer decisions and outcomes, and to maintain independence of observations. We included only the claims at post-transfer destination hospitals, excluding claims for pre-transfer stays at outside hospitals, because our analysis is focused on outcomes of patients at referral hospitals.

Variables

The primary outcome variable was hospital-specific risk-standardized 30-day mortality from the date of hospital admission. We obtained death dates from the Medicare Beneficiary Summary File. To control for variation in baseline risk we designed a risk-adjustment strategy analogous to that used in the current CMS performance measure for AMI mortality; the primary difference is that we did not have access to outpatient data and therefore used Elixhauser comorbidities from inpatient claims rather than the hierarchical condition category (HCC) schema. Variables for risk-adjustment included age, sex, comorbidities in the manner of Elixhauser,¹⁴ history of prior percutaneous coronary intervention (PCI) or coronary artery bypass grafting (CABG), presence of anterior MI, and presence of inferolateral or posterior MI.¹

Analysis

Descriptive analyses—To characterize the cohort, we examined demographic and clinical characteristics for the two groups of patients: those natively admitted to a referral hospital, and those admitted in transfer. We did not test significance of differences in demographic or clinical characteristics, because the size of the cohort was likely to indicate statistical significance even for small but clinically non-meaningful differences. We calculated the median and interquartile range of the absolute number and proportion of patients admitted in transfer.

Calculating hospital-specific risk-adjusted mortality rates—We used hierarchical logistical regression to generate hospital-specific risk-standardized 30-day mortality rates (RSMR). The RSMR is the ratio of predicted to expected mortality and is both *risk* and *reliability* adjusted. In lower-volume hospitals, where small changes in the absolute number of patients can create instability in the absolute mortality estimates, the RSMR “shrinks” the mortality rate toward the population mean. Conversely, for hospitals with large numbers of patients and for which performance estimates are more reliable, the RSMR approximates conventional risk-adjusted mortality rates. This approach is common in the current benchmarking literature and is identical to the approach CMS uses in its hospital pay-for-performance programs.^{1,12,13}

To generate hospital-specific RSMRs, we fit a random-effects logistic regression model (Equation 1) for patient i in hospital j , in which the dependent variable Y_{ij} was 30-day mortality, and the independent variables $x_{1i}-x_{ni}$ were age (as quadratic splines), sex, comorbidities (as indicator covariates), history of PCI, history of CABG, location of MI (as indicator covariates). **To estimate standard errors, we used bootstrapping with replacement to account for patient clustering at the hospital level.**¹⁵

$$\text{logit}(Y_{ij}) = \beta_1 x_{1i} \dots \beta_n x_{ni} + (\mu + \omega_j) \quad \text{Equation 1}$$

In this model, $\beta_1-\beta_n$ are the coefficients for the independent variables, μ is the mean intercept across all patients, and ω_j is the hospital-specific random intercept term, which accounts for clustering of patients at the hospital level. We calculated expected probability of

mortality for patients within each hospital by using the mean value across all hospitals as the common intercept (μ). Thus, the expected mortality rate is the number of deaths expected if patients with the same characteristics were treated at a “reference” hospital. Next, we calculated predicted probability of mortality for patients within each hospital by estimating the hospital-specific mean from the random-intercept model ($\mu + \omega_j$). Thus, the predicted mortality rate is based upon observed patient characteristics and **estimated** hospital-level **random effects**. Finally, we calculated RSMRs for each hospital as the ratio of predicted to expected mortality multiplied by the national average for the cohort. We performed this analysis separately for natively admitted patients and those admitted in transfer, yielding two unique RSMRs for each hospital. We evaluated the discriminative power of the models using the area under the receiver-operator curve.

Comparing performance assessment across patient groups—To determine the degree to which RSMR for natively admitted patients is associated with RSMR for transferred patients, and thus provides similar information regarding hospital performance, we assessed both the correlation in RSMRs and agreement in hospital rankings by RSMR. We used Pearson’s correlation coefficient to assess the linear relationship between RSMR for natively admitted patients and RSMR for transferred patients. We categorized hospitals by quartile for RSMR for the two groups of patients and determined the number of hospitals that moved up or down at least two quartiles between the groups. These hospitals were therefore in the top quartile of performance for one group and below the median for the other, or in the bottom quartile of performance for one group and above the median for the other group. We also assessed the agreement in ranking using a standard weighted kappa statistic to account for multiple quartiles.

Characteristics of Hospitals with Concordant and Discordant Performance—We next examined characteristics of hospitals with similar performance for patients admitted in transfer and natively admitted patients, in comparison with those hospitals with discordant performance across the two groups of patients. We defined hospitals with “discordant performance” as those that moved up or down at least two performance quartiles between natively admitted patients and those admitted in transfer. We considered separately those hospitals with comparatively higher performance for natively admitted patients and those hospitals with comparatively higher performance for patients admitted in transfer. We defined hospitals with “similar performance” across the patient groups as all others—i.e. those hospitals in the same performance quartile, as well as those that moved up or down only a single quartile of performance. We obtained hospital characteristics from HCRIS, including total beds and hospital metropolitan statistical area (MSA) size—as well as MedPAR, including the number of AMI hospitalizations per hospital and the number of AMI patients undergoing PCI and CABG. We compared these hospital characteristics across the three hospital groups using Kruskal-Wallis testing for non-parametric distributions, adjusted for multiple comparisons.

Sensitivity Analysis—We conducted a sensitivity analysis in which we calculated the RSMR for transferred patients adjusting for the length of stay in the transferring hospital prior to transfer, because a delay in transfer and definitive management can influence

outcomes for patients with AMI,¹⁶ and it is possible that patients with varying duration of pre-transfer hospitalization represented fundamentally different patient populations.

We performed all analyses using SAS version 9.0 (Carey, NC) and STATA version 14.0 (College Station, TX). The use of de-identified patient-data for this study was reviewed and approved by the University of Pittsburgh Office of Human Research Protections (PRO11070007).

RESULTS

Patient and Hospital Selection and Characteristics

Out of 4,207 hospitals, 304 (7.2%) had at least 15 patients natively admitted and admitted in transfer and were included in the primary analysis. Within these hospitals, there were 77,711 natively admitted patients (median per hospital 232, interquartile range [162–321]), and 11,829 patients admitted in transfer (median per hospital 26, IQR [19–46]). The cohort selection flow diagram is depicted in Figure 1. There was variation among included hospitals in both the volume and the proportion of AMI patients who were natively admitted vs. admitted in transfer (median proportion of patients admitted in transfer 11.0%, IQR 7.9%–17.2%).

Characteristics of natively admitted and transferred patients are shown in Table 1. In comparison with natively admitted patients, patients admitted in transfer had a similar age and sex distribution. Transferred patients were more likely to have a history of prior PCI (6.1% vs. 3.2%) and to undergo CABG surgery (21.6% vs. 10.2%). Rates of PCI during admission were similar (47.5% vs. 46.3%). Transferred patients were less likely to have an anterior MI (5.0% vs. 9.7%) or to require ICU admission (71.6% vs. 75.3%), and had a lower unadjusted 30-day mortality rate (7.2% vs. 11.5%).

Comparison of Hospital Performance

Our risk-adjustment models had good discriminative power, with c-statistics of 0.74 for natively admitted patients and 0.72 for patients admitted in transfer. Based on these models there was a statistically significant but weak correlation between hospital RSMRs for natively admitted patients and those admitted in transfer (Pearson's $r=0.24$, $p<0.001$, Figure 2). Out of the total 304 hospitals included in the analysis, 102 (33.6%) moved up or down at least two quartiles of performance, and 30 hospitals (9.9%) moved three performance quartiles across the two groups of patients. The complete distribution of performance quartiles and changes is shown in Table 2. Overall, there was very poor agreement for hospital ranking by RSMR for natively admitted and transferred patients (weighted kappa = 0.09, $p=0.01$).

Examination of Hospitals with Discordant Performance

Of the 102 hospitals moving at least two quartiles of performance, 50 hospitals (16.4% of the total number of hospitals) had comparatively lower ranks for natively admitted patients and 52 hospitals (17.1%) had comparatively lower ranks for patients admitted in transfer. We categorized the 202 remaining hospitals as having similar performance for the two patient

groups. Hospitals with similar performance across natively admitted and transferred patients were slightly larger and cared for more AMI patients than those with discordant performance. There were no other major differences between groups, nor were any of the differences statistically significant when adjusted for multiple comparisons (Table 3).

Sensitivity Analysis

When we included length of stay at the transferring hospital as a covariate, the results did not change. There remained a statistically significant but weak association between hospital RSMRs for natively admitted patients and those admitted in transfer (Pearson's $r=0.25$, $p<0.0001$). There were again 50 hospitals with comparatively lower ranks for natively admitted patients and 52 hospitals with comparatively lower ranks for patients admitted in transfer.

DISCUSSION

In a national study of elderly patients with acute myocardial infarction we found little correlation between risk-standardized mortality for natively admitted patients and risk-standardized mortality for patients admitted in transfer. Additionally, there was very poor agreement in hospital ranking by RSMR for these two patient groups—hospitals that had relatively low risk-standardized mortality for one group of patients often had relatively high risk-standardized mortality for the other group of patients. These findings suggest that the current practice of attributing outcomes for patients admitted in transfer to the transferring, rather than referral hospital, results in performance assessments that do not provide insight about the quality of care for patients after interhospital transfer for AMI.

Our results suggest that the domains of quality differ between transferred and natively admitted AMI patients. It is likely that natively admitted patients benefit primarily from speedy reperfusion and early administration of beta-blockade;^{16–19} while transferred patients benefit primarily from prevention of iatrogenic injury (such as infections) and late postoperative complications.^{20–22} There is not a reason that these different domains of quality necessarily track together, potentially leading to the finding of discordant performance for natively admitted patients and those admitted in transfer. Indeed, prior research in other fields demonstrates disparate performance by the same providers caring for different groups of patients.^{23,24} Quality measurement and performance benchmarking are integral to value based purchasing and other quality-focused health policies,^{25–29} underscoring the importance of accounting for the impact of interhospital transfers on hospital performance.

Our results also highlight potential flaws in quality improvement programs that depend on accurate performance assessment. At the local level, clinicians at a tertiary care hospital with low AMI mortality based on national benchmarking data may not be aware that their hospital has worse-than-expected outcomes for patients admitted in transfer, and therefore fail to implement changes targeting that patient population. Alternatively, hospital-wide efforts to improve outcomes for natively admitted patients may be inefficient or inappropriate when outcomes for transferred patients are relatively good. At the regional level, efforts to transfer patients to the best referral hospitals can't succeed without accurate

data on the outcomes of transferred patients at tertiary facilities. Indeed, despite evidence that interhospital transfer may be beneficial for individual patients,^{5,30} there does not appear to be any relationship between increased transfers and patient outcomes at the hospital level across the US health care system.¹² At the same time, hospitals without procedural capabilities do not consistently transfer patients to the nearest high-performing procedure hospital, highlighting an opportunity to improve triage and transfer practices.¹³

Accurately measuring and effectively improving outcomes for patients undergoing interhospital transfer are increasingly important health policy priorities. Nearly 20% of patients with AMI undergo interhospital transfer, and this proportion is increasing over time.⁶ As hospital systems become more centralized through the implementation of regional systems of care,³¹ it is likely that interhospital transfer will be increasingly common for patients with AMI and other medical conditions. AMI mortality is a component of Medicare's value based purchasing program, meaning that the current approach to outcome attribution affects not only measurement and clinical care but also hospital finances.²⁹ Thus, it is critical that we create quality measures that provide accurate information regarding quality of care for this group of transferred patients.

Designing quality measures that accurately and fairly account for quality of care surrounding interhospital transfer will require careful consideration of the impact of modeling decisions. One approach would involve using marginal structural models to treat hospital quality as a time-varying covariate,^{32,33} apportioning the influence of hospital quality on patient outcomes based on the time of treatment relative to the outcome. In this case, a hospital that delivers high-quality care would not be punished for the impact of lower quality care at downstream facilities. However, such an approach could also "adjust away" the decision of one hospital to transfer patients to a lower-quality tertiary care hospital, when in fact we may want to incentivize transfers to higher quality hospitals. An approach to hospital benchmarking that accounts for variation in quality across multiple care settings will therefore require both complex statistical models and thoughtful consideration of their policy implications.

Our finding of substantial variation in the proportion of transferred patients at referral hospitals, in concert with existing data on variation in transfer rates at non-procedure hospitals,¹³ also raises questions regarding the potential impact of the many complex incentives surrounding interhospital transfer decisions. Insurance considerations, hospital networks, the impact of transfers on hospital benchmarking, and incentives for patients and physicians may influence both the decision to transfer a patient and the ultimate transfer destination.^{34,35} Future studies should explore how these incentives surrounding interhospital transfer influence transfer destination, clinical outcomes and quality measurement.

Our work has several limitations. First, as with all analyses of administrative claims data, our models lack granular clinical information on severity of illness, which may limit their discriminative capabilities. Additionally, we did not have access to outpatient data and therefore used Elixhauser comorbidities from inpatient claims rather than HCCs as in the CMS models. However, our models had discriminative performance equal to those used by

CMS in its AMI hospital profiling program, increasing the face validity of our findings.¹ Importantly, although administrative coding may vary across hospitals, it is unlikely to vary within a given hospital for natively admitted and transferred patients, so coding practices are unlikely to explain our findings. Similarly, the administrative data lack information on stability of the patient at the time of transfer, quality of care during medical transport, and other patient factors that could influence clinical outcomes. Second, because our analysis was limited to Medicare fee-for-service beneficiaries, the findings may not generalize to younger patients or those with Medicare Advantage insurance plans. Third, because AMI care pathways involve revascularization procedures, our findings may not extrapolate to hospital benchmarking for other conditions that are less dependent upon specific procedures or services that may trigger the decision to transfer a patient. Fourth, the fact that hospitals with concordant performance cared for higher volumes of transferred patients could be related to greater stability of the statistical estimates for mortality at higher-volume hospitals. However, given the significant overlap in patient volumes in hospitals with discordant and concordant performance, reflecting the fact that even higher-volume hospitals can have discordant performance, our findings are unlikely to represent a purely statistical phenomenon. Finally, only a relatively small proportion of hospitals care for significant numbers of transferred patients and were therefore included in our analysis. Nevertheless, these are large, tertiary hospitals that care for a disproportionate number of overall patients with AMI, including nearly three quarters of AMI transfers in our cohort, increasing the importance of accurately assessing their performance.

CONCLUSIONS

Hospital-specific risk-standardized mortality for natively admitted patients with acute myocardial infarction is only weakly associated with hospital-specific risk-standardized mortality for patients with acute myocardial infarction admitted in transfer from another hospital. Future research is needed explore the mechanism underlying these findings, including contributions from quality of care prior to and during transfer, and to develop novel performance metrics that simultaneously provide both a more comprehensive assessment of patient outcomes throughout an episode of care and a more granular evaluation of outcomes for different groups of patients at centers caring for a significant number of patients transferred from other hospitals.

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References

1. Krumholz HM, Wang Y, Mattera JA, Wang Y, Han LF, Ingber MJ, 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* [Internet]. 2006; 113(13):1683–92. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/16549637>.
2. Krumholz HM, Wang Y, Mattera JA, Wang Y, Han LF, Ingber MJ, et al. An administrative claims model suitable for profiling hospital performance based on 30-day mortality rates among patients with heart failure. *Circulation* [Internet]. 2006; 113(13):1693–701. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/16549636>.

3. Lindenauer PK, Bernheim SM, Grady JN, Lin Z, Wang Y, Wang Y, et al. The performance of US hospitals as reflected in risk-standardized 30-day mortality and readmission rates for medicare beneficiaries with pneumonia. *J Hosp Med*. 2010 Aug; 5(6):E12–18.
4. Liem AL, van 't Hof AW, Hoorntje JC, de Boer MJ, Suryapranata H, Zijlstra F. Influence of treatment delay on infarct size and clinical outcome in patients with acute myocardial infarction treated with primary angioplasty. *J Am Coll Cardiol* [Internet]. 1998 Sep; 32(3):629–33. [cited 2016 Oct 3]. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/9741503>.
5. Westfall JM, Kiefe CI, Weissman NW, Goudie A, Centor RM, Williams OD, et al. Does interhospital transfer improve outcome of acute myocardial infarction? A propensity score analysis from the Cardiovascular Cooperative Project. *BMC Cardiovasc Disord* [Internet]. 2008; 8:22. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/18782452>.
6. Bernheim SM, Wang Y, Bradley EH, Masoudi FA, Rathore SS, Ross JS, et al. Who is missing from the measures? Trends in the proportion and treatment of patients potentially excluded from publicly reported quality measures. *Am Heart J* [Internet]. 2010; 160(5):943–5. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/21095284>.
7. Harder B, Comarow A. Hospital quality reporting by US News & World Report: why, how, and what's ahead. *JAMA* [Internet]. 2015; 313(19):1903–4. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/25988456>.
8. Robinowitz DL, Dudley RA. Public reporting of provider performance: can its impact be made greater? *Annu Rev Public Health* [Internet]. 2006; 27:517–36. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/16533128>.
9. Hibbard JH, Stockard J, Tusler M. Does Publicizing Hospital Performance Stimulate Quality Improvement Efforts? *Health Aff* [Internet]. 2003 Mar 1; 22(2):84–94. [cited 2016 Jan 29]. Available from: <http://content.healthaffairs.org.pitt.idm.oclc.org/content/22/2/84.long>.
10. Frølich A, Talavera JA, Broadhead P, Dudley RA. A behavioral model of clinician responses to incentives to improve quality. *Health Policy* [Internet]. 2007 Jan; 80(1):179–93. [cited 2016 Sep 13]. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/16624440>.
11. Kosseim M, Mayo NE, Scott S, Hanley JA, Brophy J, Gagnon B, et al. Ranking hospitals according to acute myocardial infarction mortality: should transfers be included? *Med Care* [Internet]. 2006 Jul; 44(7):664–70. [cited 2016 Aug 29]. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/16799361>.
12. Barreto-Filho JA, Wang Y, Rathore SS, Spatz ES, Ross JS, Curtis JP, et al. Transfer Rates From Nonprocedure Hospitals After Initial Admission and Outcomes Among Elderly Patients With Acute Myocardial Infarction. *JAMA Intern Med* [Internet]. 2014 Feb 1; 174(2):213. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/24296747>.
13. 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* [Internet]. 2010; 3(5):468–75. Available from: <http://circoutcomes.ahajournals.org/cgi/doi/10.1161/CIRCOUTCOMES.110.957993>.
14. Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. *Med Care* [Internet]. 1998; 36(1):8–27. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/9431328>.
15. Efron B, Tibshirani R. Bootstrap Methods for Standard Errors. *Stat Sci* [Internet]. 1986; 1(1):54–75. [cited 2016 Oct 14]. Available from: <http://www.jstor.org/stable/2245500>.
16. Terkelsen CJ, Sørensen JT, Maeng M, Jensen LO, Tilsted H-H, Trautner S, et al. System delay and mortality among patients with STEMI treated with primary percutaneous coronary intervention. *JAMA* [Internet]. 2010; 304(7):763–71. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/20716739>.
17. Indications for fibrinolytic therapy in suspected acute myocardial infarction: collaborative overview of early mortality and major morbidity results from all randomised trials of more than 1000 patients. Fibrinolytic Therapy Trialists' (FTT) Collaborative. *Lancet* (London, England) [Internet]. 1994; 343(8893):311–22. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/7905143>.
18. Cannon CP, Gibson CM, Lambrew CT, Shoultz DA, Levy D, French WJ, et al. Relationship of symptom-onset-to-balloon time and door-to-balloon time with mortality in patients undergoing

- angioplasty for acute myocardial infarction. JAMA [Internet]. 2000; 283(22):2941–7. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/10865271>.
19. Berger PB, Ellis SG, Holmes DR, Granger CB, Criger DA, Betriu A, et al. Relationship between delay in performing direct coronary angioplasty and early clinical outcome in patients with acute myocardial infarction: results from the global use of strategies to open occluded arteries in Acute Coronary Syndromes (GUSTO-IIb) trial. Circulation [Internet]. 1999; 100(1):14–20. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/10393675>.
 20. Jeger RV, Tseng C-H, Hochman JS, Bates ER. Interhospital transfer for early revascularization in patients with ST-elevation myocardial infarction complicated by cardiogenic shock—a report from the SHould we revascularize Occluded Coronaries for cardiogenic shock? (SHOCK) trial and registry. Am Heart J [Internet]. 2006; 152(4):686–92. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/16996836>.
 21. Hannan EL, Racz MJ, Walford G, Ryan TJ, Isom OW, Bennett E, et al. Predictors of readmission for complications of coronary artery bypass graft surgery. JAMA [Internet]. 2003; 290(6):773–80. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/12915430>.
 22. Guru V, Tu JV, Etchells E, Anderson GM, Naylor CD, Novick RJ, et al. Relationship between preventability of death after coronary artery bypass graft surgery and all-cause risk-adjusted mortality rates. Circulation [Internet]. 2008; 117(23):2969–76. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/18541752>.
 23. Ingraham AM, Haas B, Cohen ME, Ko CY, Nathens AB. Comparison of hospital performance in trauma vs emergency and elective general surgery: implications for acute care surgery quality improvement. Arch Surg (Chicago, Ill 1960) [Internet]. 2012; 147(7):591–8. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/22430094>.
 24. Barbash IJ, Le TQ, Barnato AE, Angus DC, Kahn JM. Judging Hospitals for Care of All Critically Ill Patients Versus Care of All Intensive Care Unit Patients: is There a Difference? American Thoracic Society International Meeting. 2015:A5201.
 25. Staiger DO, Dimick JB, Baser O, Fan Z, Birkmeyer JD. Empirically derived composite measures of surgical performance. Med Care [Internet]. 2009; 47(2):226–33. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/19169124>.
 26. Dimick JB, Staiger DO, Birkmeyer JD. Ranking hospitals on surgical mortality: the importance of reliability adjustment. Health Serv Res [Internet]. 2010; 45(6 Pt 1):1614–29. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/20722747>.
 27. Chen LM, Staiger DO, Birkmeyer JD, Ryan AM, Zhang W, Dimick JB. Composite quality measures for common inpatient medical conditions. Med Care [Internet]. 2013; 51(9):832–7. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/23942222>.
 28. Pronovost PJ, Miller M, Wachter RM, M K, GC F, PK L, et al. The GAAP in Quality Measurement and Reporting. JAMA [Internet]. 2007 Oct 17;298(15):1800. [cited 2016 Jul 12]. Available from: <http://jama.jamanetwork.com/article.aspx?doi=10.1001/jama.298.15.1800>.
 29. Centers for Medicare & Medicaid Services (CMS), HHS. Medicare program; hospital inpatient value-based purchasing program. Final rule. Fed Regist [Internet]. 2011 May 6; 76(88):26490–547. [cited 2016 Oct 10]. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/21548401>.
 30. Ranasinghe I, Barzi F, Brieger D, Gallagher M. Long-term mortality following interhospital transfer for acute myocardial infarction. Heart [Internet]. 2015; 101(13):1032–40. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/25736049>.
 31. Wallace, DJ., Angus, DC., Seymour, CW., Barnato, AE., Kahn, JM. Critical Care Bed Growth in the United States: a Comparison of Regional and National Trends. Am J Respir Crit Care Med [Internet]. 2014. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/25522054>.
 32. Sato T, Matsuyama Y. Marginal structural models as a tool for standardization. Epidemiology [Internet]. 2003 Nov; 14(6):680–6. [cited 2016 Oct 11]. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/14569183>.
 33. Robins JM, Hernán MA, Brumback B. Marginal structural models and causal inference in epidemiology. Epidemiology [Internet]. 2000 Sep; 11(5):550–60. [cited 2016 Oct 11]. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/10955408>.

34. Gombeski WR, Konrad D, Kanoti G, Ulreich S, Skilogianis J, Clough J. Selection of a hospital for a transfer: the roles of patients, families, physicians and payers. *J Hosp Mark* [Internet]. 1997; 12(1):61–77. [cited 2016 Aug 29]. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/10179671>.
35. 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* [Internet]. 2003; 138(11):882–90. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/12779298>.

Figure 1.
Cohort Selection Flow Diagram

Figure 2. Comparison of Hospital Performance

Hospitals that perform well for natively admitted patients do not necessarily perform well for patients admitted in transfer. Each data point represents an individual hospital, with risk-standardized 30-day mortality for natively admitted patients (X-axis) vs. risk-standardized 30-day mortality for patients admitted in transfer (Y-axis). Hospitals ranked in the top quartile for one group and the bottom quartile for another group are shaded in black. Hospitals that moved up or down two performance quartiles are shaded in grey.

Table 1**Patient Characteristics**

	Natively Admitted Patients N=77341	Patients Admitted in Transfer N=11790
Mean Age	77.3±8.1	76.3±7.1
Race		
White	67070(86.72)	10270(87.11)
Black	6878(8.89)	880(7.46)
Other	3393(4.39)	640(5.43)
Female Gender	35194(45.50)	5319(45.11)
Comorbidity Count		
0	4004(5.18)	512(4.34)
1	13369(17.29)	1929(16.36)
2	17675(22.85)	2615(22.18)
3+	42293(54.68)	6734(57.12)
Key Comorbidities		
Diabetes Mellitus	24270(31.38)	4032(34.20)
Liver Disease	375(0.48)	44(0.37)
Metastatic Cancer	629(0.81)	52(0.44)
Other Cancer	1094(1.41)	114(0.97)
PCI		
History of PCI	2444(3.16)	714(6.06)
During Admission	35837(46.34)	5603(47.52)
CABG		
History of CABG	416(0.54)	66(0.56)
During Admission	7848(10.15)	2544(21.58)
Anterior MI	7495(9.69)	582(4.94)
ICU Admission	58298(75.38)	8451(71.68)
Hospital LOS	5.8±6.3	6.2±7.0
30-Day Mortality	8890(11.49)	841(7.13)

Data are reported as N(%) for categorical variables or mean ± standard deviation for continuous variables. PCI=percutaneous coronary intervention; CABG=coronary artery bypass grafting; ICU=intensive care unit; LOS=length of stay

Changes in Hospital Performance Quartiles for Natively Admitted and Transferred Patients

Table 2

	Performance Quartiles for Patients Admitted in Transfer			
	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Performance Quartiles for Natively Admitted Patients	Quartile 1	18	16	16
	Quartile 2	20	18	18
	Quartile 3	16	24	20
	Quartile 4	14	18	22

Hospitals in quartile 1 have the lowest RSMRs, and hospitals in quartile 4 have the highest RSMRs.

RSMR=Risk Standardized Mortality Rate

Table 3**Hospital Characteristics**

	Hospitals with Similar Performance Across the Groups N=202	Hospitals Comparatively Better for Natively Admitted Patients N=50	Hospitals Comparatively Better for Patients Admitted in Transfer N=52
Hospital Beds, Mean (SD)	393 (235)	376 (186)	378 (181)
Total AMI Claims, Median (IQR)	272.5 (196, 389)	259 (184, 340)	248 (195.5, 340)
Number of Natively Admitted Patients, median (IQR)	236 (164, 328)	237 (155, 322)	223.5 (158, 300.5)
Number of Patients Admitted in Transfer, median (IQR)	28 (19, 48)	24.5 (18, 39)	23 (19, 44.5)
Treatment with PCI			
Number of Patients, median (IQR)	127 (89, 180)	121 (85, 160)	116 (87, 152)
Proportion of Patients, mean (SD)	0.467 (0.103)	0.468 (0.091)	0.460 (0.090)
Treatment with CABG			
Number of Patients, median (IQR)	32.5 (22, 46)	26.5 (12, 41)	29 (21, 41)
Proportion of Patients, mean (SD)	0.122 (0.055)	0.102 (0.055)	0.116 (0.044)
MSA Size, N (%)			
Small	6 (3.0%)	0 (0.0%)	0 (0.0%)
Medium	85 (42.1%)	24 (48.0%)	26 (50.0%)
Large	111 (55.0%)	26 (52.0%)	26 (50.0%)

MSA=metropolitan statistical area; PCI=percutaneous coronary intervention; CABG=coronary artery bypass grafting.

Hospitals with similar performance across groups were those in the same performance quartile and those that moved up or down only one performance quartile across groups. Hospitals comparatively better for natively admitted patients improved two performance quartiles relative to performance for patients admitted in transfer. Hospitals comparatively better for patients admitted in transfer improved two performance quartiles relative to performance for natively admitted patients.