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Hospital-Level Variation in Angina and Mortality at One-Year after Myocardial Infarction: Insights from the Triumph Registry

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Abstract

Background—Despite calls to expand measurement of acute myocardial infarction (AMI) outcomes to include symptom burden, little has been done to describe hospital-level variation in this patient-centered outcome, or its association with mortality. Understanding the relationship between symptoms and longer-term mortality could inform the importance of these outcomes for monitoring quality of care.

Methods and Results—Among 4,316 patients with AMI treated at 24 hospitals participating in the TRIUMPH study, we assessed risk-standardized 1-year symptom burden as measured by the Seattle Angina Questionnaire Angina Frequency score (SAQ-AF) and mortality attributed to the hospital that provided acute AMI care. Median odds ratios (MORs) were employed to assess outcome variation and reflect the relative odds of an outcome for two patients with identical covariates at different, randomly selected, hospitals. We then evaluated the correlation between hospital-level mortality and angina. Finally, we determined the extent to which variation in mortality and angina was explained by achievement of AMI performance measures. We observed hospital variation in risk-adjusted 1-year mortality (range 4.9% to 8.6%, median odds ratio [MOR] 1.30, $p=0.01$) and angina (range 17.7% to 29.4%, MOR=1.34, $p<0.001$). At the hospital level, mortality and angina at 1-year were weakly correlated ($r=0.40$, 95% confidence interval 0.00–0.68, $P=0.05$). Accounting for the quality of AMI care did not attenuate variation in risk-adjusted 1-year mortality or angina.

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Conclusion—Symptom burden and mortality vary at the hospital level following AMI and are only weakly correlated. These findings suggest that symptom burden should be considered a separate quality domain that is not well captured by current quality metrics.

Keywords

Introduction

To spur improvement in hospital care for acute myocardial infarction (AMI), significant emphasis has been placed on optimizing hospital-level mortality outcomes.¹⁻³ However, mortality may fail to capture the breadth of the patient experience, such as health status measures that include functional status, health related quality of life, and symptom burden.^{4, 5} Thus, it is unclear that mortality alone is sufficient to quantify the quality of AMI care, unless it is highly correlated with patient-reported outcomes. Presently, little work has been done to describe health status and its relationship to mortality. Understanding this relationship can help clarify the need for direct assessment of symptom burden after AMI across hospitals to improve the outcomes and value of care.

Prior studies of hospital AMI mortality outcomes have largely been limited to 30-days post-discharge.^{1, 6, 7} In an era of increasing accountability for the entirety of longitudinal care and patient outcomes,^{8, 9} there is a growing need to evaluate and understand variation in long term mortality and symptom outcomes.

Accordingly, we evaluated the extent to which one-year mortality and symptom burden following AMI varies among a contemporary cohort of hospitals that enrolled patients in the TRIUMPH registry. We then determined the hospital-level relationship between one-year mortality and angina outcomes. Insights from our investigation should help determine whether the direct measurement of health status among AMI patients identifies a different aspect of the quality of longitudinal care compared with mortality outcomes alone.

Methods

Study population

AMI patients from 24 U.S. hospitals were prospectively enrolled in the TRIUMPH study between June 2005 and December 2008. The hospitals enrolling in TRIUMPH are from diverse geographic regions, include academic, inner-city, and non-university hospitals, and are highly variable in size, with a range of 66 to 1000 beds. The median hospital enrollment in the TRIUMPH study was 135 patients (IQR 58 – 185). For inclusion, patients had to have biomarker evidence of AMI and either 20 minutes of ischemic signs/symptoms or ST-segment changes on electrocardiogram during the first 24 hours of hospitalization. Additional details on the TRIUMPH study have been previously reported.¹⁰ Each participating hospital obtained Institutional Review Board approval, and all patients gave informed consent.

Outcomes

The primary outcomes for this study included symptom burden and mortality at 1-year. Symptom burden was assessed with the Seattle Angina Questionnaire Angina Frequency (SAQ-AF) score and was dichotomized as any angina (SAQ-AF <100) versus no angina (SAQ-AF =100), given the distribution of scores with a significant proportion of patients having no angina at 1 year and greater ease of clinical interpretation.¹¹ It was completed by telephone interview 1 year after each patient's AMI admission. All-cause mortality was determined through a query of the Social Security Death Master File as well as by 1-year telephone interviews. Baseline patient demographics, socioeconomic status, psychosocial status, health status, medical history, presentation, and arrival medications were obtained by trained chart abstractors and interviewers during the index AMI hospitalization.

Explanatory Variables

Improvements in AMI mortality have coincided with improvements in achievement of performance measures for in-hospital AMI care.¹² Whether variation in symptom burden is also explained by currently endorsed performance measures of AMI care is unknown. Therefore, we conducted a secondary analysis assessing the extent of variability in hospital outcomes explained by AMI performance measures. Explanatory variables were hospital-level achievement of performance measures for AMI applicable at the time that the study was conducted (ASA and beta blockers within 24 hours of arrival and at discharge, ACEI/ARB at discharge, PCI <90 minutes for STEMI/LBBB, and smoking cessation instructions at discharge).¹² These were obtained, along with any patient-specific contraindications for treatment, from chart abstraction. Performance measures were applied only to ideal candidates (i.e. those without documented contraindications).¹⁰ Cardiac rehabilitation referral and statin prescribed at discharge were not considered in the primary analysis because these were adopted as performance measures in 2008, after enrollment of most of the cohort.¹³ However, as evidence was available to support these processes of care for patients with AMI prior to cohort inception, we conducted secondary analyses including these emerging performance measures.

Statistical analysis

Hierarchical logistic regression models were used to assess hospital-level variation in the 1-year outcomes of angina (any vs. none) and mortality. Variation in these outcomes was assessed first without adjustment and then after adjustment for patient risk factors. The angina model included adjustment for all patient characteristics listed in Table 1, which were chosen *a priori* based on clinical judgment and previously published studies. For mortality, to avoid model over-fitting due to relatively few events,¹⁴ we restricted adjustment to those factors that have been previously demonstrated to be associated with mortality or were clinically judged highly likely to be prognostic in this population: age, sex, diabetes, prior MI, chronic heart failure, left ventricular systolic dysfunction, prior cerebrovascular accident or transient ischemic attack, systolic blood pressure, heart rate, hemoglobin, glomerular filtration rate, dialysis, and the Medical Outcomes Study 12-Item Short Form Physical Component Summary (SF-12 PCS).^{15, 16}

Median odds ratios (MORs) were used to assess the variability in hospital-level patient outcomes. The MOR is a function of the between-hospital variance estimates and reflects the median odds of performance (or outcomes) of two patients with identical covariates treated at two different, randomly selected, hospitals.¹⁷ For the analysis of 1-year outcomes, we also calculated hospital-level risk-standardized angina and mortality rates using the method currently endorsed by CMS for hospital profiling. First, we calculated the ratio of predicted events to expected events for each hospital, where predicted events were computed as the sum of the predicted probabilities of events *including* that hospital's specific random effect, and expected events were computed as the sum of the predicted probabilities *excluding* the hospital effect; that is, for an "average" other hospital within the cohort. Next, we multiplied each hospital's predicted/expected ratio by the overall study event rate, to obtain risk-standardized event rates. This approach shrinks estimates for low-volume hospitals toward the study mean to correct for bias due to over-fitting and multiple comparisons when comparing rates across hospitals.¹⁸ We plotted each hospital's risk standardized 1-year angina rate against their risk-standardized 1-year mortality rate and assessed the relationship using Spearman's correlation coefficient while treating the data as correlated binomial variables and used generalized estimating equations to estimate the correlation.

We assessed the variability in hospital achievement of AMI performance measures using MOR. We then added patient-level covariates for achievement of AMI performance measures to the above risk-adjustment model of 1-year outcomes and repeated the above analyses, to determine the extent to which hospital-level variation in angina and 1-year mortality was explained by index AMI quality of care. We evaluated the explanatory effect of performance on outcomes by *F* tests adjusted for patient risk factors. In addition, we visually compared the effect on hospital variability by plotting hospital risk-standardized outcome rates before vs. after adjustment. In secondary analyses, statin therapy and cardiac rehab referral at discharge were added to the model to determine if hospital achievement of these emerging performance measures explained variation in patient outcomes.

Multiple imputation methods were used to account for potential bias and uncertainty due to missing data (only 4% of patients were missing data on more than two variables; the maximum missing data rate for any single variable was 8%) using IVEware Version 0.1. Missing covariates were stochastically imputed using sequential regression imputation based on a model including hospital, all performance measures, all variables listed in Table 1 and the outcomes of 1-year mortality and angina.¹⁹ Twenty imputed data sets were generated, the analyses described above were repeated for each data set, and the results from each were pooled to obtain the final model estimates presented here. Finally, 1-year SAQ angina frequency scores were missing on 33% of patients due to lost follow-up. However, any bias due to missing data that is attributable to observed patient characteristics is corrected for by the inclusion of these factors in the model used to calculate risk-standardized angina rates.²⁰ As a sensitivity analysis, we performed the angina analyses, imputing 1-year angina frequency scores on the basis of observed patient characteristics as well as 1- and 6-month scores and survival status. All analyses were conducted in SAS version 9.3 and R version 2.15.3.

Results

Of the 4,340 AMI patients enrolled in the TRIUMPH study, we studied the 4,316 patients who survived to hospital discharge. The average age was 59 years, 67% were male, and slightly less than half reported having any angina in the 4 weeks prior to their AMI (Online supplement Table 1).

Mortality

The overall mortality rate at 1-year was 6.2%, with crude hospital mortality rates ranging from 0% to 10.8%. Smoothed estimates of hospital mortality rates (from an unadjusted hierarchical model accounting for small hospital sample sizes) ranged from 3.0% to 9.8%, which represented moderate variation (MOR= 1.53, $p<0.001$). After adjustment for patient risk factors, hospital risk-standardized mortality rates ranged from 4.9% to 8.6%, and the MOR was 1.30, $p=0.01$.

Angina and its Relationship to Mortality

The overall incidence of angina 1-year after AMI was 23%, with crude hospital angina rates ranging from 9.3% to 66.7%. Smoothed estimates of hospital angina rates ranged from 14.6% to 40.5%, and this variation was statistically significant (MOR= 1.55, $p<0.001$). After adjustment for patient risk factors, hospital risk-standardized angina rates ranged from 17.7% to 29.4%, which remained statistically significant (MOR=1.34, $p<0.001$). Risk-standardized mortality rates and angina among hospitals were weakly correlated ($r = 0.40$, 95% CI 0.00 to 0.68, $p = 0.05$; Figure 1). In a sensitivity analysis with imputed 1-year angina frequency scores on the basis of observed patient characteristics as well as 1- and 6-month scores, risk-adjusted 1-year angina rates ranged from 19.1% to 37.4% (MOR 1.41) (Online Supplement; Table 2). In this analysis, risk-standardized mortality was moderately correlated with risk-standardized angina ($r=0.53$, 95% CI 0.18 to 0.77, $P=0.006$) (Online Supplement; Figure 1).

Achievement of AMI Performance Measures and Impact on Mortality and Angina

AMI performance measures were met for the majority of patients for aspirin within 24 hours (97.5%), beta blocker within 24 hours (88.2%), aspirin at discharge (95.5%), ACEI/ARB at discharge (85.4%), and beta-blockers at discharge (93.3%). The proportion of patients who received primary PCI for STEMI/LBBB within 90 minutes was 53% (Online Supplement Table 3). Hospital-level variation in the achievement of AMI performance measures was statistically significant for 6 of the 7 individual measures and a composite measure. Pronounced variation was noted for hospital-level achievement of primary PCI within 90 minutes (median 52.5%, range 12.1%-73.1%, MOR 2.19) and smoking cessation instructions (median 79.2%, range 31.6%-93.8%, MOR 2.72). Of the remaining measures, variation was more modest with MORs ranging from 1.19 ACEI/ARB at discharge to 1.91 for aspirin within 24 hours of presentation (Figure 2). For the emerging performance measures of statin therapy and cardiac rehab referral at discharge, the variation in statin at discharge was modest (MOR 1.60, $p<0.001$) while there was pronounced variation in cardiac rehabilitation referral (MOR 4.75, $p<0.001$) (Figure 2). Although the absolute

variation for some measures was small (e.g. aspirin use), the MOR reflects the relative variation in odds of achieving a measure and thus remained substantial for most measures.

Variation in hospital 1-year mortality was not attenuated by adjustment for established in-hospital AMI performance measures (range = 5.0% to 8.3%, MOR = 1.29, $p=0.96$ vs. adjustment for patient risk factors only). Similarly, inclusion of the emerging measures of statin prescription at discharge and cardiac rehabilitation referral did not attenuate between-hospital variation (range = 5.3% to 7.9%, MOR = 1.25, $p=0.83$ vs. adjustment for patient risk factors only). The association between hospital risk-adjusted and risk-plus-performance-adjusted 1-year mortality rates is shown in Figure 3.

Variation in hospital 1-year presence of angina rates was not attenuated by adjustment for established AMI performance measures (range = 17.3% to 29.6%, MOR = 1.37, $p=0.13$ vs. adjustment for patient risk factors only). Inclusion of the emerging measures of statin prescription at discharge and cardiac rehabilitation referral did not attenuate between-hospital variation in angina rates (range = 17.1% to 29.3%, MOR = 1.38, $p=0.14$ vs. adjustment for patient risk factors only). The association between hospital risk-adjusted and risk-plus-performance-adjusted 1-year angina rates is shown in Figure 3.

Discussion

In the TRIUMPH study of 24 diverse hospitals, we found significant variation in 1-year risk-adjusted outcomes of mortality and symptom burden after AMI across hospitals. Among patients with identical covariates, the odds of mortality at 1-year were 25% greater when treated at one randomly selected hospital as compared with another. Variation in symptom burden was even greater with a nearly 40% greater odds of angina at 1-year when comparing treatment at two randomly selected hospitals. Among patient with symptom status captured at 1-year, there was only a weak correlation between 1-year mortality and angina burden at the hospital-level and moderate correlation when missing data on 1-year angina was imputed. These findings suggest mortality and symptom outcomes reflect different and complementary aspects of the quality of longitudinal care. Furthermore, variation in achievement of established and emerging AMI performance measures did not explain variation in 1-year patient outcomes.

The observed hospital-level variability in 1-year outcomes are consistent with the range of variation in 30-day outcomes that has been demonstrated in prior studies. For instance, in 2006 among Medicare hospitals, 30-day risk standardized mortality varied from 10.6 to 21.6%.³ In contrast to previous studies that have evaluated variation in short-term mortality, our study is unique in the assessment of patient symptom burden 1 year after AMI, an outcome of great importance to patients. While hospital-level risk-standardized mortality rates did vary across hospitals, the absolute variation in symptom burden was much larger. Additionally, there was no significant correlation between mortality rates and symptom outcomes. As depicted in Figure 1, some hospitals with lower mortality rates had higher angina burden while others that had lower angina burden had higher mortality rates. This observation suggests that the evaluation of hospital-level symptom burden as an outcome would identify a different distribution of hospitals than if one were to evaluate mortality

alone. Thus, these data show that symptom burden is important for the full assessment of the longitudinal care of MI patients.

The importance of measuring patient symptom burden in determining the quality of a hospital's care has been increasingly emphasized in recent years. For instance, in the 2011 performance measures for patients with coronary artery disease, annual assessment of symptom burden was added as a performance measure.²¹ Additionally, a recent AHA statement suggested that patient health status measures could be utilized as quality metrics.⁵ Finally, patient-reported health status outcomes that include symptom burden are a key part of efforts to support high-value health care.^{22, 23} The present study adds to the growing emphasis on health status outcomes by demonstrating the importance of symptom assessment in addition to mortality outcomes for the differentiation of high and low performing hospitals.

Increasingly, optimizing the quality of longitudinal care (e.g. adequacy of follow-up,²⁴ optimal dosing of risk-modifying therapy,²⁵ medication adherence²⁶) is being suggested as a means to improve patient long-term outcomes. However, unlike short-term AMI outcomes that are more easily attributed to a hospital, there are challenges to identifying a locus of accountability for long-term outcomes. As care delivery moves toward Accountable Care Organizations in which provider groups accept responsibility for the quality of care for a patient population over time,^{8, 9} there is a need for these organizations to consider how to manage not only the acute, but also the long-term outcomes of their patients. In the near term, hospitals may provide a reasonable focus for initial study of longitudinal care given that most physicians are directly or indirectly affiliated with a local acute care hospital.²⁷ Study of hospital systems with low long-term mortality and symptom burden following AMI may identify strategies to optimize longitudinal care delivery and patient outcomes. These insights may then inform emerging ACOs to optimize quality of care and patient outcomes.

Our study suggests in-hospital AMI care is not a principle driver of variation in 1-year mortality or symptom burden outcomes. In prior studies, short-term mortality was modestly associated with hospital AMI performance.^{28,29} One prior study evaluated the correlation between hospital achievement of AMI performance measures and 1-year mortality and found a small absolute reduction in risk-adjusted mortality rates of 0.012 when comparing the 75th to 25th percentile hospitals achieving composite performance measures.³⁰ Although gaps in the quality of in-hospital AMI care were observed in our study, particularly for smoking cessation and referral to rehab, the opportunities to improve long-term patient outcomes though further emphasis on current AMI performance measures may be limited.

Several limitations of this study should be noted. As an observational study, we cannot exclude the possibility of unmeasured confounding. The analytic cohort included the 24 hospitals that participated in the TRIUMPH study. Given our hospital-level analysis, our study has limited power to identify small associations between AMI processes and long-term outcomes. Furthermore, findings from TRIUMPH-participating hospitals may not be generalizable to other non-participating hospitals. However, the hospitals in the registry are from diverse geographic regions and are highly variable in size.¹⁰ Additionally, the demonstration of significant variability in angina and mortality outcomes at one year in this

sample of facilities speaks to the importance of our findings. We are also limited by missing data on angina frequency scores at 1-year in 33% of our patient sample. However, in a sensitivity analysis in which 1-year angina frequency scores were imputed on the basis of observed patient characteristics, 1- and 6-month scores, and survival status, hospital risk-adjusted mortality and angina were at most moderately correlated. We employed median odds ratios to assess variation.¹⁷ Odds ratios can diverge from rate ratios, however methods for estimation of median rate ratios have not been validated for the hierarchical random-effects framework used in the current analysis. Further, median odds ratios convey the same information regardless of whether the outcome discussed is performance or failure to achieve performance and thus are particularly useful in the context of this analysis. Prior studies have shown that angina burden predicts patient outcomes.³¹ Therefore, patients with 1-year mortality may have also had the highest angina burden. However, our analysis using imputed 1-year angina burden includes mortality in the model to partially account for this competing risk. Furthermore, the absolute variation in angina burden far exceeds the variation in mortality, suggesting that competing risk does not explain our findings. Consistent with recommendations in the comparison of risk-standardized hospital outcomes,³² our analysis did not account for additional treatment and process measures beyond the explanatory variables of interest (e.g. performance measures). Thus, we did not evaluate the extent to which utilization of antianginal medications or revascularization may explain hospital-level variation in mortality and angina burden. This is an area for future investigation.

In conclusion, we found significant hospital-level variability in angina burden and mortality in the year following AMI, with minimal correlation between hospital-level angina burden and mortality. This suggests that current measures of quality do not quantify important patient-centered outcomes and should be supplemented with direct assessments of patients' symptoms and quality of life. Finally, achievement of AMI performance measures did not decrease the variability in mortality and angina burden observed at one year. Further investigation of longitudinal care delivery may offer opportunities to improve long-term outcomes following AMI.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. Risk-Standardized Angina vs. Mortality

Figure 2.

Hospital Variation in AMI Performance Measures. Median odds ratios (MORs) were employed to assess outcome variation and reflect the relative odds of an outcome for two patients with identical covariates at different, randomly selected, hospitals.

Figure 3.

Hospital risk-adjusted and risk-plus-performance-adjusted outcomes. Variation in hospital 1-year mortality and symptom outcomes was not attenuated by adjustment for in-hospital AMI performance measures