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Regional Variation In Hospitalization Rates: Causes And Implications

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Regional Variation in Hospitalization Rates: Causes and Implications

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Regional Variation in Hospitalization Rates: Causes and Implications

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Admission rates vary by regions and states, but the extent by which variation in regional admission rates are related to variation in the medical need of populations and the association with hospital outcomes is unknown. To address these issues, we examine two cardiovascular conditions that differ in physician discretion to admit, acute myocardial infarction (AMI), less discretionary, and heart failure (HF), more discretionary. We first determined whether regional cardiovascular risk factors predict admission rates and then examined whether regional admission rates were related to 30-day risk-standardized mortality and readmission rates (RSMRs and RSRRs).

We used 2006-2008 Medicare ICD-9-CM claims data and the Medicare Denominator file to determine AMI and HF admission rates. The statewide prevalence of cardiovascular risk factors were obtained from the 2007 Behavioral Risk Factor Surveillance System. First, the relationship between statewide AMI and HF admission rates and cardiovascular risk factors was determined by a multivariate, least squares linear regression model. Second, hierarchical logistic models were used to estimate hospital RSMRs and RSRRs and then were aggregated to the level of hospital referral regions (HRRs). The correlation (R^2) was obtained by linear regression to characterize the relationship between both AMI and HF admission rates and regional RSMRs and RSRRs. Where significant relationships were observed, "cross condition" analyses were performed comparing admission rates of one condition against the RSMR or RSRR of the other in an effort identify potentially confounded relationships.

In the first analysis, cardiovascular risk factors explained 49% of the variation observed in statewide AMI admission rates and 50% of the variation in HF admission rates. In the second analysis, regional AMI admission rate was not correlated with AMI RSMR (R^2 0.01, 95% CI 0.00-0.04). Regional HF admission rate was inversely correlated with HR RSMR (R^2 0.13, 95% CI 0.07-0.21). Regional AMI hospitalization rate was weakly correlated with AMI RSRR (R^2 0.05, 95% CI 0.02-0.11). Regional HF admission rate was modestly correlated with HF RSRR (R^2 0.25, 95% CI 0.17-0.34). In the cross condition analyses, regional HF admission rate was not associated with AMI RSMR (R^2 0.00, 95% CI 0.00-0.02) but was associated with AMI RSRR (R^2 0.25, 95% CI 0.17-0.34).

Cardiovascular risk factors explain part, but not all, of the variation in AMI and HF admission rates. The modest association between regional HF admission rate, a more discretionary admission condition, and both AMI and HF RSRRs suggests a system propensity to patients. The same was not seen true of AMI a less discretionary admission condition. The modest inverse relationship between regional HF admission rate and HF RSMR, which was not observed with AMI RSMR, suggests an unmeasured confounder affecting the HF RSMR model.

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Table of Contents

Introduction

Beginnings of Small Area Variation Research

Nearly 40 years ago, Dr. John Wennberg published a landmark paper in *Science* entitled "Small Area Variations in Health Care Delivery." Based on observations from Vermont's health care delivery monitoring system, he demonstrated that the utilization of inpatient hospitalization and surgical procedures varied dramatically between neighboring hospitals.[1]

Wennberg and others went on to show that admission rates for discretionary medical conditions such as heart failure, and surgical procedures such as hysterectomy, varied as much as 400%.[2-4] Furthermore, admission rates for discretionary conditions were observed to be highly correlated with supply characteristics, such as hospital bed per capita and number of health care employees per capita.[5] In contrast, non-discretionary admission such as hip fracture and acute myocardial infarction showed relatively little variation in regional rates and were not associated with supply characteristics.[4] These conditions were identified as non-discretionary based on two key features. First, nearly all patients who experienced these conditions presented to hospitals. Second, and more importantly, when patients with these conditions presented to hospital emergency departments, they were all admitted for inpatient care.

This phenomenon was not limited to Vermont. Similar observations of marked variation in utilization of discretionary surgical procedures were made across the United

States and internationally in countries such as Norway, the United Kingdom and Canada.[3] This observation -- that marked variation occurs within nations with vastly different health care systems -- led Wennberg to propose a theory called "practice style factor."[4] Variation in inpatient utilization, he proposed, was highest for conditions in which there was little consensus in the benefit of hospitalization or surgical intervention. Where there was a clear understanding of the need to hospitalize patients as in the event of AMI or a hip fracture, he noted there was minimal regional variation in hospitalization rates. [4, 6] In a commentary in *Health Affairs* in 1984 Wennberg notes that this variation exists not only to the potential detriment of patients who may be hospitalized for unnecessarily, but also to the potential detriment of society who bears the cost of hospitalizations.[6]

Today in 2011, the causes and consequences of regional variation in hospitalization rates have taken on renewed and substantive importance through the passage of the Patient Protection and Affordable Care Act of 2010. The law allows for accountable care organizations (ACOs) -- a regional network of health care providers -- to negotiate contracts with Medicare on the basis of quality and efficient delivery of services. However, when it comes to inpatient care, there exists a rudimentary understanding of the causes and consequences associated with variation in regional admission rates. This limited understanding is exemplified by the broad options previously considered by the Centers for Medicare and Medicaid Services to reduce spending such as reducing reimbursements to hospitals in areas where the elective admission rate exceeds 120% of the national average.[7] In this setting, where

reimbursement may be tied to efficiency of care delivered, there is little consensus as to what constitutes appropriate population level admission rates. In this two-part study, we examine two distinct facets of regional variation in admission rates: (1) do regional risk profiles explain variation in regional hospitalization rates for specific medical conditions? and (2) among the patients hospitalized, do regional hospitalization rates explain regional differences in patient mortality and readmission?

We provide additional background for each question and go on to describe how we seek to contribute to the understanding of what constitutes appropriate use of inpatient care.

Part I: Medical Need and Inpatient Utilization

The first step to better understand regional variation in hospitalization rates is to ascertain whether this variation is reflective of the underlying medical need of the population. Quantifying medical need, however, can be difficult. While studies that have examined this issue disagree about the exact contribution of population health towards hospitalization rates, in collective, they made clear that it is implausible that differences in patient characteristics account for the variation in hospitalization rates.[2, 3, 6, 8, 9] Nevertheless, the broad applicability of these findings has been hampered by one or more of the following study characteristics:

(1) Examination of general health and total hospitalization rates but lacking specificity to a particular disease process;[2, 5, 8-14]

(2) Examination hospitalization rates using patient level predictors from a nationally representative sample, which by its very design, could not by measure the effect

of regional differences in practices regarding inpatient use, also known as individual fallacy;[11] and/or

(3) Examination of hospitalization rates of a few select regions that could not be reasonably extrapolated to the entire nation.[12, 15, 16]

Studies have yet to make use of high quality, multifaceted regional health risk factor data to examine the association between regional health risk profile and hospitalization rates across the entire nation. Furthermore, the relationship between condition-specific risk profile and hospitalization rates remains unexamined.

Prior work has demonstrated that general hospitalization rates are largely independent of population risk profile. In Part I of this study, we propose a focused examination of the degree to which variation in regional cardiovascular hospitalization rates are unexplained by differences in regional cardiovascular risk profiles. More specifically, we propose an examination of hospitalization rates for acute myocardial infarction (AMI), a less discretionary condition and heart failure (HF), a more discretionary condition. We specify cardiovascular disease because of the extensive body of research identifying risk factors and the ongoing collection of cardiovascular risk factor data through the Centers for Disease Control programs such as the Behavioral Risk Factor Surveillance System (BRFSS) -- a high quality and validated regional health surveillance database with detailed data of the prevalence of cardiovascular risk factors.[17]

To reiterate, our goal is to identify how much of the regional variation in AMI and HF hospitalization rates is explained by regional variation in cardiovascular risk profile.

Part II: Inpatient Utilization and Patient Outcomes

Beyond the need to examine the relationship between regional hospitalization rates and risk profiles, there has been a long articulated need to examine the extent to which difference in regional health outcomes are explained by regional differences in hospitalization rates.[16, 18, 19] Prior studies have worked to answer this question adding key insights into the nature of this relationship.[12, 15, 16]

The most famous of these studies compared hospitalization rates and patient outcomes in New Haven and Boston.[12, 15, 16] Using a retrospective design examining select regions Wennberg demonstrated that Boston had higher hospitalization rates for discretionary conditions, a longer length of stay, and greater per patient reimbursements from Medicare.[15, 16] Despite this disparity in hospitalization rates, New Haven and Boston had the same age-, sex- and race-adjusted mortality rate. Fisher followed up using the same construct to determine if readmission rates varied between Boston and New Haven.[12] Among patients hospitalized for non-discretionary conditions, Fisher found that risk-standardized readmission rates were higher in Boston relative to New Haven. These studies provided a detailed portrait of two cities with similar patient populations and significantly different hospitalization rates with no discernable difference in patient outcomes. While this question was first explored by Wennberg and

Fisher the limitation of these analyses lies in the inability to extrapolate these findings beyond New Haven and Boston.

Since their publication 17 years ago, there have been two major advances that allow for a nationwide analysis. First, data on condition specific hospitalization rates are readily available for every region in the nation. Second, there have been key advances in the field of measurement science. The use of hierarchical generalized linear models has allowed for more accurate estimation of risk-standardized readmission and mortality rates. Specifically, risk-standardized readmission and mortality rates developed by Krumholz et al. use hierarchical models that draw upon demographics and longitudinal patient-level clinical data to appropriately risk adjust.[20-22] These measures are endorsed the National Quality Forum and are produced for the Centers of Medicare and Medicaid Services (CMS). Furthermore, risk-standardized readmission and mortality rates for heart failure, acute myocardial infarction and pneumonia are calculated for every hospital and are publicly reported CMS. In essence, these risk-standardized outcomes measures provide a widely accepted indication of quality – patient readmission and mortality – independent of patient characteristics.

In Part II of this study, we examine whether variation in risk-standardized readmission and mortality rates is explained by variation in hospitalization rates. Specifically we examine this relationship for two cardiovascular conditions, AMI and HF.

Hospitalization Rates and Risk-Standardized AMI and HF Outcomes

AMI hospitalization rates have previously been shown to vary moderately from region to region. In addition, hospitalization for AMI is considered to be largely non-

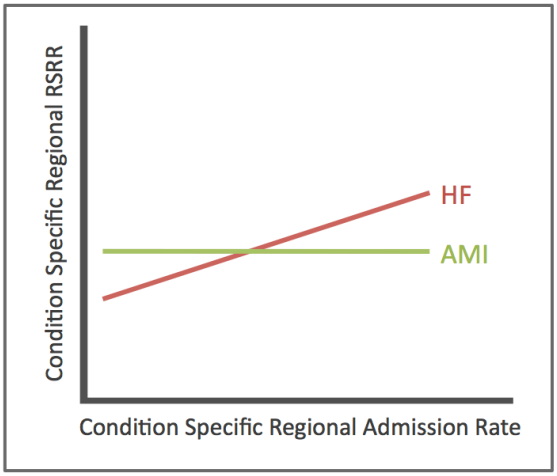
discretionary, meaning community incidence is thought to approximate hospitalization rates.

Given the nature of AMI hospitalizations, we expect regional AMI risk-standardized readmission rates to vary independently of AMI hospitalization rates.

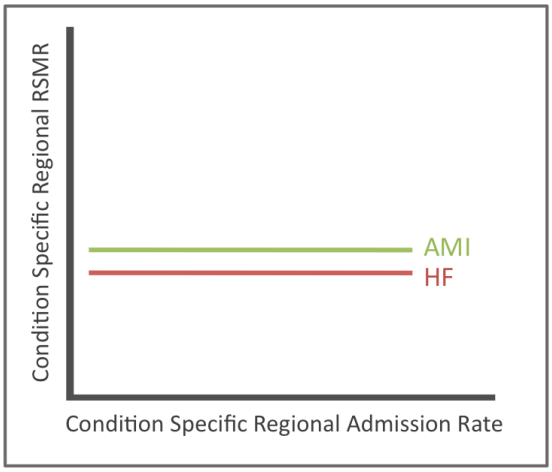
Stated differently, we expect there to be no association between regional AMI risk-standardized readmission rates and AMI hospitalization rates (Box 1). For similar reasons, we hypothesize no association regional AMI risk-standardized mortality rates and AMI hospitalization rates (Box 2).

On the other hand, HF hospitalization rates have previously been shown to vary highly from region to region. In addition, hospitalization for HF is considered to be more

Box 1: Condition Specific Readmission Analysis



Box 2: Condition Specific Mortality Analysis



discretionary and dependent on hospital and regional practices. For instance, given the same circumstances, a hypothetical patient hospitalized in one region may be treated as an outpatient and not hospitalized in another region. Given the discretionary nature of HF hospitalizations, we expect that regional HF risk-standardized readmission rates are

explained in part by regional HF hospitalization rates. Stated differently, we expect an association between regional HF risk-standardized readmission rates and HF hospitalization rates (Box 1). While we hypothesize that regional HF risk-standardized readmission rates are explained in part by hospitalization rates, we expect no relationship between regional HF risk-standardized mortality rates and HF hospitalization rates (Box 2). That is, while healthier patients may be admitted in regions with high HF hospitalization rates, our expectation is that the risk adjustment in the mortality model will appropriately reflect the decreased risk of mortality among these healthier patients.

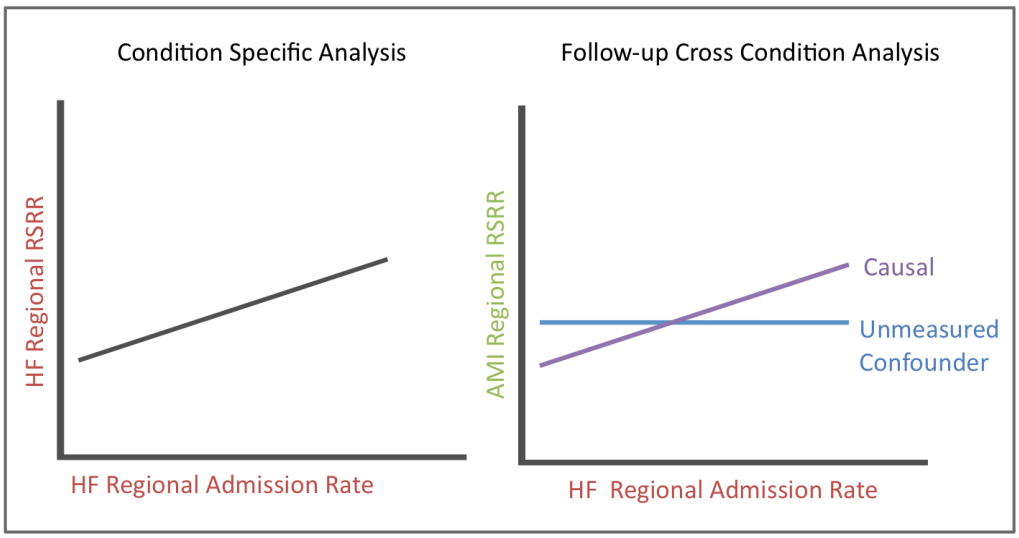
Exploring Unmeasured Confounders as Alternative Explanations

When examining the relationship between hospitalization rates and risk-standardized readmission rates, if all assumptions are accepted, then a correlation, positive or inverse, would indicated that regional variation in outcomes is explained in part by variation in hospitalization rates. However, in examining all possible explanations, assumptions must be questioned and further investigated. One particular assumption is that the risk-standardized readmission model is unbiased and an observed relationship is not confounded. For example, earlier we hypothesized a positive association between regional HF hospitalization rates and HF risk-standardized readmission rates. This may indicate lower quality in higher HF hospitalization regions or it may be the product of a systematic bias in the risk-standardized readmission model giving the appearance of poor quality in regions with higher HF hospitalization rates. In particular, in this example, an alternative explanation is that regions with high HF

hospitalization rates treat a sicker patient population (hence the high hospitalization rate) who are also sicker in ways not captured by the HF risk-standardized readmission model. This, in effect, would give the appearance of poor quality by way of higher readmission rates in regions with high HF hospitalization rates when in reality the observed relationship is confounded. To address this issue, we plan to perform "cross condition analyses." Continuing with the current example, to further analyze the relationship between regional HF hospitalization rates and HF risk-standardized readmission rates, we would examine the relationship between regional HF hospitalization rate and regional AMI risk-standardized readmission rate. This analysis allows us to provide additional evidence to discern whether an observed relationship is causal or confounded. In theory, the two are unrelated and should produce no correlation. However, if a similar positive association is observed between regional HF hospitalization rates and both HF and AMI risk-standardized readmission rates, then it may be taken as evidence of a causal relationship; specifically, that the observed positive relationship between HF hospitalization rates and HF risk-standardized readmission rates indicates lower quality in high admitting regions. On the other hand, if the relationship observed between regional HF hospitalization rate and HF risk-standardized readmission rates was not observed between regional HF hospitalization rate and AMI risk-standardized readmission rates, then it may be taken as evidence of a confounded relationship; specifically, that observed positive relationship between HF hospitalization rates and HF risk-standardized readmission rate is confounded by an unmeasured variable such as sickness of the patient population (Box 3).

As outlined above, given the discretionary nature of HF admissions, we hypothesize a positive correlation between regional HF hospitalization rate and HF risk-standardized readmission rate. Further, we believe this is a causal relationship and not due to an unmeasured confounder. Therefore, we also hypothesize a positive correlation between regional HF hospitalization rate and AMI risk-standardized readmission rate. As previously stated, hospitalization for AMI is believed to be a non-discretionary and as such we expect neither a relationship between regional AMI hospitalization rate and AMI risk-standardized readmission rate nor a relationship with HF risk-standardized readmission rate.

Box 3: Analysis for Determining if Observed Relationship is Causal or Confounded



Hypothesis and Specific Aims

Central Hypotheses:

Hypothesis 1 There is significant regional variation in the hospitalization rates for cardiovascular diseases such HF and AMI

Hypothesis 2 Cardiovascular need, as defined by the risk profile, explains only part of the variation observed in HF and AMI hospitalization rates

Hypothesis 3 Variation in regional risk-standardized readmission rates is explained in part by variation in regional hospitalization rates for HF, a more discretionary condition, but not regional hospitalization rates for AMI, a less discretionary condition.

Hypothesis 1: Specific Aim

Variation in admission rates is highest for discretionary conditions such as HF and variation in admission rates is lowest for conditions that have been less discretionary such as AMI

Hypothesis 2: Specific Aims

Aim 2.1 Individual cardiovascular risk factors are associated with regional variation in HF and AMI admission rates

Aim 2.2 Regional variation in HF and AMI hospitalization rates are incompletely explained by regional variation in cardiovascular risk profile

Hypothesis 3: Specific Aims

Aim 3.1 There is no association between regional AMI hospitalization rate and AMI risk-standardized readmission rates

Aim 3.2 There is a positive association between regional HF admission rate and HF risk-standardized readmission rates

Aim 3.3 There is no association between regional AMI hospitalization rate and HF risk-standardized readmission rates reinforcing the hypothesis that variation in risk-standardized readmission rates is unexplained by variation in AMI hospitalization rates

Aim 3.4 There is a positive association between regional HF admission rate and AMI risk-standardized readmission rate reinforcing the hypothesis that variation in risk-standardized readmission rate is explained, in part, by variation in HF hospitalization rates (i.e. evidence for a causal relationship)

Aim 3.5 There is a no association between regional AMI admission rate and AMI risk-standardized mortality rate

Aim 3.6 There is a no association between regional HF admission rate and HF risk-standardized mortality rate

Methods

State and Regional Admission Rates and Variation

The study population included Medicare fee-for-services patients, age 65 and older that were hospitalized between January 1, 2006 and December 31, 2008. Patients with principal discharge diagnosis of AMI and HF, as determined by *International Classification of Diseases, 9th Revision, Clinical Modification,* were included (please see supplemental table A and B for details). Data were obtained from the MedPAR dataset, a subset of the standard analytic files and enrollment databases of the Center for Medicare and Medicaid Services.

For this analysis, all admissions meeting the abovementioned criteria were included. Admission data was linked to the 2006 American Hospital Association (AHA) Annual Survey of Hospitals using Medicare Provider ID by Medicare Provider ID (variable "HCFAID").[23] Using geographic information in the 2006 AHA Annual Survey of Hospitals, admissions were aggregated to the hospital referral region (HRR) and state level. HRR are 306 functional geographic regions created based on patterns of referral for complex cardiac surgeries and neurosurgical procedures.[24] They are used as a proxy hospital and regional catchment areas in order to study regional variation.[9, 26-29] Medicare enrollment for each HRR and state was obtained from the Dartmouth Atlas Project.[25]

Admission rates for AMI and HF were obtained by dividing the annual regional admissions by regional enrollment. Variation in the admission rates among the 306 HRRs was calculated using a volume-weighted coefficient of variation (CV). Using the

coefficient of variation was more advantageous than using standard deviation (σ) because as a dimensionless, scale invariant metric, it allows for the comparison of various distributions of admission rates.[3] If CV is given by the formula:

$$CV = SD / \bar{x}, \quad \text{where} \quad SD = \text{standard deviation for all } x_i$$
$$\bar{x} = \text{mean of all } x_i$$
$$x_i = \text{resource/criterion for } i\text{th cell.}$$

However, if there are n regions and if w_i is the population of the ith region, then the volume-weighted coefficient of Variation (CV_W) is given by:[26]

$$CV_W = \left(\sum_{i=1}^{n} w_i (x_i - \bar{x}_W)^2 / \sum_{i=1}^{n} w_i\right)^{1/2} / \bar{x}_W$$

$$\text{where } \bar{x}_W = \sum_{i=1}^{n} w_i x_i / \sum_{i=1}^{n} w_i .$$

Part I: Defining and Assessing Cardiovascular Risk Profile

We defined cardiovascular risk profile as the prevalence of cardiovascular risk factors in a given region. We used data from the 2007 Behavioral Risk Factor Surveillance System (BRFSS) to assess the burden of cardiovascular risk factor in each state. The BRFSS is a high quality and validated on-going telephone survey system, tracking self-reported health conditions and risk behaviors across the United States.[17, 27] Cardiovascular risk factors were chosen based on the existing literature and included the community prevalence of diabetes, hyperlipidemia, obesity, hypertension, angina/coronary artery disease, tobacco use, inactivity, and history of prior myocardial infarction (please see supplemental table C for detailed description of the variables used).[28-33]

Part I: Statewide Admission Rates

Cardiovascular surveillance data in its most detailed form, from BRFSS or any other source is only available at the state level. Therefore, for the analyses in Part I, admission counts were aggregated to the state level and statewide enrollment data was used to calculate statewide hospitalization rates for AMI and HF.

Part I: Statistical Analysis

First, we conducted bivariate analyses to compare the statewide prevalence of individual cardiovascular risk factors and statewide admission rates for AMI and HF.

Then, we used a population-weighted standard least squares regression model to estimate the relationship between the prevalence of all cardiovascular risk factors and statewide hospitalization rates for AMI and HF. Because our objective in this analysis was to determine the predictive power of cardiovascular risk profile as defined by the aggregate of cardiovascular risk factors, colinearity of individual parameters in the model was not considered. Had our objective been to determine the individual drivers of the relationship between cardiovascular risk factors and hospitalization rates, a model with minimal colinearity would have been developed.

Part II: Study Population for Risk Standardized Readmission and Mortality Rates

Risk-standardized readmission rates and risk-standardized mortality rates were calculated based on the population of Medicare fee-for-service patients, 65 years of age and older who were hospitalized between January 1, 2006 and December 31, 2008. Patients who had a principle discharge diagnosis of AMI and HF, as determined by

International Classification of Diseases, 9th Revision, Clinical Modification were included (please see supplemental table A and B for details). Data were obtained from the MedPAR dataset, a subset of the standard analytic files and enrollment databases of the Center for Medicare and Medicaid Services. This data from 2006 to 2008 included demographic information, principal and secondary discharge diagnoses codes, procedure codes and discharge disposition. We included patients with 12 months of continuous enrollment in Medicare fee-for-service prior to hospitalization to obtain existing comorbid conditions for the purpose of risk adjustment. Medicare Part A and B data were used to determine patients' existing comorbidities, medical history and use of procedures in the 12 months prior to the indexed admission. Patients who were transferred during a hospitalization were linked into a single episode of care with the outcome, readmission or mortality, attributed to the hospital where the patient was admitted first. Patients who were discharged against medical advice and patients who were discharged alive within the first day after admission were excluded from the calculation of risk-standardized readmission rates and risk-standardized mortality rates.

Part II: Modified Regional Admission Rates

For the analysis in Part II, regional hospitalization rates for AMI and HF were calculate as mentioned above with one modification. To prevent a circular analysis in the analysis comparing hospitalization rates to readmission and mortality rates, any hospitalization that occurred within 30 days of an indexed hospitalization were not counted towards a regions hospitalization rate.

Part II: Statistical Analysis

Risk-standardized readmission and mortality rates for AMI and HF were estimated using hierarchical logistic-regression models for death or readmission within 30 days of indexed hospitalization. Readmission and mortality rates were adjusted for age, sex and clinical characteristics. The mortality measure for AMI included 10 cardiovascular clinical characteristics and 15 coexisting conditions and the mortality measure for HF included 8 cardiovascular characteristics and 14 coexisting conditions. The readmission measure for AMI included 10 cardiovascular clinical characteristics and 19 coexisting conditions and the readmission measure for HF included 9 cardiovascular characteristics and 26 coexisting conditions (see supplemental table D-G for details).

Hierarchical modeling was used to account for the clustering of outcomes within hospitals. The models estimate readmission and mortality rates as a function of patient level characteristics outlined above and as a function of a random hospital-specific effect. Hospital-level random intercepts are assumed to be normally distributed to account for clustering and permit separation of inter- and intra-hospital variation. The rates are calculated as a ratio of predicted to expected readmissions or deaths. The expected number of events is estimated using an individual hospital's patient mix and the *average* hospital specific intercept term whereas the predicted number of events is estimated using an individual hospital's patient mix and the *individual* hospital-specific intercept term. The risk-standardized readmission and mortality rate are calculated by multiplying the ratio of predicted to expected by the unadjusted national readmission or mortality rate.

The RSRR and RSMR models for AMI and HF were developed for CMS, have been endorsed by the National Quality Forum and adhere to national published standards for outcome measures.[34] Mortality and readmission models are based on administrative data and validated against models using medical records.[20, 21, 35]

Hospital risk-standardized mortality and readmission rates were linked to the 2006 AHA Annual Survey of Hospitals using Medicare provider ID number for geographical information. HRR level risk-standardized readmission and mortality rates were produced using a volume-weighted aggregation.

The relationships between regional hospitalization rates and both risk standardized readmission and mortality rates were characterized using a volume-weighted least squares regression. Ninety five percent confidence interval was calculated for each regression coefficient (R^2) by use of the Fisher transformation.

Analyses

Risk standardized readmission and mortality rates for AMI and HF were developed at the Yale Center for Outcomes Research and Evaluation (CORE). For this analysis, hospital level output of risk standardized readmission and mortality rates for AMI and HF were produced by Changqin Wang, MD, SM, and Zhenqiu Lin, PhD. All analyses were complete by Sachin Shah. Analyses were completed with the use of SAS software, version 9.1.3 (SAS Institute), JMP software, version 9.0.0 (SAS Institute), and Access 2007 software, (Microsoft). All statistical tests were two-tailed and used a type I error rate of 0.05.

Results

Admission Rates

We indentified 826,855 admissions for AMI (AMI) at 3,927 hospitals between 2006 and 2008. During the same time, we identified 1,838,372 admissions for HF at 4,404 hospitals. Among the 306 hospital referral regions (HRRs), the AMI hospitalization rate (admissions per 1,000 enrollees) ranged from 2.3 to 23.9, with mean of 10.0 and a standard deviation of 2.7 (Figure 1). HF hospitalization rate (admissions per 1,000 enrollees) ranged from 8.0 to 45.5 with a mean of 21.7 and a standard deviation of 6.4.

State admission rates for AMI and HF displayed similar distribution patterns. Among the 50 states, the AMI hospitalization rate (admissions per 1,000 enrollees) ranged from 5.4 to 13.8 with a mean of 9.6 and a standard deviation of 1.9 (Figure 2). HF hospitalization rate (admissions per 1,000 enrollees) ranged from 9.9 to 31.8, with a mean of 20.3 and a standard deviation of 5.7.

Variation

The volume-weighted coefficient of variation (CV_W) for regional AMI and HF admission rates were 0.24 and 0.26, respectively (Table 1). Historic data from 2005 shows the coefficient of variation for admission rates of common conditions varies from 0.09, for colon resection for colon cancer to 0.39 for gastroenteritis. The variation in regional admission rates for colectomy and hip fracture were 38% and 48% of the variation observed in AMI and HF admission rates, respectively.

Part I: Admission Rates and Individual Cardiovascular Risk Factors

All individual cardiovascular risk factors were significantly associated with AMI hospitalization rates (Figure 3). Statewide prevalence of cardiovascular disease (angina or coronary artery disease) had the strongest association with statewide AMI hospitalization rates (R^2 of 0.42, $p<0.001$), (Table 2). Statewide prevalence of daily tobacco use had the weakest association with statewide AMI hospitalization rates (R^2 of 0.14, $p=0.008$). Statewide prevalence of diabetes, high cholesterol, obesity, inactivity, hypertension and prior history of AMI were all significantly associated with statewide AMI hospitalization rates ($p<0.05$ for all).

All individual cardiovascular risk factors were significantly associated with HF hospitalization rates (Figure 4). The statewide prevalence of inactive adults (adults not meeting recommended amount of physical activity) had the strongest association with statewide HF hospitalization rates (R^2 of 0.54, $p<0.001$), (Table 3). Statewide prevalence of high cholesterol had the weakest association with statewide HF hospitalization rates (R^2 of 0.12, $p=0.013$). Statewide prevalence of diabetes, daily tobacco use, obesity, hypertension, prior history of AMI and cardiovascular disease (angina or coronary artery disease), were all significantly associated with statewide HF hospitalization rates ($p<0.05$ for all).

Part I: Cardiovascular Risk Profile as Predictive of State Hospitalization Rates

The summary of fit of the cardiovascular risk profile model used to predict statewide AMI hospitalization rates is shown in Table 4. The model produces an R^2 of

0.49 (observed vs. predicted), and the composite model has an *F* statistic of 5.02 ($p<0.001$), (Figure 5 and Table 4).

The summary of fit of the cardiovascular risk profile model used to predict statewide HF hospitalization rates is shown in Table 5. The model produced an R^2 of 0.51 (observed vs. predicted), and the composite model has an *F* statistic of 5.25 ($p<0.001$), (Figure 6 and Table 5).

Part II: Admission Rates and Risk Standardized Readmission Rates (RSRRs)

The volume-weighted linear regression shows regional AMI hospitalization rate to be weakly associated with regional AMI risk-standardized readmission rate (R^2 of 0.05, 95%CI 0.01-0.11, $p<0.001$), (Figure 7). In contrast, regional HF hospitalization rate was modestly associated with HF risk-standardized readmission rate (R^2 of 0.32, 95%CI 0.23-0.40, $p<0.001$), (Figure 8).

Cross-condition analysis showed that regional AMI hospitalization rate was weakly albeit significantly associated with HF risk-standardized readmission rate (R^2 of 0.07, 95%CI 0.02-0.13, $p<0.001$), (Figure 9). In contrast, regional HF hospitalization rate was modestly associated with AMI risk-standardized readmission rate (R^2 of 0.28, 95%CI 0.20-0.37, $p<0.001$), (Figure 10).

Part II: Admission Rates and Risk Standardized Mortality Rates (RSMRs)

Volume-weighted linear regression shows regional AMI hospitalization rate was not significantly associated with regional AMI risk-standardized mortality rate (R^2 of 0.0, 95%CI 0.00-0.04, $p=0.07$), (Figure 11). In contrast, regional HF hospitalization rate was

modestly and inversely associated with HF risk-standardized mortality rate (R^2 of 0.17, 95%CI 0.10-0.25, p<0.001), (Figure 12).

Cross-condition analysis showed that regional AMI hospitalization rate was weakly, albeit significantly, associated with HF RSMR (R^2 of 0.03, 95%CI 0.00-0.08, p=0.004), (Figure 13). Regional HF hospitalization rate was not significantly associated with AMI risk-standardized mortality rate (R^2 of 0.00, 95%CI 0.00-0.02, p=0.619), (Figure 14).

Discussion

In line with previous work, we found that there continues to be considerable regional variation in hospitalization rate for cardiovascular disease. The causes and implications of this variation are important to patients, physicians and policymakers alike.

In Part I of this analysis we found that statewide prevalence of traditional cardiovascular risk factors are modestly associated with statewide AMI and HF hospitalization rates. In aggregate, the cardiovascular risk profile explains 49% of the variation observed in statewide AMI hospitalization rates. Similarly, in aggregate, the cardiovascular risk profile explains 65% of the variation observed in statewide HF hospitalization rates. While much of the variation in admission rates is explained by the underlying burden of cardiovascular risk factors, a large portion of the variation is unexplained and may be unwarranted. While this is consistent with prior examinations of all-cause admission rates and general population health, this relationship has not been previously quantified for cardiovascular hospitalization.

Given the less discretionary nature of AMI admissions relative to HF admissions, we expected regional cardiovascular risk profile would explain larger portion of the variation in AMI hospitalization rates relative to HF hospitalization rates. We did not observe this, which may be due to ecologic fallacy, a limitation in our study design described below.

In Part II of this analysis, we found that regional variation in AMI risk-standardized readmission rates and risk-standardized mortality rates are not explained by regional variation in AMI hospitalization rates. This is consistent with prior observations that admission for AMI is less discretionary than other conditions.

On the other hand, we found that HF risk-standardized readmission rates are explained in part by HF hospitalization rates. This observation is lent additional weight because, in the cross-condition analysis, we found that AMI risk-standardized readmission rates are also explained in part by HF hospitalization rates. We believe the two observations taken together provide evidence for a causal relationship -- expressly that regional HF hospitalization rate carries some information about the regional propensity to admit.

In addition, we came upon an observation that suggests regional variation in HF risk-standardized mortality rates are explained in part by regional HF hospitalization rates -- specifically that regions with high HF hospitalization rates tend to have lower HR risk-standardized mortality rates. The casual nature of this relationship was called into question when the cross-condition analysis showed none of the variation in AMI risk-standardized mortality rates was explain HF admission rates. We believe the two observations taken together provide evidence that the observed relationship between regional HF risk-standardized mortality rate and HF hospitalization rate is due to an unmeasured confounder. Specifically, we believe that regions with higher HF hospitalization rates may be admitting healthier patients whose minimal risk of death is

not inadequately captured by the risk standardization model and therefore it appears as though regions with higher hospitalization rates provide.

Forty years after variation in inpatient utilization was first described, we believe our study add to the understanding of this variation in two key ways.

First, as studies examine the implications of the regional variation in inpatient utilization, we believe this work demonstrates that large variation in hospitalization rates are unexplained by regional variation in risk profiles.

Second, we found that variation in HF and AMI risk-standardized readmission rates are explained in part by regional HF hospitalization rates but are not explained by regional AMI hospitalization rates. We believe this association is due to the observation that HF admissions are more discretionary than AMI admissions; in fact, we believe that regional HF hospitalization rate is a marker for regional propensity to admit (and readmit) patients. In this study we were not able to examine the association between cardiovascular risk profile adjusted regional admission rate and regional outcomes. This is our next step and we believe that analysis will allow for a more precise examination of the unmeasured regional propensity to admit.

Our study had a number of limitations. First, our statewide analysis is subject to ecologic fallacy -- the misattribution of regional characteristics to individuals. However, we are unable to remedy this given the paucity of patient level risk factor data. Second, we only examined AMI and HF and the findings may not be easily translated other common medical conditions such as pneumonia. Third, regional RSMRs and RSRRs were calculated using volume-weighted aggregation where a more precise regional estimate

could be developed using a three level hierarchical model. Finally, we examined AMI and HF outcomes with respect to mortality and readmission and did not examine functional health status, which was not possible with administrative data.

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Figures References and Legends

Figure 1. Distribution and Central Tendencies of Regional Acute Myocardial Infarction Admissions / 1000 enrollees (top) and Heart Failure Admissions / 1000 enrollees (bottom)

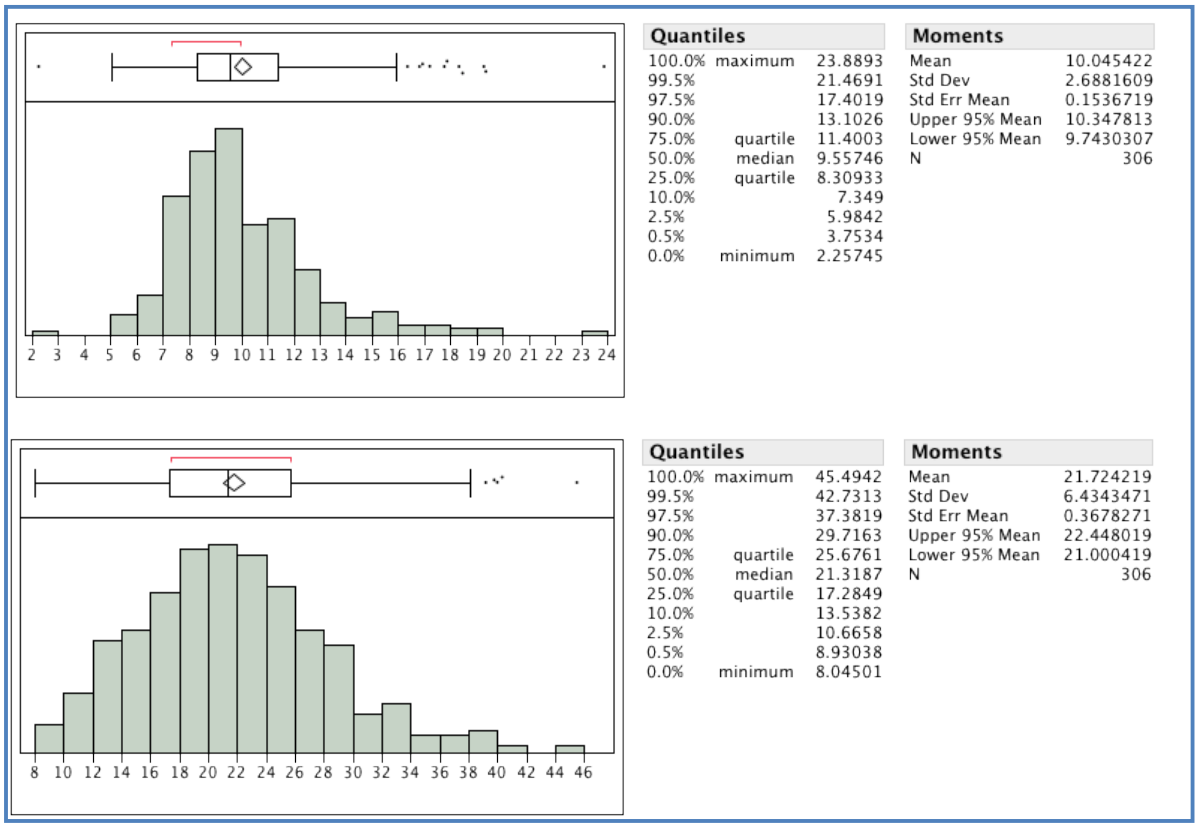


Figure 2. Distribution and Central Tendencies of State Acute Myocardial Infarction Admissions / 1000 enrollees (top) and Heart Failure Admissions / 1000 enrollees (bottom)

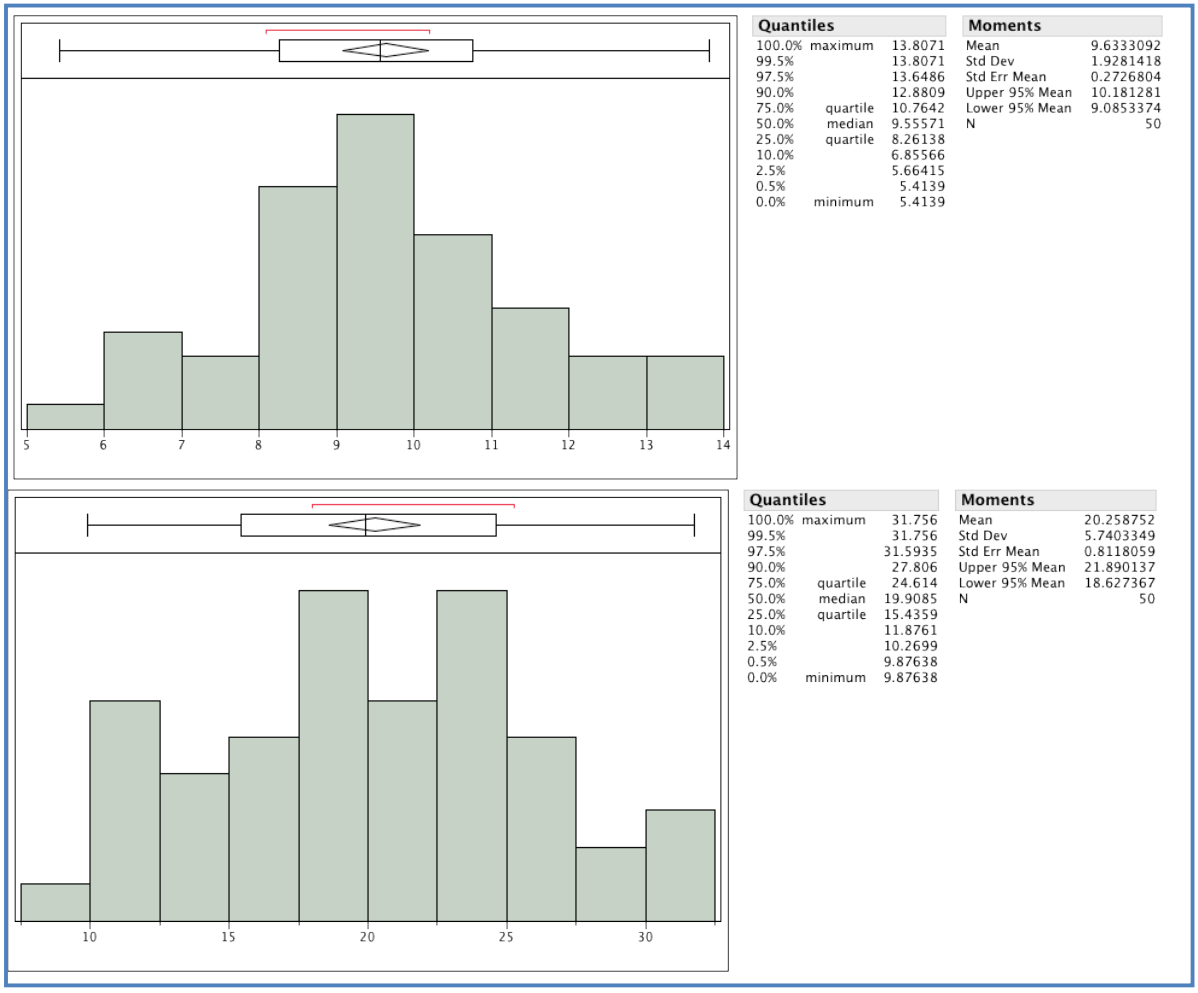


Figure 3. Bivariate Comparisons between Statewide Prevalence of Individual Cardiovascular Risk Factors by Acute Myocardial Infarction Admission Rates (Panels A through I)

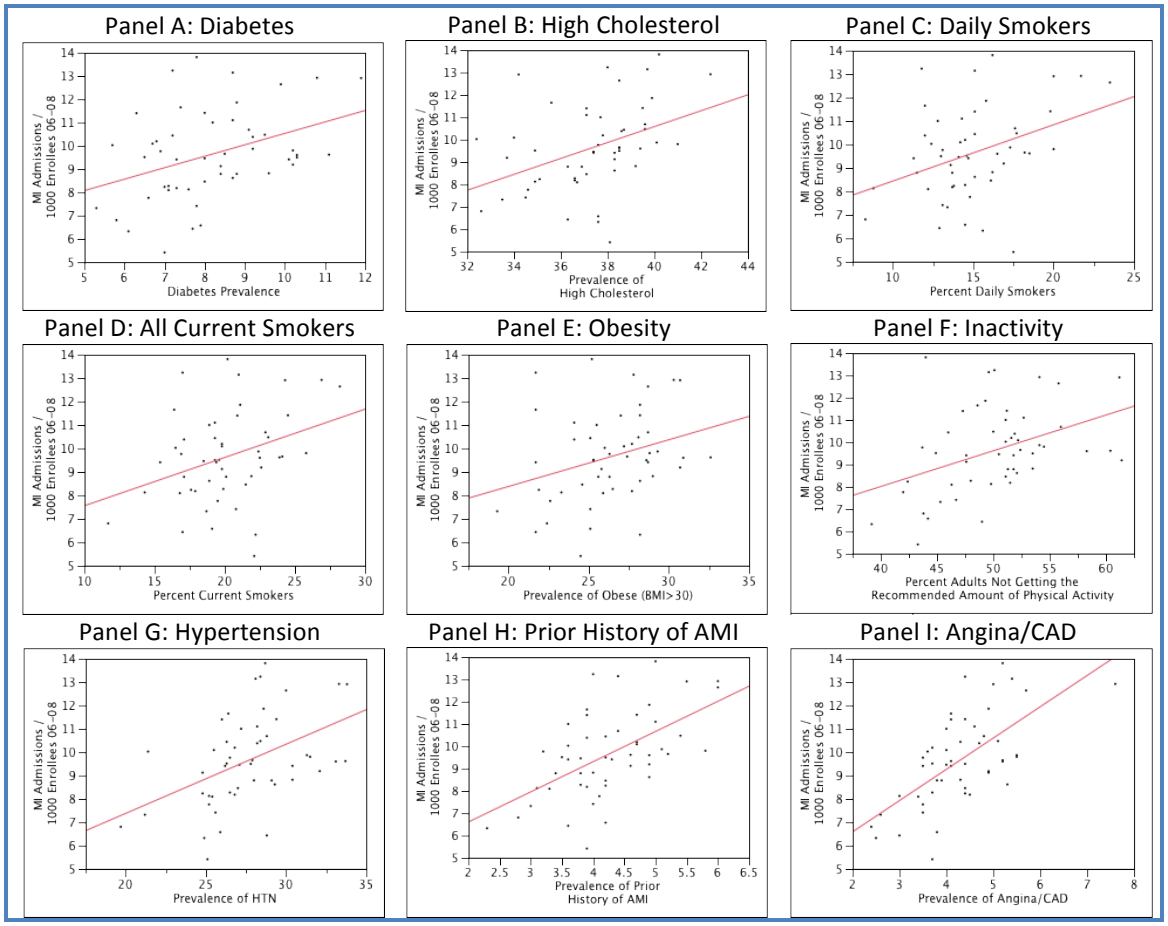


Figure 4. Bivariate Comparisons between Statewide Prevalence of Individual Cardiovascular Risk Factors by Heart Failure Admission Rates (Panel A through I)

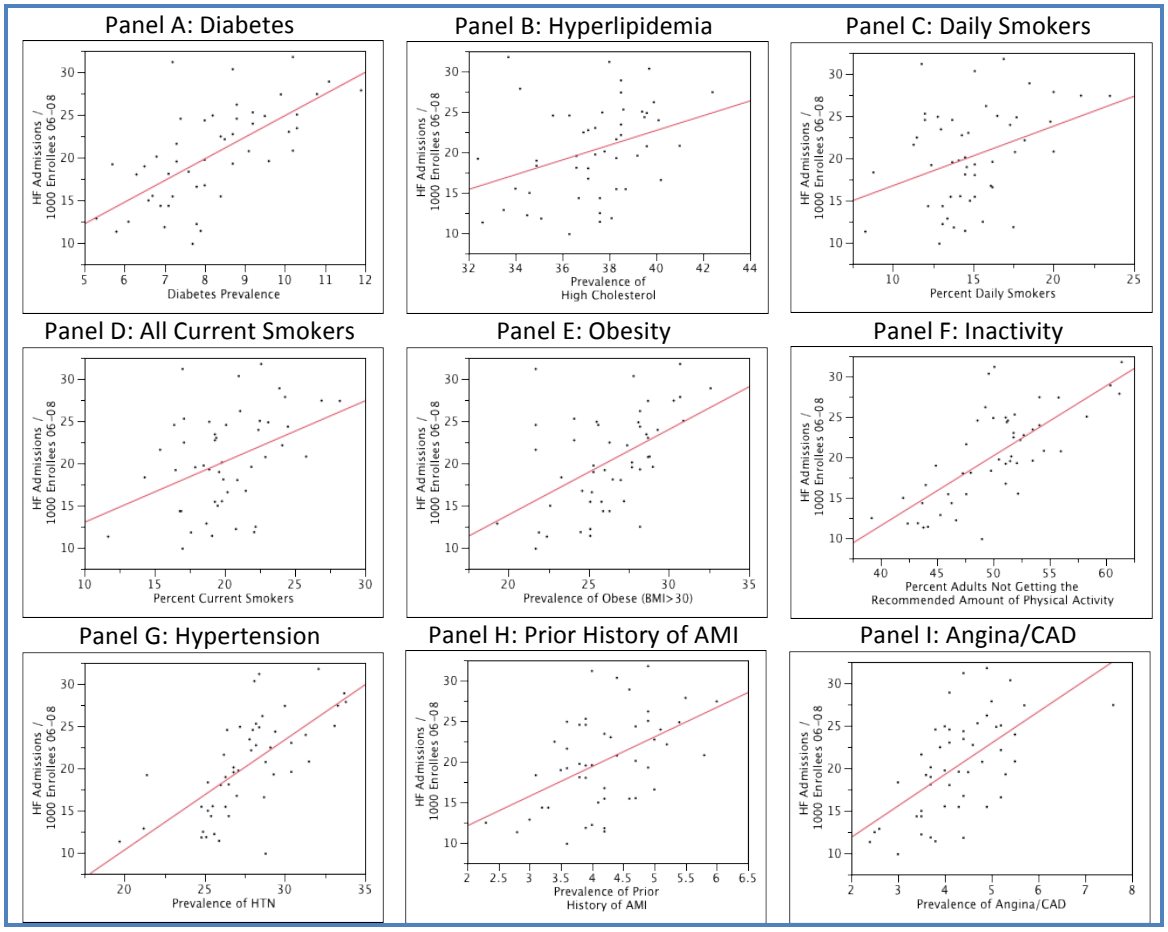


Figure 5. Volume-Weighted Multivariate Model of Cardiovascular Risk Profile as Predictive of Statewide Acute Myocardial Infarction Admission Rates

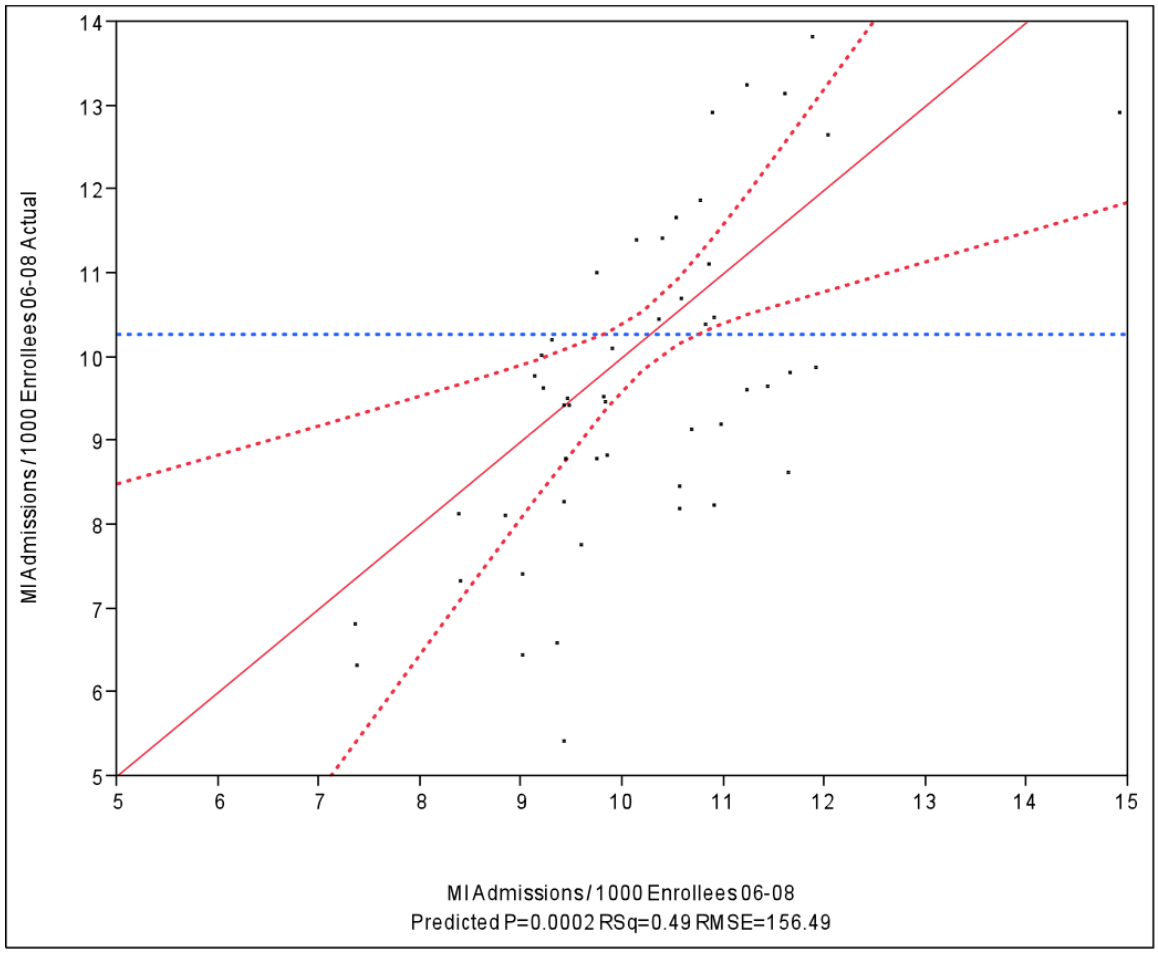


Figure 6. Volume-Weighted Multivariate Model of Cardiovascular Risk Profile as Predictive of Statewide Heart Failure Admission Rates from 2006 to 2008

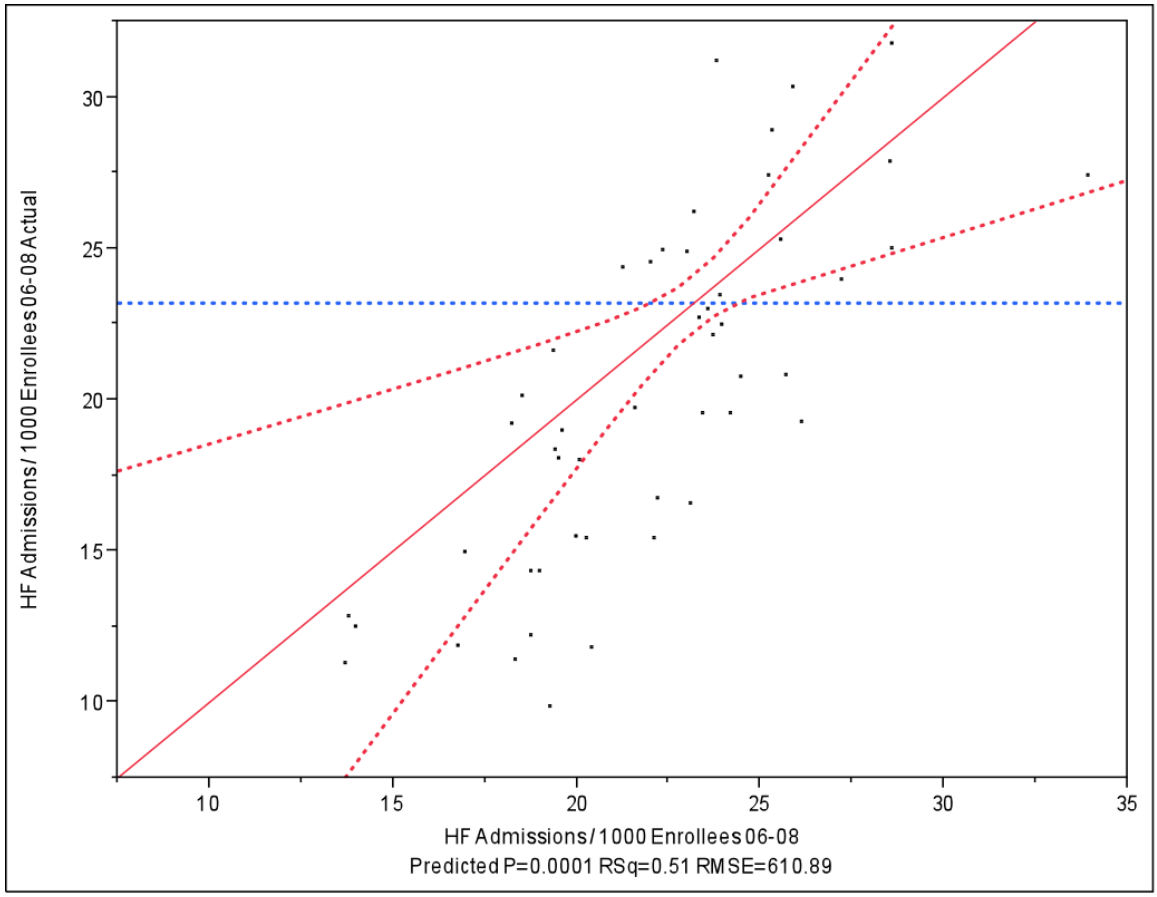


Figure 7. Relationship between Regional Acute Myocardial Infarction Admission Rate and Risk-Standardize Readmission Rate

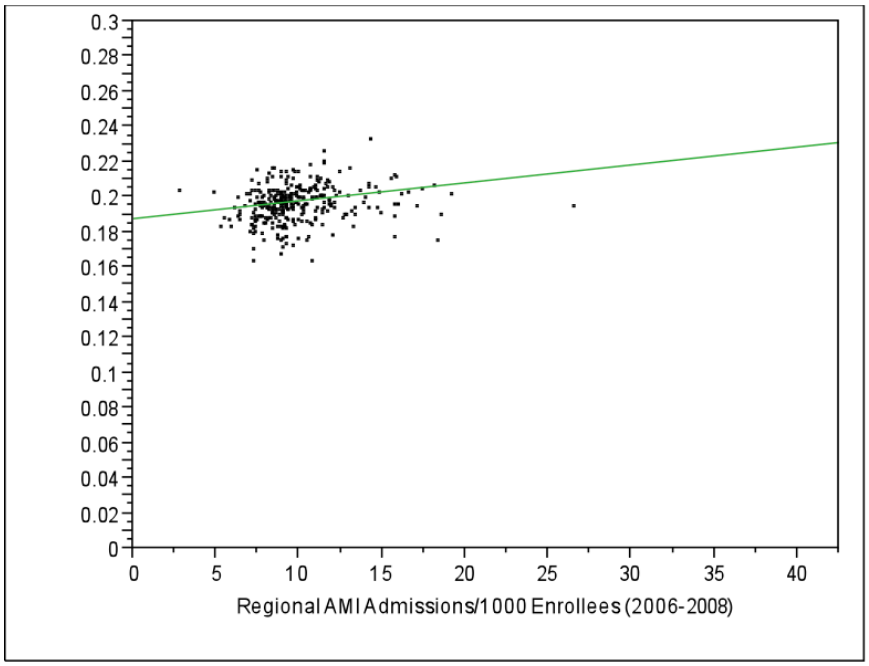


Figure 8. Relationship between Regional Heart Failure Admission Rate and Risk-Standardized Readmission Rate

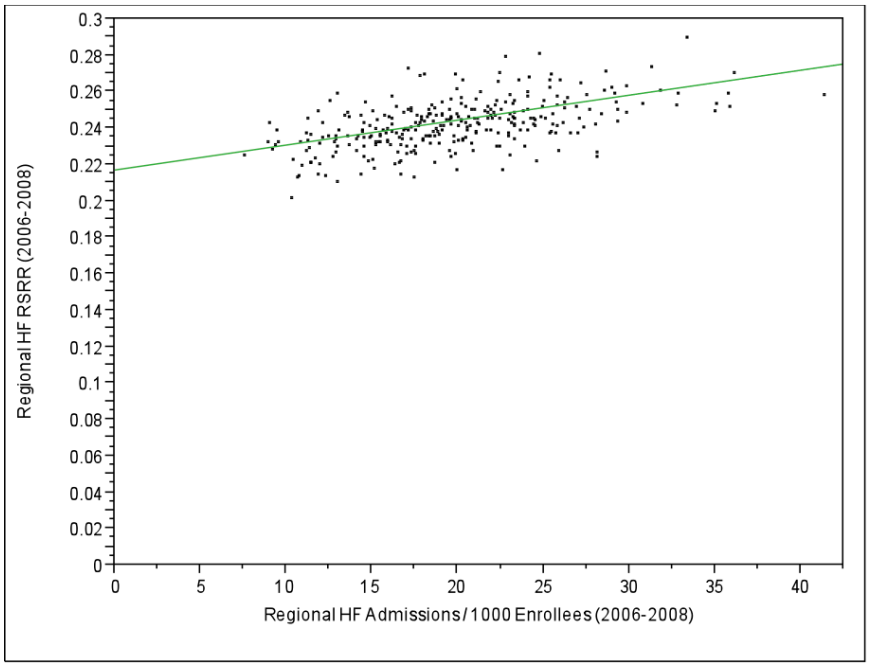


Figure 9. Relationship between Regional Acute Myocardial Infarction Admission Rate and Regional Heart Failure Risk-Standardized Readmission Rate

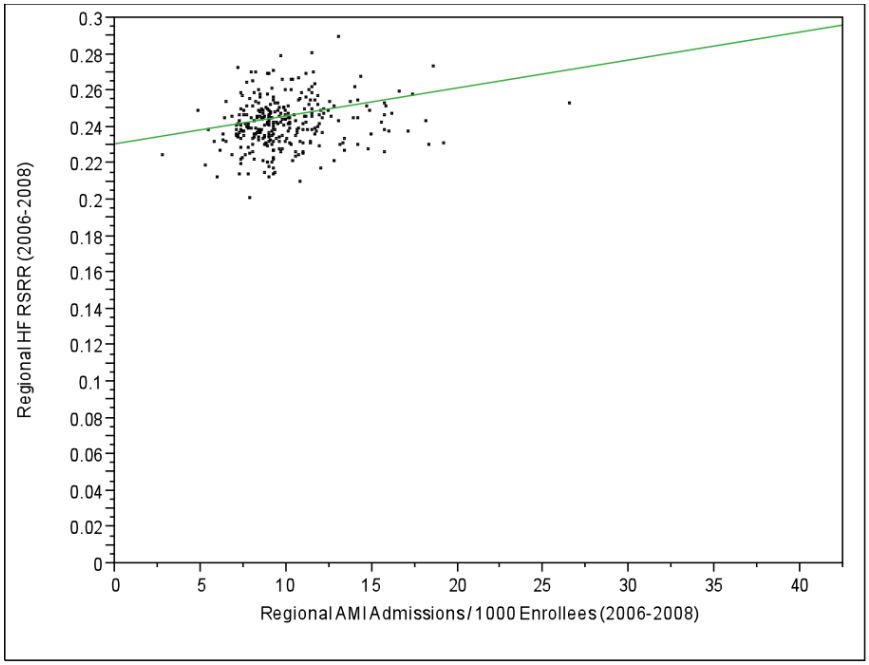


Figure 10. Relationship between Regional Heart Failure Admission Rate and Regional Acute Myocardial Infarction Risk-Standardized Readmission Rate

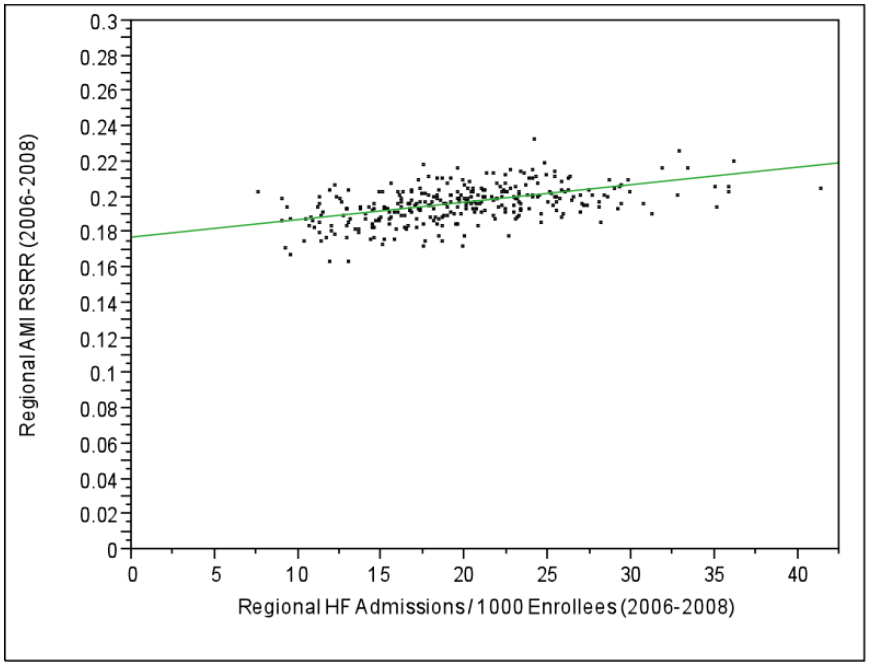


Figure 11. Relationship between Regional Acute Myocardial Infarction Admission Rate and Risk-Standardize Mortality Rate

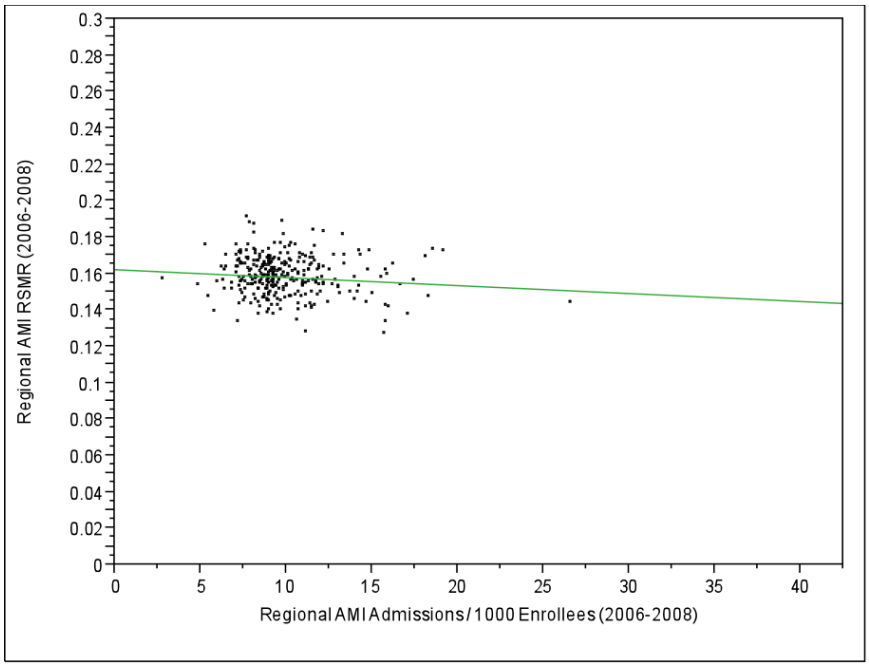


Figure 12. Relationship between Regional Heart Failure Admission Rate and Risk-Standardized Mortality Rate

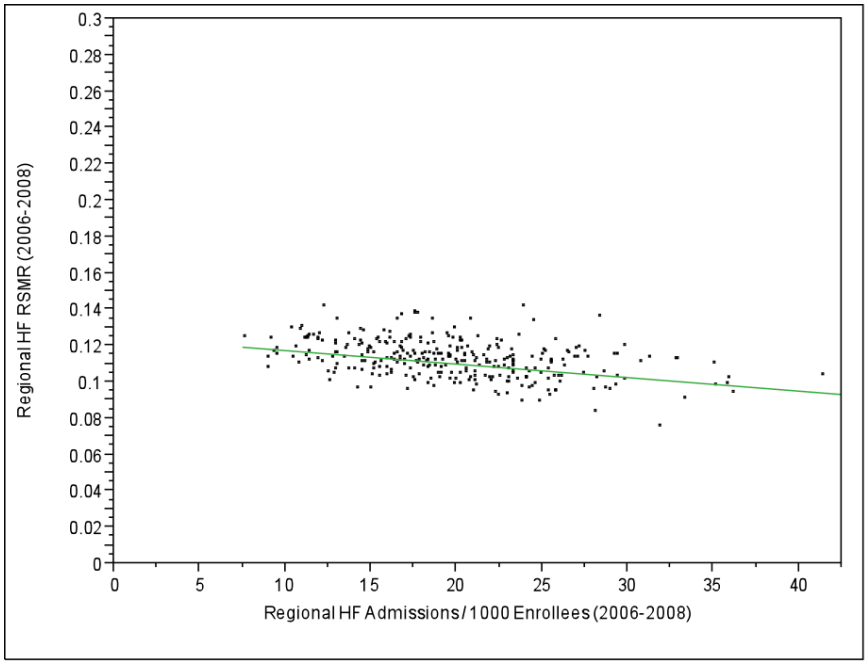


Figure 13. Relationship between Regional Acute Myocardial Infarction Admission Rate and Regional Heart Failure Risk-Standardized Mortality Rate

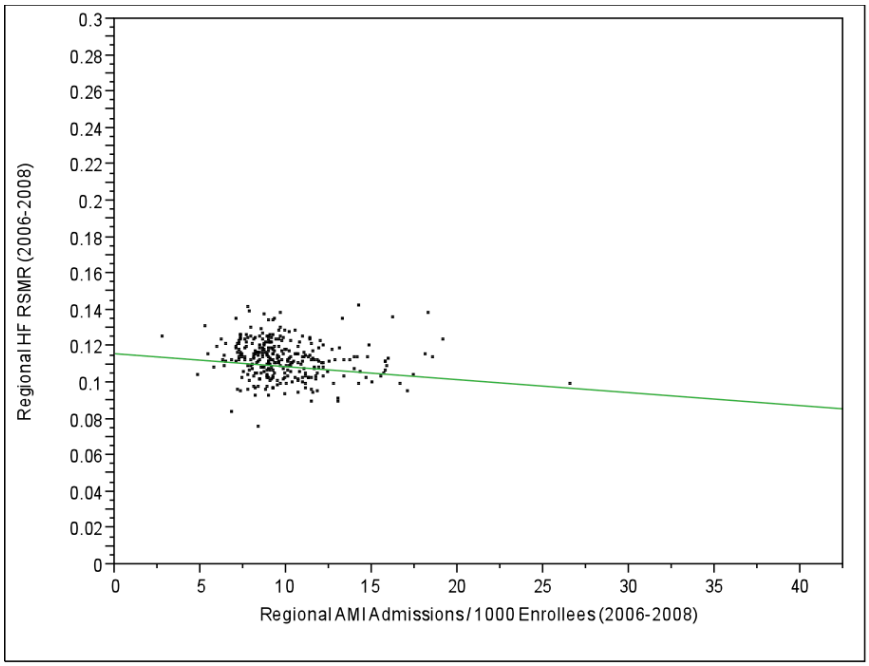
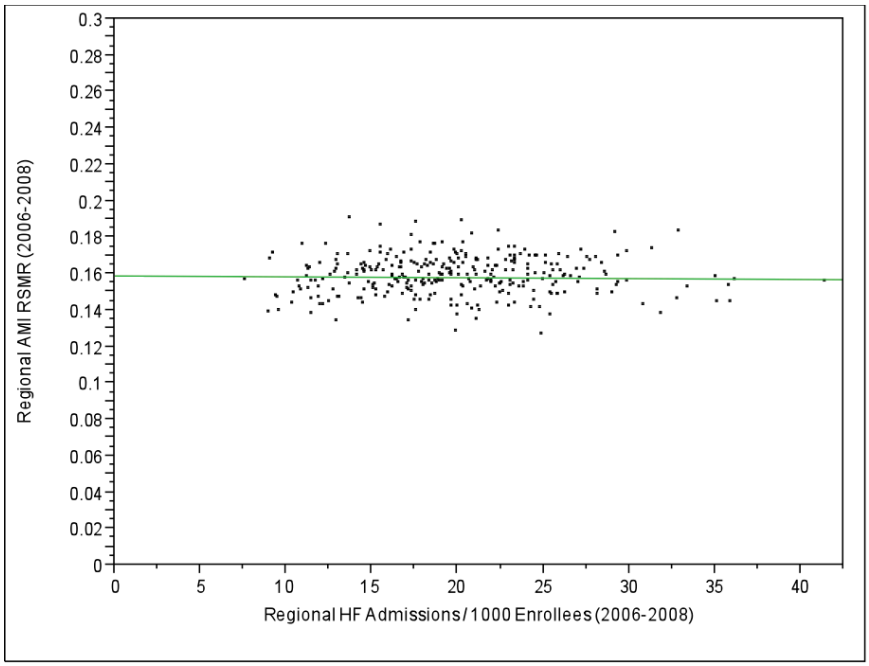


Figure 14. Relationship between Regional Heart Failure Admission Rate and Regional Acute Myocardial Infarction Risk-Standardized Mortality Rate



Tables

Table 1: Regional Distribution and Coefficient of Variation of Selected Admission Conditions

Admission Diagnosis (Admission per 1,000 Medicare Enrollees)	Mean	Standard Deviation	Range	Weighted Coefficient of Variation (CV_W)	Variation Relative to AMI
- Conditions in Current Analysis (2006-2008) -					
Acute Myocardial Infarction	10.0	2.7	2.3-23.9	0.24	1.00
Heart Failure	21.7	6.4	8.0-45.5	0.26	1.08
- Historic Data for Comparison (2005) -					
Percutaneous Coronary Intervention (PCI)	11.39	2.29	7.42-16.71	0.20	0.83
Angiography	21.89	4.31	14.64-33.31	0.20	0.83
Coronary Artery Bypass Surgery (CABG)	4.86	0.91	2.81-6.61	0.19	0.79
Hip Fracture	7.53	0.77	6.37-9.09	0.10	0.48
Resection for Colon Cancer	1.71	0.16	1.30-2.01	0.09	0.38
Angina	1.04	0.31	0.59-1.91	0.30	1.25
Gasteroenteritis	1.35	0.52	0.51-2.93	0.39	1.63

Table 2: Bivariate Comparison between Statewide Prevalence of Individual Cardiovascular Risk Factors and Acute Myocardial Infarction Admission Rates

Risk Factor	Slope	Standard Error	R^2	P Value
Prevalence of Diabetes	0.49	0.17	0.15	0.006
Prevalence of High Cholesterol	0.36	0.12	0.17	0.003
Percent Daily Smokers	0.24	0.09	0.14	0.008
Percent Current Smokers	0.21	0.08	0.12	0.016
Prevalence of Obesity	0.20	0.09	0.09	0.037
Percent Adults Inactivity	0.16	0.05	0.17	0.003
Prevalence of Hypertension	0.30	0.08	0.21	<0.001
Prevalence of Prior History of AMI	1.35	0.28	0.32	<0.001
Prevalence of Angina/CAD	1.33	0.23	0.42	<0.001

Table 3: Bivariate Comparison between Statewide Prevalence of Individual Cardiovascular Risk Factors and Heart Failure Admission Rates

Risk Factor	Slope	Standard Error	R^2	P Value
Prevalence of Diabetes	2.53	0.41	0.44	<0.001
Prevalence of High Cholesterol	0.91	0.35	0.12	0.013
Percent Daily Smokers	0.71	0.26	0.13	0.009
Percent Current Smokers	0.72	0.24	0.16	0.004
Prevalence of Obesity	1.01	0.25	0.26	<0.001
Percent Adults Inactivity	0.86	0.11	0.54	<0.001
Prevalence of Hypertension	1.31	0.20	0.46	<0.001
Prevalence of Prior History of AMI	3.64	0.88	0.26	<0.001
Prevalence of Angina/CAD	3.70	0.71	0.36	<0.001

Table 4: Volume-Weighted Multivariate Model of Cardiovascular Risk Profile as Predictive of Statewide Acute Myocardial Infarction Admission Rates, Summary of Fit (a), Analysis of Variance (b), and Parameter Estimates (c)

Summary of Fit	
RSquare	0.49461
RSquare Adj	0.395997
Root Mean Square Error	156.4914
Mean of Response	10.27332
Observations (or Sum Wgts)	829684

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	982654.9	122832	5.0157
Error	41	1004072.5	24490	**Prob > F**
C. Total	49	1986727.4		0.0002*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	t Ratio	Prob>|t|
Prevalence of Angina/CAD	1.61775	0.49976	3.24		0.0024*
Prevalence of Obese (BMI>30)	-0.1129	0.12399	-0.91		0.3679
Diabetes Prevalence	-0.2831	0.31382	-0.90		0.3722
Prevalence of HTN	0.14516	0.16422	0.88		0.3819
Prevalence of High Cholesterol	-0.0555	0.14052	-0.40		0.6948
Percent Daily Smokers	0.01326	0.13281	0.10		0.9209
Prevalence of Prior History of AMI	-0.0517	0.57017	-0.09		0.9282
Percent Adults Inactive	0.00112	0.09033	0.01		0.9902

Table 5: Volume-Weighted Multivariate Model of Cardiovascular Risk Profile as Predictive of Statewide Heart Failure Admission Rates, Summary of Fit (a), Analysis of Variance (b), and Parameter Estimates (c)

Summary of Fit	
RSquare	0.505898
RSquare Adj	0.409487
Root Mean Square Error	610.8854
Mean of Response	23.1894
Observations (or Sum Wgts)	1846603

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	15665673	1958209	5.2473
Error	41	15300422	373181	**Prob > F**
C. Total	49	30966095		0.0001*

Parameter Estimates

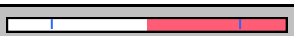
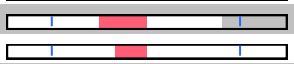
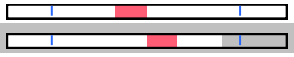
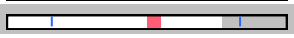
Term	Estimate	Std Error	t Ratio	t Ratio	Prob>|t|
Prevalence of Angina/CAD	3.89068	1.29854	3.00		0.0046*
Prevalence of HTN	0.55920	0.43763	1.28		0.2085
Prevalence of Prior History of AMI	-1.5199	1.53551	-0.99		0.3281
Percent Daily Smokers	-0.2379	0.35594	-0.67		0.5076
Percent Adults Inactive	0.16414	0.24913	0.66		0.5137
Prevalence of High Cholesterol	-0.2315	0.36876	-0.63		0.5336
Diabetes Prevalence	0.24692	0.81746	0.30		0.7641
Prevalence of Obese (BMI>30)	-0.02914	0.33050	-0.09		0.9302

Table 6: Relationship between Regional Admission Rates for Acute Myocardial Infarction (AMI) and Heart Failure (HF), and Risk Standardized Readmission Rates (RSRR)

Admission Rate (Independent)	Condition RSRR (Dependent)	Slope	Standard Error	R^2 (95% CI)	P Value
AMI	AMI	1.0×10^{-3}	2.5×10^{-4}	0.05 (0.01-0.11)	<0.001*
HF	HF	1.4×10^{-3}	1.2×10^{-4}	0.32 (0.23-0.40)	<0.001*
AMI	HF	1.5×10^{-3}	3.3×10^{-4}	0.07 (0.02-(0.13)	<0.001*
HF	AMI	9.9×10^{-4}	9.1×10^{-5}	0.28(0.20-0.37)	<0.001*

Table 7: Relationship between Regional Admission Rates for Acute Myocardial Infarction (AMI) and Heart Failure (HF), and Risk Standardized Mortality Rates (RSMR)

Admission Rate (Independent)	Condition RSMR (Dependent)	Slope	Standard Error	R^2 (95% CI)	P Value
AMI	AMI	-4.4×10^{-4}	2.4×10^{-4}	0.01 (0.00-0.04)	0.067
HF	HF	-7.5×10^{-4}	9.4×10^{-5}	0.17 (0.10-.25)	<0.001*
AMI	HF	-7.2×10^{-4}	2.5×10^{-4}	0.03 (0.00-0.08)	0.004*
HF	AMI	-5.1×10^{-5}	1.0×10^{-4}	0.00 (0.00-0.02)	0.619

Supplemental Tables

Supplemental Table A: ICD-9-CM definition of Acute Myocardial Infarction

ICD-9-CM	Description
410.00	AMI (anterolateral wall) – episode of care unspecified
410.01	AMI (anterolateral wall) – initial episode of care
410.10	AMI (other anterior wall) – episode of care unspecified
410.11	AMI (other anterior wall) – initial episode of care
410.20	AMI (inferolateral wall) – episode of care unspecified
410.21	AMI (inferolateral wall) – initial episode of care
410.30	AMI (inferoposterior wall) – episode of care unspecified
410.31	AMI (inferoposterior wall) – initial episode of care
410.40	AMI (other inferior wall) – episode of care unspecified
410.41	AMI (other inferior wall) – initial episode of care
410.50	AMI (other lateral wall) – episode of care unspecified
410.51	AMI (other lateral wall) – initial episode of care
410.60	AMI (true posterior wall) – episode of care unspecified
410.61	AMI (true posterior wall) – initial episode of care
410.70	AMI (subendocardial) – episode of care unspecified
410.71	AMI (subendocardial) – initial episode of care
410.80	AMI (other specified site) – episode of care unspecified
410.81	AMI (other specified site) – initial episode of care
410.90	AMI (unspecified site) – episode of care unspecified
410.91	AMI (unspecified site) – initial episode of care

Supplemental Table B: ICD-9-CM definition of Heart Failure

ICD-9-CM	Description
402.01	Malignant hypertensive heart disease with congestive heart failure (CHF)
402.11	Benign hypertensive heart disease with CHF
402.91	Hypertensive heart disease with CHF
404.01	Malignant hypertensive heart and renal disease with CHF
404.03	Malignant hypertensive heart and renal disease with CHF & renal failure (RF)
404.11	Benign hypertensive heart and renal disease with CHF
404.13	Benign hypertensive heart and renal disease with CHF & RF
404.91	Unspecified hypertensive heart and renal disease with CHF
404.93	Hypertension and non-specified heart and renal disease with CHF & RF
428.xx	Heart failure codes

Supplemental Table C: 2007 BRFSS Cardiovascular Risk Factor Variables Defined

Source: BRFSS 2007 State Sample
Sample: State adult population (18+)

Variable	Definition
Diabetes	Percent of adults who answered yes to, "Have you ever been told by a doctor that you have diabetes" excluding pregnancy related diabetes
High Cholesterol	Percent of adults who have had their cholesterol checked and been told that it was high
Daily Smokers	Percent of adults who currently smoke and smoke every day
Obese	Percent of adults with BMI greater than 30
Inactive Adults	Percent of adults reporting neither 30+ min of moderate physician activity 5 day or more/week nor vigorous physical activity 3 or more days/week
HTN	Percent of adults who have been told they have high blood pressure
Prior MI	Percent of adults reporting that they have ever had a heart attack or myocardial infarction
Angina/CAD	Percent of adults who have ever been told that they have angina or coronary heart disease

Supplemental Table D: Acute Myocardial Infarction Risk Standardized Readmission Rate Model Variables

Domain	**Variable**	**Code(s)**
Demographic	Age-65 (years above 65, continuous) Male	n/a
Cardiovascular	- History of PCI - History of CABG - Congestive heart failure - Acute coronary syndrome - Anterior myocardial infarction - Other location of myocardial infarction - Angina pectoris/old myocardial infarction - Coronary atherosclerosis/other chronic ischemic heart disease - Valvular and rheumatic heart disease Arrhythmias	- ICD-9-CM V45.82, 00.66, 36.01, 36.02, 36.05, 36.06, 36.07 - ICD-9-CM V45.81, 36.10-36.16 - CC 80 - CC 81, 82 - ICD-9-CM 410.00-410.19 - ICD-9-CM 410.20-410.69 - CC 83 - CC 84 - CC 86 - CC 92, 93
Comorbidities	- Cerebrovascular disease - Stroke - Vascular or circulatory disease - Hemiplegia, paraplegia, paralysis, functional disability - Diabetes and DM complications - Renal failure - End-stage renal disease or dialysis - Other urinary tract disorders - COPD - History of pneumonia - Asthma - Disorders of fluid/electrolyte/acid-base - History of infection - Metastatic cancer and acute leukemia - Cancer - Iron deficiency and other/unspecified anemias and blood disease - Decubitus ulcer or chronic skin ulcer - Dementia and senility - Protein-calorie malnutrition	- CC 97-99, 103 - CC 95, 96 - CC 104-106 - CC 67-69, 100-102, 177, 178 - CC 15-20, 119, 120 - CC 131 - CC 129, 130 - CC 136 - CC 108 - CC 111-113 - CC 110 - CC 22, 23 - CC 1, 3-6 - CC 7 - CC 8-12 - CC 47 - CC 148, 149 - CC 49, 50 - CC 21

Supplemental Table E: Heart Failure Risk Standardized Readmission Rate Model Variables

Domain	Variable	Code(s)
Demographic	Age-65 (years above 65, continuous) Male	n/a
Cardiovascular	- History of CABG - Congestive heart failure - Acute coronary syndrome - Arrhythmias Cardio-respiratory failure and shock - Valvular and rheumatic heart disease - Vascular or circulatory disease - Chronic atherosclerosis - Other and unspecified heart disease	- CC 80 - CC 81, 82 - CC 92, 93 - CC 79 - CC 86 - CC 104-106 - CC 83, 84 - CC 94
Comorbidities	- Hemiplegia, paraplegia, paralysis, functional disability - Stroke - Renal failure - COPD - Diabetes and DM complications - Disorders of fluid/electrolyte/acid-base - Other urinary tract disorders - Decubitus ulcer or chronic skin ulcer - Other gastrointestinal disorders - Peptic ulcer, hemorrhage, other specified gastrointestinal disorders - Severe hematological disorders - Nephritis - Dementia and senility - Metastatic cancer and acute leukemia - Cancer Liver and biliary disease - End-stage renal disease or dialysis - Asthma Iron deficiency and other/unspecified anemias and blood disease - Pneumonia - Drug/alcohol abuse/dependence/psychosis - Major pysch disorders - Depression - Other psychiatric disorders - Fibrosis of lung and other chronic lung disorders - Protein-calorie malnutrition	- CC 67-69, 100-102, 177, 178 - CC 95, 96 - CC 131 - CC 108 - CC 15-20, 119, 120 - CC 22, 23 - CC 136 - CC 148, 149 - CC 36 - CC 34 - CC 44 - CC 132 - CC 49, 50 - CC 7 - CC 8-12 - CC 25-30 - CC 129, 130 - CC 110 CC 47 - CC 111-113 - CC 51-53 - CC 54-56 - CC 58 - CC 60 - CC 109 - CC 21

Supplemental Table F: Acute Myocardial Infarction Risk Standardized Mortality Rate Model Variables

Domain	Variable	Code(s)
Demographic	Age-65 (years above 65, continuous) Male	n/a
Cardiovascular	- History of PTCA - History of CABG - History of heart failure (HCC 80) - History of MI (HCC 81) - AntMI_1 (ICD9 410.00-410.19) - AntMI_2 (ICD9 410.20-410.69) - Unstable angina (HCC 82) - Chronic atherosclerosis (HCC 83, 84) - Cardiopulmonary-respiratory failure - and shock (HCC 79) - Valvular heart disease (HCC 86)	 - HCC 80 - HCC 81 - ICD9 410.00-410.19 - ICD9 410.20-410.69 - HCC 82 - HCC 83, 84 - HCC 79 - HCC 86
Comorbidities	- Hypertension - Stroke - Cerebrovascular disease - Renal failure - COPD - Pneumonia - Diabetes - Protein-calorie malnutrition - Dementia - Hemiplegia, paraplegia, paralysis, functional disability - Peripheral vascular disease - Metastatic cancer - Trauma in last year - Major psych disorders - Chronic liver disease	- HCC 89, 91 - HCC 95, 96 - HCC 97-99, 103 - HCC 131 - HCC 108 - HCC 111-113 - HCC 15-20, 120 - HCC 21 - HCC 49, 50 - HCC 100-102, 68, 69, 177, 178 - HCC 104, 105 - HCC 7, 8 - HCC 154-156, 158-162 - HCC 54-56 - HCC 25-27

Supplemental Table G: Heart Failure Risk Standardized Mortality Rate Model Variables

Domain	**Variable**	**Code(s)**
Demographic	Age-65 (years above 65, continuous) Male	n/a
Cardiovascular	- History of PCTA - History of CABG - History of heart failure - History of AMI - Unstable angina - Chronic atherosclerosis - Cardiopulmonary-respiratory failure and shock - Valvular heart disease	 - HCC 80 - HCC 81 - HCC 82 - HCC 83, 84 - HCC 79 - HCC 86
Comorbidities	- Hypertension - Stroke - Renal failure - COPD - Pneumonia - Diabetes - Protein-calorie malnutrition - Dementia - Hemiplegia, paraplegia, paralysis, functional disability - Peripheral vascular disease - Metastatic cancer - Trauma in last year - Major psychiatric disorder - Chronic liver disease	- HCC 89, 91 - HCC 95, 96 - HCC 131 - HCC 108 - HCC 111-113 - HCC 15-20, 120 - HCC 21 - HCC 49, 50 - HCC 100-102, 68, 69, 177, 178 - HCC 104, 105 - HCC 7, 8 - HCC 154-156, 158-162 - HCC 54-56 - HCC 25-27