2013 Measures Updates and Specifications: Acute Myocardial Infarction, Heart Failure, and Pneumonia 30-Day Risk-Standardized Mortality Measure (Version 7.0)

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1. HOW TO USE THIS REPORT

This report describes three of the Centers for Medicare and Medicaid Services (CMS) mortality measures used in the Hospital Inpatient Quality Reporting (IQR) program and publicly reported on *Hospital Compare*: the hospital-level 30-day risk-standardized mortality rates (RSMRs) following acute myocardial infarction (AMI), heart failure (HF), and pneumonia.

This report is intended to provide a single source of information about the current measures for a wide range of readers. Within this report we provide an overview of the measure methodology, describe methodology updates to the measures and the national results for 2013 public reporting, and describe our quality assurance processes. The appendices provide further details, including concise tables of measure specifications and a list of the annual updates each year since public reporting began in 2007.

Specifically, the reader can find:

- **An overview of the AMI, HF and pneumonia mortality measures (Section 2)**
  - History of the measures
  - Measure cohort
    - included and excluded hospitalizations
    - how transferred patients are handled
  - Outcome
  - Risk-adjustment variables
  - Data sources
  - Mortality rate calculation
  - Categorization of hospitals' performance

- **2013 Measure Updates (Section 3)**

- **2013 Measure Results (Section 4)**
  - Results from the models that are used for the Hospital Inpatient Quality Reporting (IQR) program in 2013.

- **Quality assurance process (Section 5)**

The Appendices contain detailed measure information, including:

- Appendix A: Measure specifications;
- Appendix B: Annual updates to measures since measure development;
- Appendix C: Definitions for common terms; and
- Appendix D: RTI's memorandum on updates to the Condition Category (CC) map.

For additional references, the original measure methodology and development technical report as well as prior updates and specifications reports (formerly called measure maintenance reports) are also available on the claims-based mortality measure page of *QualityNet*:

- Risk-Adjustment Models for AMI and HF 30-Day Mortality: Report prepared for the Centers for Medicare & Medicaid Services (2005)[1]
- Risk-Adjustment Methodology for Hospital Monitoring/Surveillance and Public Reporting Supplement #1: 30-Day Mortality Model for Pneumonia: Report prepared for the Centers for Medicare & Medicaid Services (2006)[2]
- 2008-2012 Measure Maintenance Technical Reports: Acute Myocardial Infarction, Heart Failure, and Pneumonia 30-Day Risk-Standardized Mortality Measures[3-7]

The AMI, HF, and pneumonia mortality measure methodologies are also described in the peer-reviewed medical literature.[8-10]

2. BACKGROUND AND OVERVIEW OF MEASURE METHODOLOGY

2.1 Background on Mortality Measures

In June 2007, CMS began publicly reporting hospital 30-day RSMRs for AMI and HF for the nation's non-federal* short-term acute care and critical access hospitals. CMS added the pneumonia mortality measure in August 2008. In 2011, CMS and the Veterans Health Administration (VA) collaborated to update the mortality measures to include hospitalizations for patients admitted for AMI, HF, or pneumonia in VA hospitals. These three measures complement the 30-day readmission measures CMS reports for AMI, HF, and pneumonia.[11-13] The mortality measures are posted on *Hospital Compare*, and CMS updates them annually.

CMS contracted with YNHHSC/CORE to prepare the 30-day AMI, HF, and pneumonia mortality measures for 2013 public reporting through a process of measures maintenance. Measures maintenance is an annual process to improve the measures by responding to stakeholder input on the measures and incorporating advances in the science or changes in coding.

2.2 Overview of Measure Methodology

The 2013 risk-adjusted mortality measures use the National Quality Forum (NQF)-endorsed methodology set forth in the initial measure methodology reports[1,2] with slight refinements to the measures as listed in Appendix B and described in the prior measures maintenance reports.[3-7] Below, we provide an overview of the methodology.

2.2.1 Cohort

Index Admissions Included in Measures

An *index admission* is the hospitalization considered for the mortality outcome.

The mortality measures include index admissions for patients:

- Who are enrolled in Medicare fee-for-service (FFS) or VA beneficiaries;
- Aged 65 years or over;
- Discharged from non-federal acute care hospitals or VA hospitals;
- Having a principal discharge diagnosis of AMI, HF, or pneumonia for each respective measure. For specific International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) codes used to define the cohort for each condition, refer to Appendix A; and
- Medicare FFS beneficiaries with an index admission within a non-federal hospital are included if they have been enrolled in Part A and Part B Medicare for the 12 months prior to and including the date of the index admission to ensure a full year of administrative data for risk adjustment. This requirement is dropped for patients with an index admission within a VA hospital.

* *Note: Includes Indian Health Services hospitals*

Index Admissions Excluded from the Measures[†]

The mortality measures exclude index admissions for patients:

- Discharged alive on the day of admission or the following day who were not transferred, because it is unlikely they had a clinically significant diagnosis of HF, AMI, or pneumonia;
- Who were transferred from another acute care hospital or VA hospital (the acute episode is included in the measure but the death is attributed to the hospital where the patient was initially admitted rather than the hospital receiving the transferred patient);
- With inconsistent or unknown vital status or other unreliable data (for example, date of death precedes date of admission);
- Who were enrolled in the Medicare or VA Hospice programs any time in the 12 months prior to the index admission, including the first day of the index admission, since it is likely these patients are continuing to seek comfort measures only;
- Who were discharged against medical advice (AMA), because providers did not have the opportunity to deliver full care and prepare the patient for discharge; or
- Whose admission was not the first admission in the 30 days prior to a patient's death. This exclusion criterion is applied after one admission per patient per year is randomly selected and so it is only applicable to the three-year combined data. And, it *only* happens when two randomly selected admissions occur during the transition months (June and July for data used in this report) and the patient subsequently dies. For example: a patient is admitted on June 18, 2010, and readmitted on July 2, 2010; the patient dies on July 15, 2010. If both of these admissions are randomly selected for inclusion (one for the July 2009-June 2010 time period and the other for the July 2010-June 2011 time period), the July 2, 2010, admission will be excluded to avoid assigning the death to two admissions (one between July 2009 and June 2010, and one between July 2010 and June 2011).

For patients with more than one admission in a given year for a given condition, only one index admission for that condition is randomly selected for inclusion in the cohort.

The number of admissions excluded based on each criterion is shown in Section 4 in Figure 1, Figure 3, and Figure 5 for AMI, HF, and pneumonia, respectively.

Transferred Patients

The measures include patients who are admitted to a VA or non-federal acute care hospital with a diagnosis of AMI, HF, or pneumonia and then transferred to another acute facility (VA or non-federal) if the principal discharge diagnosis (AMI, HF, or

[†] Note: As a part of data processing prior to the measure calculation, records are removed for non-short-term acute care facilities such as psychiatric facilities, rehabilitation facilities, or long-term care hospitals. Additional data cleaning steps include removing: claims with stays longer than one year, claims with overlapping dates, and stays for patients not listed in the Medicare enrollment file as well as records for providers with invalid provider IDs

pneumonia) at the second hospital matches the principal discharge diagnosis at the first hospital. The measures consider admission to the first hospital as the start of an acute episode of care and assigns the patient's outcome to the hospital that initially admitted them. The measures do not assign these patients to the hospitals that receive them. For those patients seen in the emergency department of a hospital, and then admitted to the hospital or transferred to another hospital, the measures assign them to the hospital that initially admits them as an inpatient.

2.2.2 Outcome

All-Cause Mortality

There are a number of reasons for counting all deaths in the CMS mortality measures. First, from a patient perspective, a death from any cause is an adverse event. In addition, it is difficult to make inferences about quality issues and accountability based solely on the documented cause of death. For example, a patient hospitalized for HF who develops a hospital-acquired infection may ultimately die of sepsis and multi-organ failure. It would be inappropriate to consider the patient's death to be unrelated to the care the patient received for HF during the hospitalization.

30-Day Time Frame

The measures assess mortality within a 30-day period from the date of the index admission. This standard time period is necessary so that the outcome for each patient is measured uniformly. The measures use a 30-day time frame because outcomes occurring within 30 days of admission can be influenced by hospital care and the early transition to the outpatient setting. The use of the 30-day time frame is a clinically meaningful period for hospitals to collaborate with their communities in an effort to reduce mortality.[14]

2.2.3 Risk-Adjustment Variables

The measures adjust for variables (that is, age, sex, comorbid diseases, and indicators of patient frailty) that are clinically relevant and have strong relationships with the outcome. For each patient, risk-adjustment variables are obtained from inpatient, outpatient, and physician Medicare administrative claims and VA administrative data for patients with a VA index admission, extending 12 months prior to, and including, the index admission.

The measures seek to adjust for case mix differences among hospitals based on the clinical status of the patient at the time of the index admission. Accordingly, only comorbidities that convey information about the patient at that time or in the 12 months prior – and not complications that arise during the course of the hospitalization – are included in the risk-adjustment.

The measures do not adjust for the patients' admission source or their discharge disposition (for example, skilled nursing facility) because these factors are associated with the structure of the health care system, not solely patients' clinical risk factors.

Regional differences in the availability of post-acute care providers and practice patterns might exert an undue influence on model results.

The measures also do not adjust for socioeconomic status (SES) because the association between SES and health outcomes can be due, in part, to differences in the quality of health care received by groups of patients with varying SES. Risk-adjusting for patient SES would suggest that hospitals with low SES patients should be held to different standards for patient outcomes than hospitals treating higher SES patient populations. It could also mask important disparities and minimize incentives to improve outcomes for vulnerable populations. The intention is for the measures to adjust for patient demographic and clinical characteristics while illuminating important quality differences. This methodology is consistent with guidance from NQF. Additionally, recent analyses have shown that hospitals caring for high proportions of low SES patients perform similarly on the measures to hospitals caring for low proportions of low SES patients.[15]

Please refer to Table 1, Table 6, and Table 11 in Section 4 of this report for the list of risk-adjustment variables for AMI, HF, and pneumonia, respectively.

2.2.4 Data Source

The data sources for these measures maintenance analyses are Medicare administrative claims, VA administrative data, and enrollment information for patients with hospitalizations that occurred between July 1, 2009 and June 30, 2012. The datasets also contain associated inpatient, outpatient, and physician Medicare administrative claims for the 12 months prior to the index admission and one month subsequent to the index admission for patients admitted in this time period. Please see the methodology reports[1-7] for further descriptions of these data sources and an explanation of the three-year measurement period.

2.2.5 Measure Calculation

The measures estimate hospital-level 30-day all-cause RSMRs for each condition using hierarchical logistic regression models (Appendix A). In brief, the approach simultaneously models two levels of data (patient and hospital) to account for the variance in patient outcomes within and between hospitals.[16] At the patient level, it models the log-odds of mortality within 30 days of admission using age, sex, selected clinical covariates, and a hospital-specific intercept. At the hospital level, it models the hospital-specific intercepts as arising from a normal distribution. The hospital intercept represents the underlying risk of mortality at the hospital, after accounting for patient risk. The hospital-specific intercepts are given a distribution in order to account for the clustering (non-independence) of patients within the same hospital.[16] If there were no differences among hospitals, then after adjusting for patient risk, the hospital intercepts should be identical across all hospitals.

The RSMR is calculated as the ratio of the number of "predicted" deaths to the number of "expected" deaths at a given hospital, multiplied by the national observed mortality rate. For each hospital, the "numerator" of the ratio is the number of deaths within 30 days predicted on the basis of the hospital's performance with its observed case mix,

and the "denominator" is the number of deaths expected on the basis of the nation's performance with that hospital's case mix. This approach is analogous to a ratio of "observed" to "expected" used in other types of statistical analyses. It conceptually allows for a comparison of a particular hospital's performance given its case mix to an average hospital's performance with the same case mix. Thus, a lower ratio indicates lower-than-expected mortality or better quality, and a higher ratio indicates higher-than-expected mortality or worse quality.

The "predicted" number of deaths (the numerator) is calculated by regressing the risk factors (found in Table 1, Table 6, and Table 11 for AMI, HF, and pneumonia, respectively) and the hospital-specific intercept on the risk of mortality. The estimated regression coefficients are then multiplied by the patient characteristics in the hospital. The results are then transformed and summed over all patients attributed to the hospital to get a value. The "expected" number of deaths (the denominator) is obtained by regressing the risk factors and a common intercept on the mortality outcome using all hospitals in our sample. The estimated regression coefficients are then multiplied by the patient characteristics in the hospital. The results are then transformed and summed over all patients in the hospital to get a value. To assess hospital performance for each reporting period, we re-estimate the model coefficients using the years of data in that period. This ratio is multiplied by the national rate to calculate the RSMR.

The hierarchical logistic regression models are described fully in the original methodology reports.[1,2]

2.2.6 Categorizing Hospital Performance

To categorize hospital performance, CMS estimates each hospital's RSMR and the corresponding 95% interval estimate. CMS assigns hospitals to a performance category by comparing each hospital's RSMR interval estimate to the national observed mortality rate. Comparative performance for hospitals with 25 or more eligible cases is classified as follows:

- "No different than U.S. national rate" if the 95% interval estimate surrounding the hospital's rate includes the national observed mortality rate.
- "Worse than U.S. national rate" if the entire 95% interval estimate surrounding the hospital's rate is higher than the national observed mortality rate.
- "Better than U.S. national rate" if the entire 95% interval estimate surrounding the hospital's rate is lower than the national observed mortality rate.

If a hospital has fewer than 25 eligible cases for a measure, CMS assigns the hospital to a separate category: "The number of cases is too small (fewer than 25) to reliably tell how well the hospital is performing." If a hospital has fewer than 25 eligible cases, the hospital's mortality rates and interval estimates will not be publicly reported for the measure.

Section 4 describes the distribution of hospitals by performance category in the U.S. for the July 2009 to June 2012 reporting period.

3. UPDATES TO METHODS FOR 2013 PUBLIC REPORTING

3.1 Rationale for Measure Updates

Measures maintenance ensures that the risk-standardized mortality models are continually assessed and remain valid given possible changes in the data over time, and allows for model refinements. As described in this report, for 2013 public reporting, we undertook the following measures maintenance activities:

- Incorporated ICD-9-CM coding updates for the Condition Categories;
- Validated the performance of each condition-specific model and its corresponding risk-adjustment variables in three recent one-year datasets (July 2009-June 2010, July 2010-June 2011, and July 2011-June2012);
- Evaluated and validated model performance in the three-year combined dataset (July 2009-June 2012); and
- Updated the measures' SAS pack and documentation.

3.2 Detailed Discussion of Measure Updates

3.2.1 Updates to the Condition Category (CC) Map

RTI International, contracted by CMS to maintain the CC system, assigned new ICD-9-CM codes to the existing CCs based on their clinical expertise and the historical assignment of related ICD-9-CM codes to the CCs. CCs are clinically relevant diagnostic groups of the more than 14,500 ICD-9 codes. The CCs group the ICD-9-CM codes into larger groups that are used in models to predict medical care utilization, spending, mortality, or other related measures.[17] CMS revises the ICD-9-CM CC map annually to reflect changes in ICD-9-CM codes so that the measures will capture all relevant comorbidities coded in patient claims data.

The assignment of new codes and the removal of retired codes had little impact on the model variables this year since RTI assigned the majority of new codes, which were more specific versions of retired codes, to the same CCs as retired codes. For more details on the CC changes, see Appendix D for RTI's memo to CMS detailing the map changes.

3.3 Changes to SAS Analytic Package (SAS Pack)

We revised the measure calculation SAS packs as needed to reflect updates to the CC map and any changes required for the reporting of results. The new SAS packs and documentation are available upon request by emailing cmsmortalitymeasures@yale.edu. **Do *NOT* submit patient-identifiable information (for example, Date of Birth, Social Security Number, Health Insurance Claim Number, etc.) to this address.**

4. RESULTS FOR 2013 PUBLIC REPORTING

4.1 Assessment of Updated Models

The mortality measures estimate hospital-specific 30-day all-cause RSMRs using hierarchical logistic regression models. See Section 2 of this report for a summary of the measure methodology and model risk-adjustment variables, and prior technical reports[1-7] for further details.

In this report we evaluate the performance of the models and provide national results using the data for 2013 reporting. This differs from previous reports where we provided national results using calendar year data. We fit the updated models to three single year datasets (July 2009-June 2010, July 2010-June 2011, and July 2011-June 2012) and to a combined three-year (July 2009-June 2012) dataset. We examined trends in the frequency of patient risk factors and the model variable coefficients, and compared the model performance between these datasets.

For each of the three conditions, we assessed logistic regression model performance in terms of discriminant ability for each year of data and for the three-year combined period listed above. We computed two summary statistics for assessing model performance: the predictive ability and the area under the receiver operating characteristic (ROC) curve (c-statistic). The c-statistic is an indicator of the model's discriminant ability or ability to correctly classify those who have and have not died within 30 days of admission (potential values range from 0.5 meaning no better than chance to 1.0 meaning perfect discrimination).

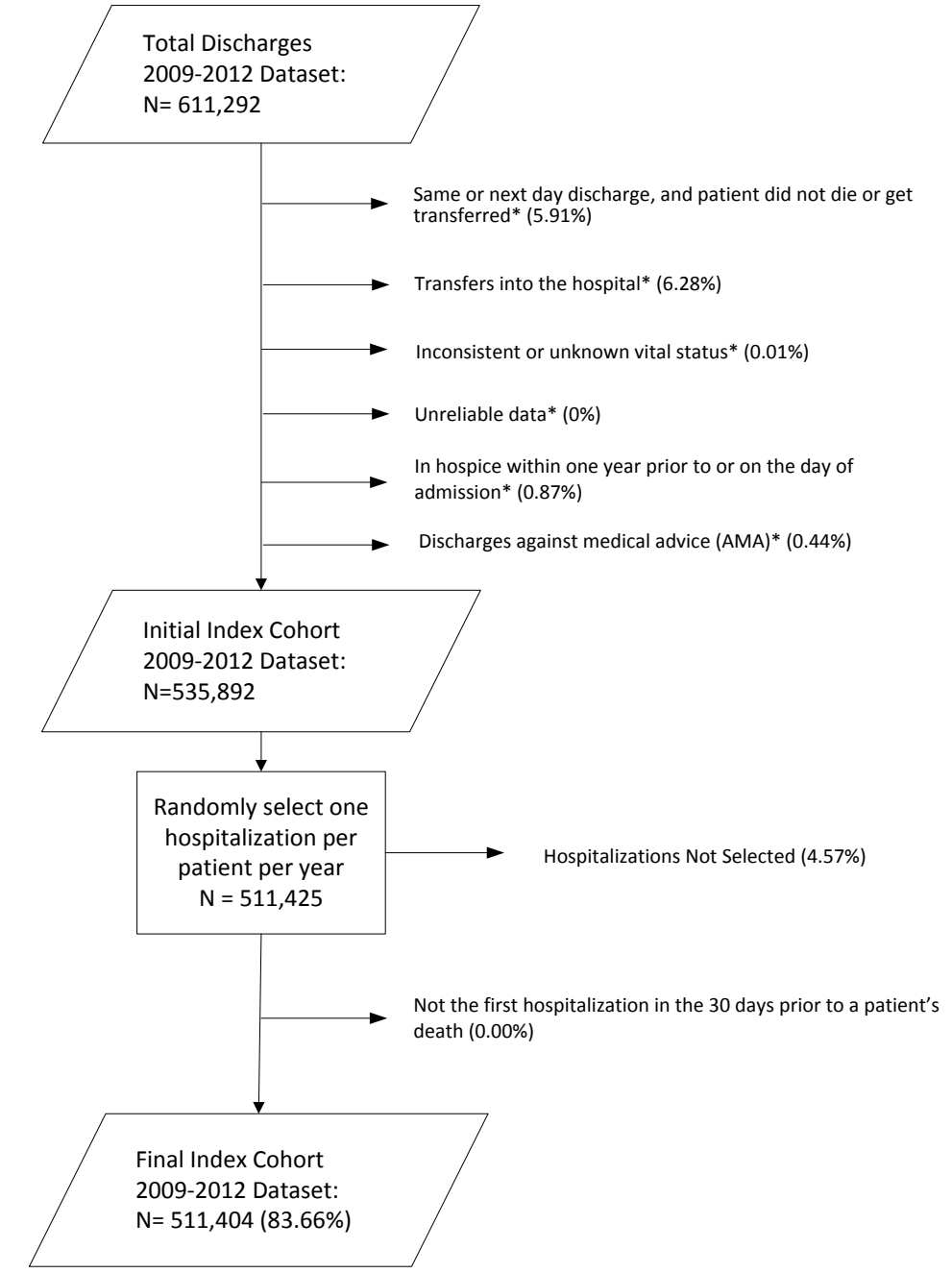
The results of these analyses for each of the three measures (AMI, HF, and pneumonia) are presented below in Sections 4.2, 4.3, and 4.4, respectively.

4.2 AMI Mortality 2013 Model Results

4.2.1 Index Cohort Exclusions

The exclusion criteria for the measures are presented in Section 2 and the percentage of AMI patients meeting each exclusion criterion in the July 2009-June 2012 dataset is presented in Figure 1.

Figure 1 – Index Cohort Sample for AMI in the July 2009-June 2012 Dataset



*Categories are not mutually exclusive

4.2.2 Frequency of AMI Model Variables

We examined the change in both observed mortality rates and frequency of clinical and demographic variables. Between the year July 2009-June 2010 and the year July 2011-June 2012, the national observed mortality rate decreased from 15.5% to 14.8%.

The frequency of some model variables increased. The increase may reflect an increased rate of comorbidity in the fee-for-service population, but is also due in part to increased hospital coding of comorbidities. In the 2012 update to the measures, we increased the number of diagnosis codes and procedure codes to align with the Version 5010 format changes required by the Department of Health and Human Services (DHHS). Hospitals could begin to submit up to 25 diagnosis and procedure codes starting in 2010. Over time, more hospitals have submitted increased numbers of codes which we are seeing translated into increased frequencies for some model variables.

During this time period, although the frequency of most of the model variables remained relatively constant, there was an increase (2% or more) in the frequency of prior cardiovascular procedures (PTCA and CABG), chronic atherosclerosis, valvular or rheumatic heart disease, hypertension, renal failure, chronic obstructive pulmonary disease, diabetes, and dementia or senility.

4.2.3 AMI Model Parameters and Performance

Table 2 shows the risk-adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for the AMI mortality model by individual year and for the combined three-year dataset. Overall, the variable effect sizes were relatively constant across years. Between-hospital variance within the combined dataset was 0.04 (SE: 0.003). If there were no systematic differences between hospitals, the between-hospital variance would be 0. In addition, model performance was stable over the three-year time period; the area under the ROC curve (c-statistic) remained constant at 0.72 (Table 3).

4.2.4 Distribution of Hospital Volumes and RSMRs

Table 4 shows the distributions of hospital admission volumes, and Table 5 shows the distributions of hospital RSMRs. These tables show the between-hospital variance by individual year and for the combined three-year dataset. The median hospital RSMR in the combined three-year dataset was 14.8% (IQR 13.8% - 15.9%).

Figure 2 shows the overall distribution of the hospital RSMRs for the combined dataset. The odds of all-cause mortality if treated at a hospital one standard deviation above the national rate were 1.5 times higher than the odds of all-cause mortality if treated at a hospital one standard deviation below the national rate. If there were no systematic differences between hospitals, the odds ratio would be 1.0.[16]

4.2.5 Distribution of Hospitals by Performance Category in the Three-Year Dataset

Out of 4564 number of hospitals in the U.S., 77 performed “better than the U.S. national rate,” 2579 performed “no different from the U.S. national rate,” and 19 performed “worse than the U.S. national rate.” 1889 were classified as “number of cases too small” (fewer than 25) to reliably tell how well the hospital is performing.

Table 1 – Frequency of AMI Model Variables over Different Time Periods (%)

Variable	07/2009-06/2010	07/2010-06/2011	07/2011-06/2012	07/2009-06/2012
Total N	173,576	171,355	166,494	511,404
Observed mortality rate	15.5	15.4	14.8	15.2
Mean Age (SD)	79.2 (8.3)	79.3 (8.3)	79.1 (8.3)	79.2 (8.3)
Male	50.8	50.9	51.7	51.1
History of PTCA	8.0	11.8	15.8	11.8
History of CABG	5.8	8.9	11.9	8.8
Congestive heart failure (CC 80)	31.0	31.1	30.9	31.0
Acute myocardial infarction (CC 81)	13.5	14.0	13.5	13.7
Other acute/subacute forms of ischemic heart disease (CC 82)	13.3	13.2	13.4	13.3
Anterior myocardial infarction (ICD-9 codes 410.00-410.19)	9.1	8.6	8.3	8.7
Other location of myocardial infarction (ICD-9 codes 410.20-410.69)	12.8	12.3	12.2	12.5
Chronic atherosclerosis (CC 83, 84)	77.6	80.9	84.5	81.0
Cardio-respiratory failure and shock (CC 79)	9.4	9.9	10.3	9.9
Valvular and rheumatic heart disease (CC 86)	26.1	28.8	31.5	28.8
Hypertension (CC 89, 91)	84.4	86.6	88.9	86.6
Stroke (CC 95-96)	7.9	7.7	7.5	7.7
Cerebrovascular disease (CC 97-99, 103)	19.8	20.3	21.0	20.4
Renal failure (CC 131)	22.9	24.6	26.2	24.5
Chronic obstructive pulmonary disease (COPD) (CC 108)	28.1	29.6	30.9	29.5
Pneumonia (CC 111-113)	23.8	24.0	23.7	23.8
Diabetes mellitus (DM) or DM complications (CC 15-20, 120)	43.4	45.0	46.5	44.9
Protein-calorie malnutrition (CC 21)	5.4	6.2	6.6	6.0
Dementia or senility (CC 49, 50)	18.3	19.7	20.8	19.6
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177, 178)	5.9	6.1	6.5	6.2
Peripheral vascular disease (CC 104, 105)	26.4	26.7	27.7	26.9
Metastatic cancer, acute leukemia and other major cancers (CC 7, 8)	3.9	3.8	4.0	3.9
Trauma in last year (CC 154-156, 158-162)	30.4	31.2	31.7	31.1
Major psychiatric disorders (CC 54-56)	7.0	7.6	8.2	7.6
Chronic liver disease (CC 25-27)	1.1	1.2	1.4	1.2

Table 2 – Adjusted OR and 95% CIs for the AMI Hierarchical Logistic Regression Model over Different Time Periods

Variable	07/2009-06/2010 OR (95% CI)	07/2010-06/2011 OR (95% CI)	07/2011-06/2012 OR (95% CI)	07/2009-06/2012 OR (95% CI)
Age-65	1.06 (1.05 - 1.06)	1.06 (1.05 - 1.06)	1.06 (1.06 - 1.06)	1.06 (1.06 - 1.06)
Male	1.14 (1.11 - 1.17)	1.16 (1.13 - 1.19)	1.17 (1.13 - 1.20)	1.16 (1.14 - 1.17)
History of PTCA	0.65 (0.61 - 0.69)	0.73 (0.69 - 0.76)	0.74 (0.71 - 0.77)	0.72 (0.69 - 0.74)
History of CABG	0.85 (0.80 - 0.91)	0.99 (0.94 - 1.04)	1.05 (1.01 - 1.10)	0.98 (0.95 - 1.01)
Congestive heart failure (CC 80)	1.46 (1.41 - 1.51)	1.38 (1.33 - 1.43)	1.34 (1.29 - 1.39)	1.39 (1.37 - 1.42)
Acute myocardial infarction (CC 81)	1.03 (0.98 - 1.07)	0.98 (0.94 - 1.02)	0.96 (0.92 - 1.01)	0.99 (0.96 - 1.01)
Other acute/subacute forms of ischemic heart disease (CC 82)	1.02 (0.97 - 1.07)	0.96 (0.92 - 1.01)	0.94 (0.89 - 0.98)	0.97 (0.95 - 1.00)
Anterior myocardial infarction (ICD-9 codes 410.00 410.19)	1.98 (1.90 - 2.07)	1.97 (1.89 - 2.06)	2.18 (2.08 - 2.28)	2.04 (1.99 - 2.10)
Other location of myocardial infarction (ICD-9 codes 410.20-410.69)	1.57 (1.51 - 1.64)	1.53 (1.47 - 1.60)	1.65 (1.58 - 1.73)	1.59 (1.55 - 1.63)
Chronic atherosclerosis (CC 83, 84)	0.53 (0.51 - 0.55)	0.58 (0.56 - 0.60)	0.60 (0.58 - 0.62)	0.57 (0.56 - 0.58)
Cardio-respiratory failure and shock (CC 79)	1.21 (1.16 - 1.27)	1.22 (1.16 - 1.27)	1.18 (1.13 - 1.24)	1.20 (1.17 - 1.23)
Valvular and rheumatic heart disease (CC 86)	1.03 (1.00 - 1.06)	1.02 (0.99 - 1.05)	1.10 (1.07 - 1.14)	1.05 (1.04 - 1.07)
Hypertension (CC 89, 91)	0.68 (0.65 - 0.70)	0.68 (0.66 - 0.71)	0.71 (0.68 - 0.74)	0.69 (0.67 - 0.71)
Stroke (CC 95, 96)	1.05 (1.00 - 1.11)	1.08 (1.03 - 1.14)	1.00 (0.95 - 1.06)	1.05 (1.02 - 1.08)
Cerebrovascular disease (CC 97-99, 103)	1.03 (1.00 - 1.07)	0.94 (0.91 - 0.98)	0.96 (0.93 - 1.00)	0.98 (0.96 - 1.00)
Renal failure (CC 131)	1.27 (1.23 - 1.32)	1.27 (1.23 - 1.31)	1.19 (1.15 - 1.23)	1.25 (1.22 - 1.27)
COPD (CC 108)	1.02 (0.99 - 1.05)	1.05 (1.02 - 1.09)	1.13 (1.09 - 1.16)	1.06 (1.04 - 1.08)
Pneumonia (CC 111-113)	1.44 (1.40 - 1.49)	1.49 (1.45 - 1.54)	1.53 (1.48 - 1.58)	1.48 (1.46 - 1.51)
Diabetes mellitus (DM) and DM complications (CC 15-20, 120)	1.08 (1.05 - 1.11)	1.11 (1.08 - 1.14)	1.10 (1.07 - 1.13)	1.10 (1.08 - 1.11)
Protein-calorie malnutrition (CC 21)	1.50 (1.43 - 1.58)	1.66 (1.59 - 1.74)	1.64 (1.57 - 1.72)	1.61 (1.57 - 1.66)
Dementia and senility (CC 49, 50)	1.40 (1.35 - 1.44)	1.44 (1.39 - 1.49)	1.43 (1.39 - 1.48)	1.42 (1.39 - 1.45)
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177, 178)	1.21 (1.15 - 1.28)	1.23 (1.17 - 1.30)	1.22 (1.16 - 1.29)	1.22 (1.18 - 1.26)
Peripheral vascular disease (CC 104, 105)	1.09 (1.06 - 1.13)	1.12 (1.08 - 1.15)	1.10 (1.07 - 1.14)	1.11 (1.09 - 1.13)
Metastatic cancer, acute leukemia, and other severe cancers (CC 7, 8)	1.92 (1.81 - 2.03)	1.89 (1.78 - 2.01)	2.03 (1.91 - 2.15)	1.95 (1.88 - 2.02)
Trauma in last year (CC 154-156, 158-162)	1.04 (1.01 - 1.08)	1.00 (0.97 - 1.03)	0.96 (0.93 - 0.99)	1.00 (0.99 - 1.02)
Major psychiatric disorders (CC 54-56)	1.09 (1.03 - 1.14)	1.12 (1.07 - 1.17)	1.09 (1.04 - 1.15)	1.10 (1.07 - 1.13)
Chronic liver disease (CC 25-27)	1.77 (1.59 - 1.98)	1.63 (1.47 - 1.81)	1.52 (1.37 - 1.69)	1.63 (1.53 - 1.73)
Between Hospital Variance (SE)	0.05 (0.005)	0.03 (0.005)	0.04 (0.005)	0.04 (0.003)

Table 3 – AMI Generalized Linear Modeling (Logistic Regression) Performance over Different Time Periods

Characteristic	07/2009-06/2010	07/2010-06/2011	07/2011-06/2012	07/2009-06/2012
Predictive ability, % (lowest decile – highest decile)	2.8-36.5	3.3-36.9	3.1-36.3	3.1-36.5
c-statistic	0.72	0.72	0.72	0.72

Table 4 – Distribution of Hospital AMI Admission Volumes over Different Time Periods[§]

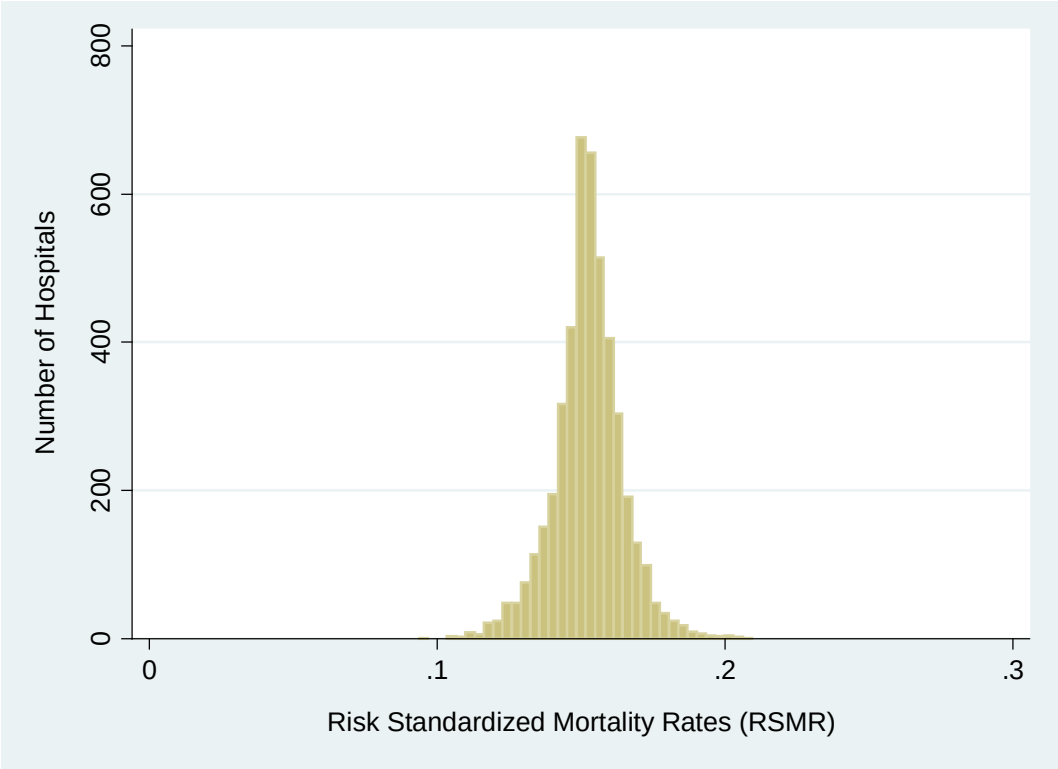
Characteristic	07/2009-06/2010	07/2010-06/2011	07/2011-06/2012	07/2009-06/2012
Number of Hospitals	4293	4244	4160	4564
Mean Number of Admissions (SD)	40.4 (55.2)	40.4 (54.9)	40.0 (54.3)	112.1 (159.9)
Range (min. – max.)	1-486	1-538	1-455	1-1479
25th percentile	5	4	4	10
50th percentile	17	17	17	40
75th percentile	55	57	57	156

Table 5 – Distribution of Hospital AMI RSMRs over Different Time Periods (%)

Characteristic	07/2009-06/2010	07/2010-06/2011	07/2011-06/2012	07/2009-06/2012
Number of Admissions	173576	171355	166494	511404
Mean (SD)	15.2 (1.4)	15.2 (1.1)	14.6 (1.2)	14.8 (1.5)
Range (min. – max.)	11.3-21.4	12.0-18.9	10.6-20.3	9.4-21.0
25th percentile	14.3	14.5	13.9	13.8
50th percentile	15.3	15.2	14.6	14.8
75th percentile	16.1	15.9	15.4	15.9

[§] Hospital volumes for third year of reporting (July 2011-2012) are lower in part due to incomplete enrollment data for discharges in June 2012.

Figure 2 – Distribution of Hospital 30-Day AMI RSMRs between July 2009 and June 2012



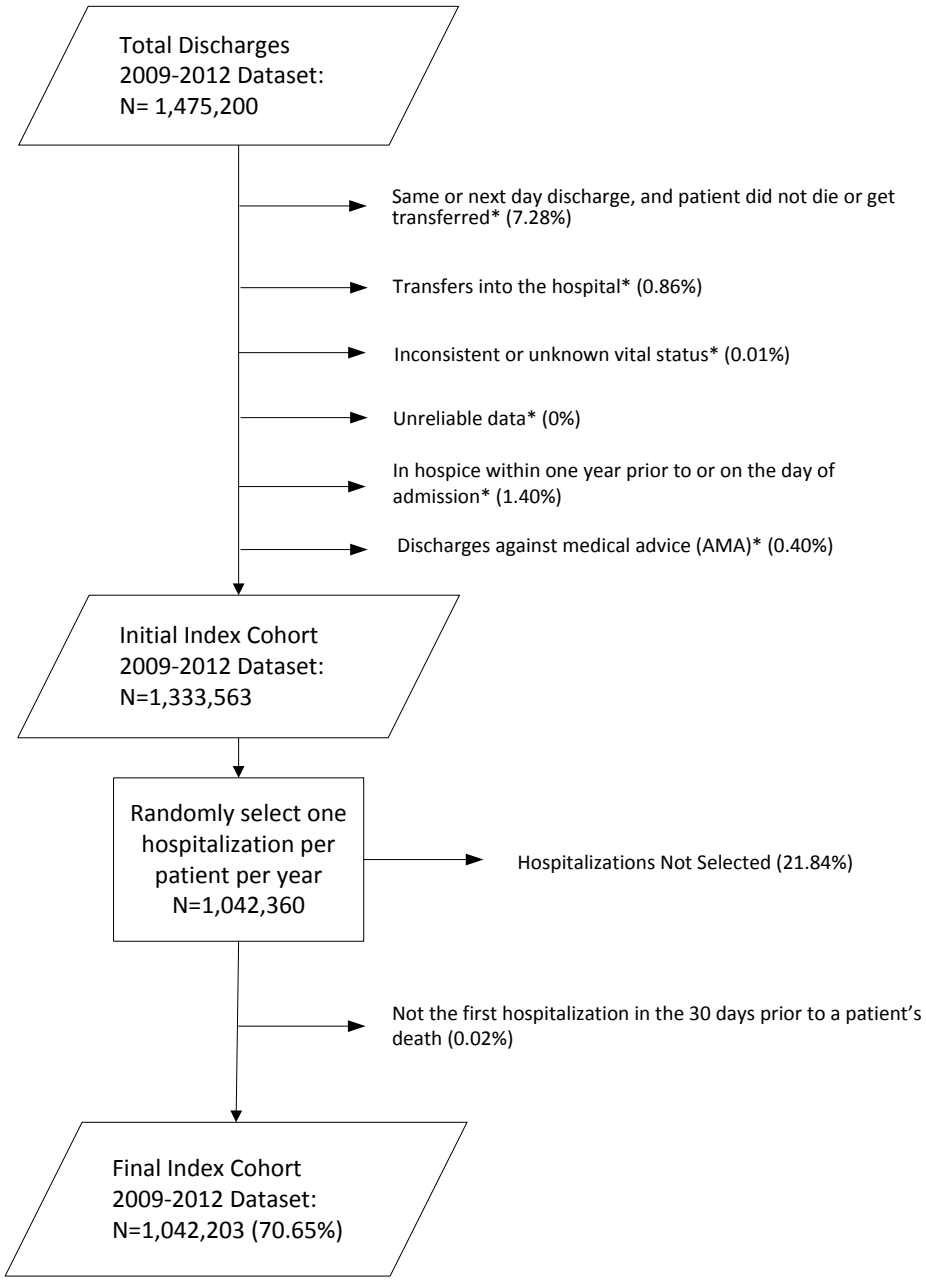
N= 4564 hospitals

4.3 HF Mortality 2013 Model Results

4.3.1 Index Cohort Exclusions

The exclusion criteria for the measures are presented in Section 2, and the percentage of HF patients meeting each exclusion criterion in the July 2009-June 2012 dataset is presented in Figure 3.

Figure 3 – Index Cohort Sample for HF in the July 2009-June 2012 Dataset



*Categories are not mutually exclusive

4.3.2 Frequency of HF Model Variables

We examined the change in both observed mortality rates and frequency of clinical and demographic variables. Between the year July 2009-June 2010 and the year July 2011-June 2012, the national observed mortality rate increased from 11.5% to 11.7% (Table 6).

As noted above, many hospitals are submitting up to 25 secondary diagnosis and procedure codes, which may be translating into increased frequency of some risk variables.

During this time period, although the frequency of most of the model variables remained relatively constant, there was an increase (2% or more) in the frequency of prior cardiovascular procedures (PTCA and CABG), chronic atherosclerosis, cardio-respiratory failure and shock, valvular or rheumatic heart disease, hypertension, renal failure, chronic obstructive pulmonary disease, diabetes, dementia and senility, vascular or circulatory disease, and trauma.

4.3.3 HF Model Parameters and Performance

Table 7 shows the risk-adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for the HF mortality model by individual year and for the combined three-year dataset. Overall, the variable effect sizes were relatively constant across years. Between-hospital variance win the combined dataset was 0.05 (SE: 0.002). If there were no systematic differences between hospitals, the between hospital variance would be 0. In addition, model performance was stable over the three-year time period; the area under the ROC curve (c-statistic) remained constant at 0.68 (Table 8).

4.3.4 Distribution of Hospital Volumes and RSMRs

Table 9 shows the distributions of hospital admission volumes, and Table 10 shows the distributions of hospital RSMRs. These tables show the between-hospital variance by individual year and for the combined three-year dataset. The median hospital RSMR in the combined three-year dataset was 11.4% (IQR: 10.4% - 12.6%).

Figure 4 shows the overall distribution of the hospital RSMRs for the combined three-year dataset. The odds of all-cause mortality if treated at a hospital one standard deviation above the national rate were 1.6 times higher than the odds of all-cause mortality if treated at a hospital one standard deviation below the national rate. If there were no systematic differences between hospitals, the odds ratio would be 1.0.[16]

4.3.5 Distribution of Hospitals by Performance Category in the Three-Year Dataset

Out of 4777 number of hospitals in the U.S., 181 performed “better than the U.S. national rate,” 3732 performed “no different from the U.S. national rate,” and 139 performed “worse than the U.S. national rate.” 725 were classified as “number of cases too small” (fewer than 25) to reliably tell how well the hospital is performing.

Table 6 – Frequency of HF Model Variables over Different Time Periods (%)

Variable	07/2009-06/2010	07/2010-06/2011	07/2011-06/2012	07/2009-06/2012
Total N	359,589	351,109	331,662	1,042,203
Observed mortality rate	11.5	11.9	11.7	11.7
Mean Age (SD)	81.1 (8.1)	81.2 (8.2)	81.2 (8.2)	81.1 (8.2)
Male	45.0	45.0	45.5	45.2
History of PTCA	6.0	9.4	12.7	9.3
History of CABG	8.4	13.9	18.8	13.6
Congestive heart failure (CC 80)	74.1	74.4	74.8	74.4
Acute myocardial infarction (CC 81)	9.7	9.7	9.7	9.7
Other acute/subacute forms of ischemic heart disease (CC 82)	12.4	12.2	12.2	12.3
Chronic atherosclerosis (CC 83, 84)	69.9	71.5	73.5	71.6
Cardio-respiratory failure and shock (CC 79)	22.3	23.7	25.6	23.8
Valvular and rheumatic heart disease (CC 86)	45.1	48.5	52.6	48.6
Hypertension (CC 89, 91)	89.5	91.5	93.3	91.4
Stroke (CC 95, 96)	10.0	9.8	9.7	9.8
Renal failure (CC 131)	43.2	46.1	49.0	46.0
COPD (CC 108)	45.5	47.1	48.7	47.0
Pneumonia (CC 111-113)	43.7	44.4	44.9	44.3
Diabetes mellitus (DM) and DM complications (CC 15-20, 120)	51.2	52.5	53.9	52.5
Protein-calorie malnutrition (CC 21)	8.4	9.4	10.3	9.3
Dementia and senility (CC 49, 50)	21.7	23.4	25.5	23.5
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100102, 177, 178)	7.4	7.8	8.7	8.0
Peripheral vascular disease (CC 104, 105)	35.5	36.4	38.5	36.7
Metastatic cancer, acute leukemia, and other severe cancers (CC 7, 8)	4.3	4.3	4.4	4.3
Trauma in last year (CC 154-156, 158-162)	38.1	39.4	40.3	39.2
Major psychiatric disorders (CC 54-56)	9.5	10.2	10.9	10.2
Chronic liver disease (CC 25-27)	2.2	2.5	3.0	2.6

Table 7 – Adjusted OR and 95% CIs for the HF Hierarchical Logistic Regression Model over Different Time Periods

Variable	07/2009-06/2010 OR (95% CI)	07/2010-06/2011 OR (95% CI)	07/2011-06/2012 OR (95% CI)	07/2009-06/2012 OR (95% CI)
Age-65	1.05 (1.05 - 1.05)	1.05 (1.05 - 1.06)	1.05 (1.05 - 1.06)	1.05 (1.05 - 1.05)
Male	1.30 (1.27 - 1.33)	1.31 (1.28 - 1.34)	1.32 (1.29 - 1.35)	1.31 (1.29 - 1.33)
History of PTCA	0.68 (0.64 - 0.72)	0.75 (0.72 - 0.78)	0.73 (0.70 - 0.76)	0.73 (0.71 - 0.75)
History of CABG	0.66 (0.63 - 0.69)	0.80 (0.77 - 0.83)	0.86 (0.84 - 0.89)	0.80 (0.78 - 0.82)
Congestive heart failure (CC 80)	1.29 (1.26 - 1.33)	1.26 (1.23 - 1.30)	1.26 (1.22 - 1.30)	1.27 (1.25 - 1.29)
Acute myocardial infarction (CC 81)	1.35 (1.30 - 1.41)	1.28 (1.23 - 1.32)	1.23 (1.19 - 1.28)	1.28 (1.25 - 1.31)
Other acute/subacute forms of ischemic heart disease (CC 82)	0.94 (0.90 - 0.97)	0.95 (0.91 - 0.98)	0.97 (0.93 - 1.01)	0.95 (0.93 - 0.97)
Chronic atherosclerosis (CC 83, 84)	0.86 (0.84 - 0.88)	0.9 (0.88 - 0.93)	0.96 (0.93 - 0.99)	0.91 (0.89 - 0.92)
Cardio-respiratory failure and shock (CC 79)	1.19 (1.16 - 1.22)	1.16 (1.13 - 1.19)	1.17 (1.14 - 1.20)	1.17 (1.16 - 1.19)
Valvular and rheumatic heart disease (CC 86)	1.00 (0.98 - 1.02)	1.04 (1.01 - 1.06)	1.07 (1.05 - 1.09)	1.03 (1.02 - 1.05)
Hypertension (CC 89, 91)	0.65 (0.63 - 0.67)	0.69 (0.66 - 0.71)	0.66 (0.64 - 0.69)	0.67 (0.65 - 0.68)
Stroke (CC 95, 96)	0.99 (0.96 - 1.03)	0.97 (0.93 - 1.00)	0.98 (0.95 - 1.02)	0.98 (0.96 - 1.00)
Renal failure (CC 131)	1.27 (1.24 - 1.30)	1.27 (1.24 - 1.30)	1.20 (1.17 - 1.23)	1.25 (1.24 - 1.27)
COPD (CC 108)	1.04 (1.01 - 1.06)	1.08 (1.05 - 1.10)	1.06 (1.03 - 1.08)	1.06 (1.04 - 1.07)
Pneumonia (CC 111-113)	1.37 (1.34 - 1.40)	1.36 (1.33 - 1.39)	1.34 (1.31 - 1.37)	1.36 (1.34 - 1.38)
Diabetes mellitus (DM) and DM complications (CC 15-20, 120)	0.96 (0.94 - 0.98)	0.96 (0.94 - 0.98)	0.99 (0.97 - 1.01)	0.97 (0.96 - 0.99)
Protein-calorie malnutrition (CC 21)	2.00 (1.94 - 2.06)	1.95 (1.90 - 2.01)	1.94 (1.88 - 2.00)	1.98 (1.94 - 2.01)
Dementia and senility (CC 49, 50)	1.30 (1.26 - 1.33)	1.33 (1.30 - 1.37)	1.35 (1.32 - 1.38)	1.33 (1.31 - 1.35)
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177, 178)	1.09 (1.05 - 1.13)	1.09 (1.05 - 1.13)	1.11 (1.07 - 1.15)	1.10 (1.07 - 1.12)
Peripheral vascular disease (CC 104, 105)	1.01 (0.99 - 1.04)	1.01 (0.99 - 1.03)	1.00 (0.98 - 1.02)	1.01 (1.00 - 1.03)
Metastatic cancer, acute leukemia, and other severe cancers (CC 7, 8)	1.86 (1.78 - 1.94)	1.84 (1.76 - 1.92)	1.83 (1.75 - 1.91)	1.85 (1.80 - 1.89)
Trauma in last year (CC 154-156, 158-162)	1.10 (1.07 - 1.12)	1.09 (1.07 - 1.11)	1.07 (1.05 - 1.09)	1.08 (1.07 - 1.10)
Major psychiatric disorders (CC 54-56)	1.13 (1.09 - 1.17)	1.11 (1.08 - 1.15)	1.11 (1.07 - 1.15)	1.12 (1.10 - 1.14)
Chronic liver disease (CC 25-27)	1.38 (1.29 - 1.47)	1.56 (1.47 - 1.65)	1.54 (1.45 - 1.63)	1.51 (1.46 - 1.56)
Between Hospital Variance (SE)	0.05 (0.004)	0.05 (0.004)	0.05 (0.004)	0.05 (0.002)

Table 8 – HF Logistic Regression Model Performance over Different Time Periods

Characteristic	07/2009-06/2010	07/2010-06/2011	07/2011-06/2012	07/2009-06/2012
Predictive ability, % (lowest decile – highest decile)	3.1-25.9	3.1-26.5	3.1-25.9	3.1-26.1
c-statistic	0.68	0.68	0.68	0.68

Table 9 – Distribution of Hospital Heart Failure Admission Volumes over Different Time Periods[§]

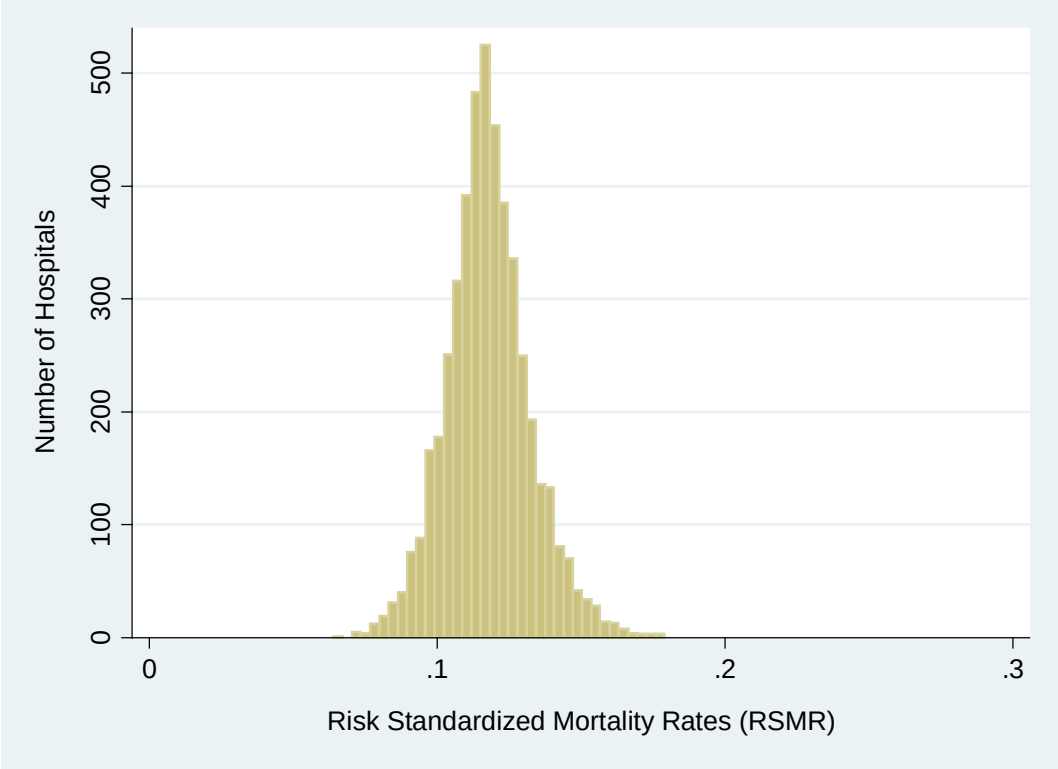
Characteristic	07/2009-06/2010	07/2010-06/2011	07/2011-06/2012	07/2009-06/2012
Number of Hospitals	4694	4674	4663	4777
Mean Number of Admissions (SD)	76.6 (89.7)	75.1 (89.2)	71.1 (85.5)	218.2 (261.8)
Range (min. – max.)	1-974	1-1014	1-943	1-2930
25th percentile	16	15	13	42
50th percentile	43	41	38	117
75th percentile	107	106	100	308

Table 10 – Distribution of Hospital Heart Failure RSMRs over Different Time Periods (%)

Characteristic	07/2009-06/2010	07/2010-06/2011	07/2011-06/2012	07/2009-06/2012
Number of Admissions	359589	351109	331662	1042203
Mean (SD)	11.4 (1.3)	11.8 (1.3)	11.6 (1.4)	11.5 (1.7)
Range (min. – max.)	7.8-16.9	7.4-16.7	7.5-17.7	6.4-17.9
25th percentile	10.5	10.9	10.7	10.4
50th percentile	11.3	11.7	11.6	11.4
75th percentile	12.2	12.6	12.4	12.6

[§] Hospital volumes for third year of reporting (July 2011-2012) are lower in part due to incomplete enrollment data for discharges in June 2012.

Figure 4 – Distribution of Hospital 30-Day HF RSMRs between July 2009 and June 2012



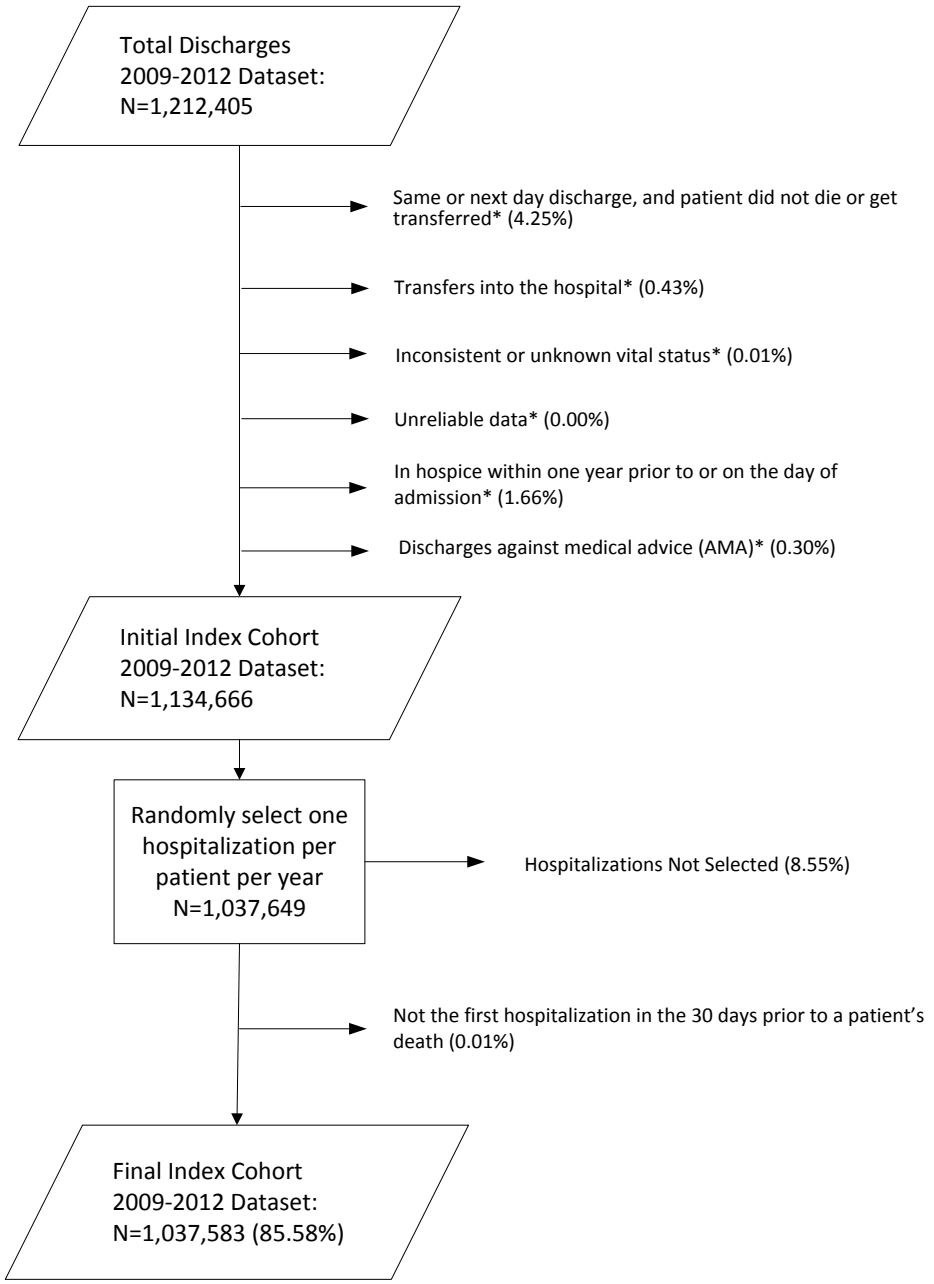
N= 4,777 hospitals

4.4 Pneumonia Mortality 2013 Model Results

4.4.1 Index Cohort Exclusions

The exclusion criteria for the measures are presented in Section 2, and the percentage of pneumonia patients meeting each exlcusion criterion in the July 2009-June 2012 dataset is presented in Figure 5.

Figure 5 – Index Cohort Sample for Pneumonia in the July 2009-June 2012 Year Dataset



*Categories are not mutually exclusive

4.4.2 Frequency of Pneumonia Model Variables

We examined the change in both observed mortality rates and frequency of clinical and demographic variables. Between the year July 2009-June 2010 and the year July 2011-June 2012, the national observed mortality rate decreased from 11.9% to 11.7% (Table 11).

As noted above, many hospitals are submitting up to 25 secondary diagnosis and procedure codes, which may be translating into increased frequency of some risk variables.

During this time period, although the frequency of most of the model variables remained relatively constant, there was an increase (2% or more) in the frequency of prior cardiovascular procedures (PTCA and CABG), chronic atherosclerosis, cardio-respiratory failure and shock, renal failure, dementia and senility, vascular or circulatory disease, trauma, iron deficiency and other/unspecified anemias and blood disease, and depression.

4.4.3 Pneumonia Model Parameters and Performance

Table 12 shows the risk-adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for the pneumonia mortality model by individual year and for the combined three-year dataset. Overall, the variable effect sizes were relatively constant across years. Between-hospital variance win the combined dataset was 0.07 (SE: 0.003). If there were no systematic differences between hospitals, the between hospital variance would be 0. In addition, model performance was stable over the three-year time period; the area under the ROC curve (c-statistic) remained constant at 0.72 (Table 13).

4.4.4 Distribution of Hospital Volumes and RSMRs

Table 14 shows the distributions of hospital admission volumes, and Table 15 shows the distributions of hospital RSMRs. These tables show the between-hospital variance by individual year and for the combined three-year dataset. The median hospital RSMR in the combined three-year dataset was 11.7% (IQR: 10.5% - 13.0%).

Figure 6 shows the overall distribution of the hospital RSMRs for the combined three-year dataset. The odds of all-cause mortality if treated at a hospital one standard deviation above the national rate were 1.7 times higher than the odds of all-cause mortality if treated at a hospital one standard deviation below the national rate. If there were no systematic differences between hospitals, the odds ratio would be 1.0.[16]

4.4.5 Distribution of Hospitals by Performance Category in the Three-Year Dataset

Out of 4817 number of hospitals in the U.S., 203 performed “better than the U.S. national rate,” 4014 performed “no different from the U.S. national rate,” and 223 performed “worse than the U.S. national rate.” 377 were classified as “number of cases too small” (fewer than 25) to reliably tell how well the hospital is performing.

Table 11 – Frequency of Pneumonia Model Variables over Different Time Periods (%)

Variable	07/2009-06/2010	07/2010-06/2011	07/2011-06/2012	07/2009-06/2012
Total N	347,585	356,694	333,370	1,037,583
Observed mortality rate	11.9	12.0	11.7	11.9
Mean Age (SD)	80.3 (8.2)	80.5 (8.3)	80.4 (8.3)	80.4 (8.3)
Male	45.9	46.0	46.3	46.1
History of PTCA	3.2	5.3	7.0	5.2
History of CABG	4.1	7.1	9.3	6.8
Congestive heart failure (CC 80)	38.5	38.7	39.1	38.7
Acute myocardial infarction (CC 81)	3.7	3.8	3.9	3.8
Other acute/subacute forms of ischemic heart disease (CC 82)	5.9	5.7	5.8	5.8
Chronic atherosclerosis (CC 83, 84)	47.0	48.4	50.0	48.4
Cardio-respiratory failure and shock (CC 79)	18.7	19.7	21.3	19.9
Hypertension (CC 89, 91)	83.2	85.2	87.0	85.1
Stroke (CC 95, 96)	9.8	9.6	9.3	9.6
Cerebrovascular disease (CC 97-99, 103)	21.3	21.5	22.0	21.6
Renal failure (CC 131)	25.1	27.1	29.2	27.1
COPD (CC 108)	53.5	54.1	55.1	54.2
Pneumonia (CC 111-113)	41.9	42.1	42.0	42.0
Protein-calorie malnutrition (CC 21)	11.7	12.5	13.2	12.5
Dementia and senility(CC 49, 50)	28.7	30.6	31.5	30.2
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102,177, 178)	8.3	8.5	8.9	8.5
Peripheral vascular disease (CC 104, 105)	29.6	30.3	31.6	30.5
Metastatic cancer, acute leukemia, and other severe cancers (CC 7,8)	9.3	9.4	9.7	9.5
Trauma in last year (CC 154-156, 158-162)	38.6	40.1	40.7	39.8
Major psychiatric disorders (CC 54-56)	12.6	13.3	14.0	13.3
Chronic liver disease (CC 25-27)	1.6	1.8	2.0	1.8
Severe hematological disorders (CC 44)	4.4	4.5	3.6	4.2
Iron deficiency/anemias/blood disease (CC 47)	51.4	54.9	58.9	55.0
Depression (CC 58)	17.5	20.8	24.3	20.8
Parkinson's/Huntington's diseases (CC 73)	4.1	4.2	4.1	4.1
Seizure disorders and convulsions (CC 74)	5.3	5.6	5.8	5.5
Fibrosis of lung and other chronic lung disorders (CC 109)	16.1	16.1	15.8	16.0
Asthma (CC 110)	10.8	11.0	11.4	11.1
Vertebral fractures (CC 157)	5.0	5.0	5.1	5.1

Table 12 – Adjusted OR and 95% CIs for the Pneumonia Hierarchical Logistic Regression Model over Different Time Periods

Variable	07/2009-06/2010 OR (95% CI)	07/2010-06/2011 OR (95% CI)	07/2011-06/2012 OR (95% CI)	07/2009-06/2012 OR (95% CI)
Age-65	1.05 (1.05 - 1.05)	1.05 (1.05 - 1.05)	1.05 (1.05 - 1.05)	1.05 (1.05 - 1.05)
Male	1.21 (1.19 - 1.24)	1.21 (1.19 - 1.24)	1.20 (1.17 - 1.22)	1.21 (1.19 - 1.22)
History of PTCA	0.60 (0.55 - 0.64)	0.74 (0.70 - 0.78)	0.77 (0.74 - 0.81)	0.73 (0.70 - 0.75)
History of CABG	0.65 (0.61 - 0.69)	0.82 (0.78 - 0.85)	0.88 (0.85 - 0.92)	0.81 (0.79 - 0.83)
Congestive heart failure (CC 80)	1.29 (1.26 - 1.32)	1.26 (1.23 - 1.29)	1.22 (1.19 - 1.25)	1.26 (1.24 - 1.28)
Acute myocardial infarction (CC 81)	1.28 (1.22 - 1.36)	1.31 (1.25 - 1.39)	1.20 (1.14 - 1.27)	1.27 (1.23 - 1.31)
Other acute/subacute forms of ischemic heart disease (CC 82)	0.94 (0.90 - 0.99)	0.89 (0.85 - 0.94)	0.93 (0.88 - 0.98)	0.92 (0.89 - 0.94)
Chronic atherosclerosis (CC 83, 84)	0.89 (0.87 - 0.91)	0.96 (0.94 - 0.99)	0.98 (0.96 - 1.01)	0.95 (0.93 - 0.96)
Cardio-respiratory failure and shock (CC 79)	1.33 (1.29 - 1.36)	1.30 (1.26 - 1.33)	1.25 (1.22 - 1.29)	1.29 (1.27 - 1.32)
Hypertension (CC 89, 91)	0.79 (0.77 - 0.81)	0.81 (0.79 - 0.84)	0.85 (0.82 - 0.88)	0.81 (0.8 - 0.83)
Stroke (CC 95, 96)	1.06 (1.02 - 1.10)	1.07 (1.03 - 1.11)	1.08 (1.04 - 1.12)	1.07 (1.05 - 1.09)
Cerebrovascular disease (CC 97-99, 103)	0.94 (0.91 - 0.96)	0.93 (0.91 - 0.96)	0.91 (0.88 - 0.93)	0.93 (0.91 - 0.94)
Renal failure (CC 131)	1.16 (1.13 - 1.19)	1.13 (1.10 - 1.15)	1.11 (1.08 - 1.14)	1.14 (1.12 - 1.15)
COPD (CC 108)	0.95 (0.93 - 0.97)	0.97 (0.94 - 0.99)	1.01 (0.98 - 1.03)	0.97 (0.96 - 0.99)
Pneumonia (CC 111-113)	1.10 (1.08 - 1.13)	1.06 (1.04 - 1.09)	1.04 (1.02 - 1.07)	1.07 (1.05 - 1.08)
Protein-calorie malnutrition (CC 21)	2.16 (2.10 - 2.22)	2.16 (2.10 - 2.22)	2.18 (2.13 - 2.24)	2.19 (2.16 - 2.22)
Dementia and senility(CC 49, 50)	1.41 (1.38 - 1.45)	1.50 (1.46 - 1.53)	1.49 (1.46 - 1.53)	1.47 (1.45 - 1.49)
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177, 178)	1.22 (1.18 - 1.27)	1.17 (1.13 - 1.22)	1.20 (1.16 - 1.25)	1.20 (1.17 - 1.22)
Peripheral vascular disease (CC 104, 105)	1.03 (1.00 - 1.05)	1.02 (1.00 - 1.05)	0.99 (0.97 - 1.01)	1.02 (1.00 - 1.03)
Metastatic cancer, acute leukemia, and other severe cancers (CC 7,8)	3.23 (3.14 - 3.33)	3.23 (3.13 - 3.32)	3.33 (3.24 - 3.44)	3.27 (3.22 - 3.33)
Trauma in last year (CC 154-156, 158-162)	1.10 (1.07 - 1.12)	1.05 (1.03 - 1.08)	1.06 (1.04 - 1.09)	1.07 (1.06 - 1.08)
Major psychiatric disorders (CC 54-56)	1.13 (1.09 - 1.16)	1.10 (1.07 - 1.14)	1.12 (1.09 - 1.16)	1.12 (1.10 - 1.14)
Chronic liver disease (CC 25-27)	1.40 (1.30 - 1.50)	1.35 (1.26 - 1.45)	1.44 (1.35 - 1.54)	1.40 (1.35 - 1.46)
Severe hematological disorders (CC 44)	1.31 (1.25 - 1.37)	1.25 (1.19 - 1.30)	1.24 (1.18 - 1.30)	1.27 (1.24 - 1.31)
Iron deficiency/anemias/blood disease (CC 47)	1.01 (0.99 - 1.04)	1.10 (1.08 - 1.13)	1.16 (1.13 - 1.19)	1.09 (1.07 - 1.10)
Depression (CC 58)	0.95 (0.93 - 0.98)	0.98 (0.95 - 1.00)	0.97 (0.95 - 1.00)	0.97 (0.95 - 0.98)
Parkinson's/Huntington's diseases (CC 73)	1.08 (1.03 - 1.13)	1.12 (1.06 - 1.17)	1.12 (1.06 - 1.17)	1.10 (1.07 - 1.14)
Seizure disorders and convulsions (CC 74)	0.97 (0.92 - 1.01)	1.02 (0.98 - 1.07)	1.01 (0.97 - 1.06)	1.00 (0.98 - 1.03)
Fibrosis of lung and other chronic lung disorders (CC109)	1.09 (1.06 - 1.12)	1.15 (1.12 - 1.18)	1.12 (1.09 - 1.15)	1.13 (1.11 - 1.14)
Asthma (CC 110)	0.66 (0.64 - 0.69)	0.69 (0.66 - 0.72)	0.69 (0.67 - 0.72)	0.68 (0.67 - 0.70)
Vertebral fractures (CC 157)	1.19 (1.14 - 1.24)	1.15 (1.10 - 1.20)	1.20 (1.15 - 1.25)	1.18 (1.15 - 1.21)
Between Hospital Variance (SE)	0.06 (0.004)	0.07 (0.004)	0.07 (0.005)	0.07 (0.003)

Table 13 – Pneumonia Logistic Regression Model Performance over Different Time Periods

Characteristic	07/2009-06/2010	07/2010-06/2011	07/2011-06/2012	07/2009-06/2012
Predictive ability, % (lowest decile – highest decile)	2.3-29.0	2.0-29.1	2.0-28.6	2.2-28.8
c-statistic	0.72	0.72	0.72	0.72

Table 14 – Distribution of Hospital Pneumonia Admission Volumes over Different Time Periods[§]

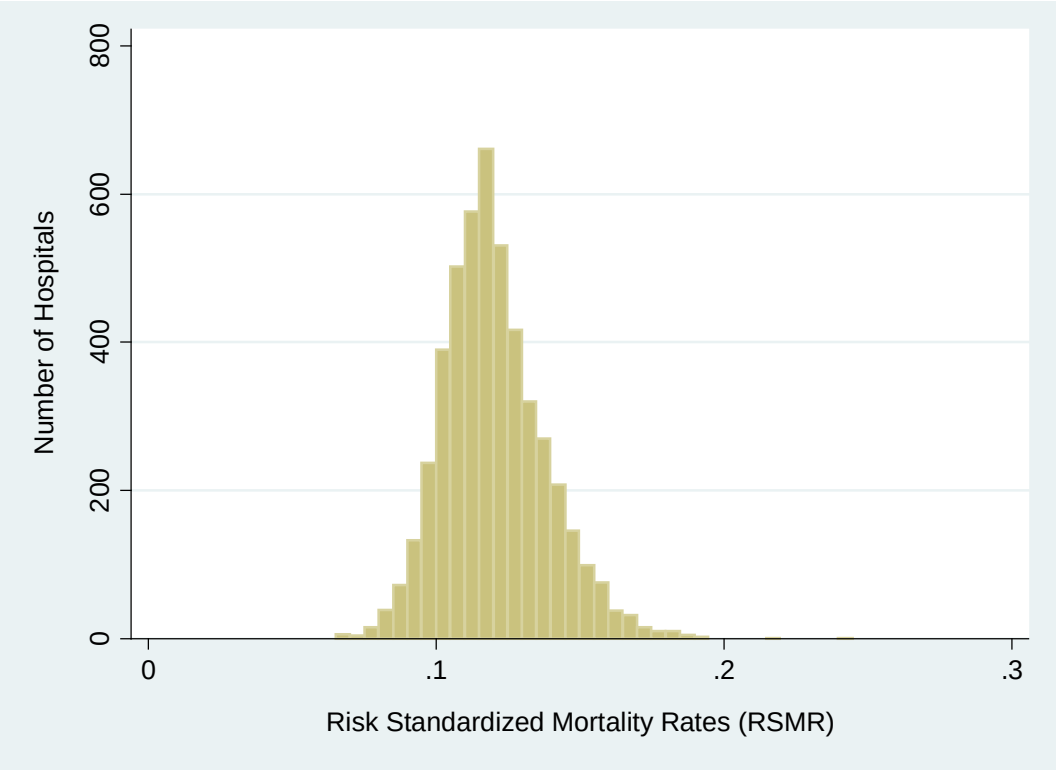
Characteristic	07/2009-06/2010	07/2010-06/2011	07/2011-06/2012	07/2009-06/2012
Number of Hospitals	4749	4744	4723	4817
Mean Number of Admissions (SD)	73.2 (69.9)	75.2 (72.5)	70.6 (69.6)	215.4 (209.7)
Range (min. – max.)	1-698	1-781	1-715	1-2194
25th percentile	24	24	22	68
50th percentile	52	53	48	150
75th percentile	101	103	97	297

Table 15 – Distribution of Hospital Pneumonia RSMRs over Different Time Periods (%)

Characteristic	07/2009-06/2010	07/2010-06/2011	07/2011-06/2012	07/2009-06/2012
Number of Admissions	347585	356694	333370	1037583
Mean (SD)	11.9 (1.6)	12.0 (1.7)	11.7 (1.7)	11.8 (1.9)
Range (min. – max.)	7.2-18.7	7.1-20.8	7.2-19.4	6.5-24.5
25th percentile	10.8	10.8	10.6	10.5
50th percentile	11.8	11.8	11.6	11.7
75th percentile	12.9	13.0	12.6	13.0

[§] Hospital volumes for third year of reporting (July 2011-2012) are lower in part due to incomplete enrollment data for discharges in June 2012.

Figure 6 – Distribution of Hospital 30-Day Pneumonia RSMRs between July 2009 and June 2012



N= 4,817 hospitals

5. QUALITY ASSURANCE (QA)

We have a two-phase approach to internal QA for the mortality measures maintenance process. These phases are described below. Please refer to Figure 7 for a detailed outline of phase I and Figure 8 for a detailed outline of phase II.

Note that this section represents QA for the subset of the work conducted by YNHHSC/CORE to maintain and report these mortality measures. It does not describe the QA to process data and create the input files, nor does it include the QA for the final processing of production data for public reporting because that work is conducted by another contractor (Mathematica Policy Research, Inc.).

5.1 Phase I

The first step in the QA process is to ensure the validity of the input data files. There were no substantial changes to the data input processing, and only one additional year of data was added to our existing data sets. Only one new field was added to support the production of another measure. There was minimal need for targeted quality checks this year, so the automated process we developed previously allowed for a thorough review of the new data sets.

In general, all condition-specific files for each reporting year are evaluated by comparing them to the prior year's QA results for the same condition/year. We conduct data validity checks, including crosschecking of death information, distributions of ICD-9-CM codes, and frequencies of key variables. We employ both manual scan and descriptive analyses to carry out these tasks. The results are reviewed for accuracy and changes over time compared to prior datasets. Any new variable constructs and other changes in formatting to the input files are also verified as part of this process. We share our QA findings with our data extraction contractor as needed.

To assure accuracy in SAS pack coding, two analysts independently write SAS code for any changes made in calculating the mortality measures: data preparation, sample selection, hierarchical modeling, and calculation of RSMR. This process highlights any programming errors in syntax or logic. Once the parallel programming process is complete, the analysts cross-check their codes by analyzing datasets in parallel, checking for consistency of output and reconciling any discrepancies.

5.2 Phase II

A third analyst reviews the finalized SAS code and recommends changes to the coding and readability of the SAS pack, where appropriate. The primary analyst receives the suggested changes for possible re-coding or program documentation.

This phase also includes a comparison of prior years' risk-adjustment coefficients and variable frequencies. This enables us to check for potential inconsistencies in the data as well as the impact of any changes to the SAS pack.

Figure 7 – YNHHSC/CORE QA Phase I

Yale-CORE QA Processes

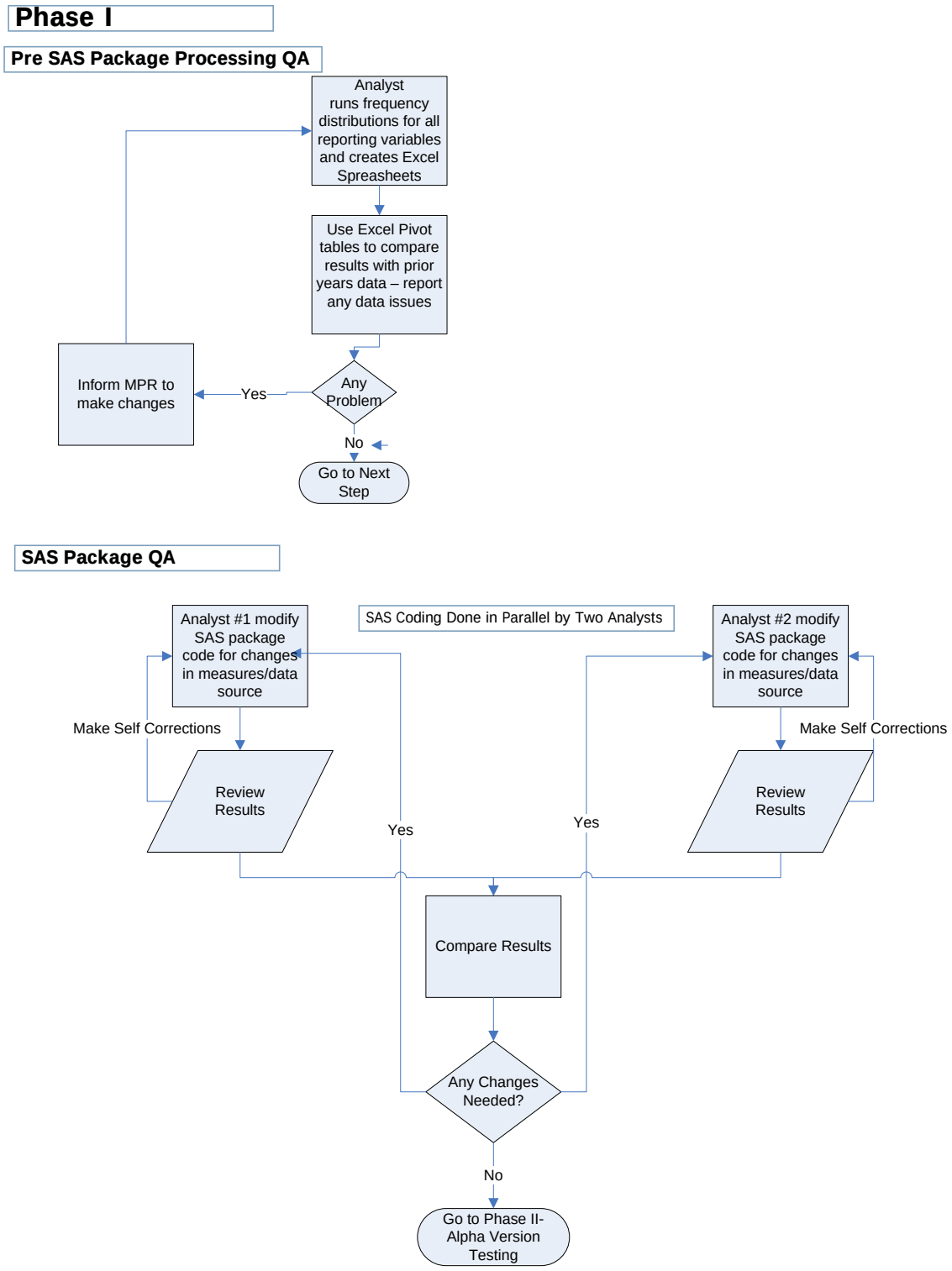
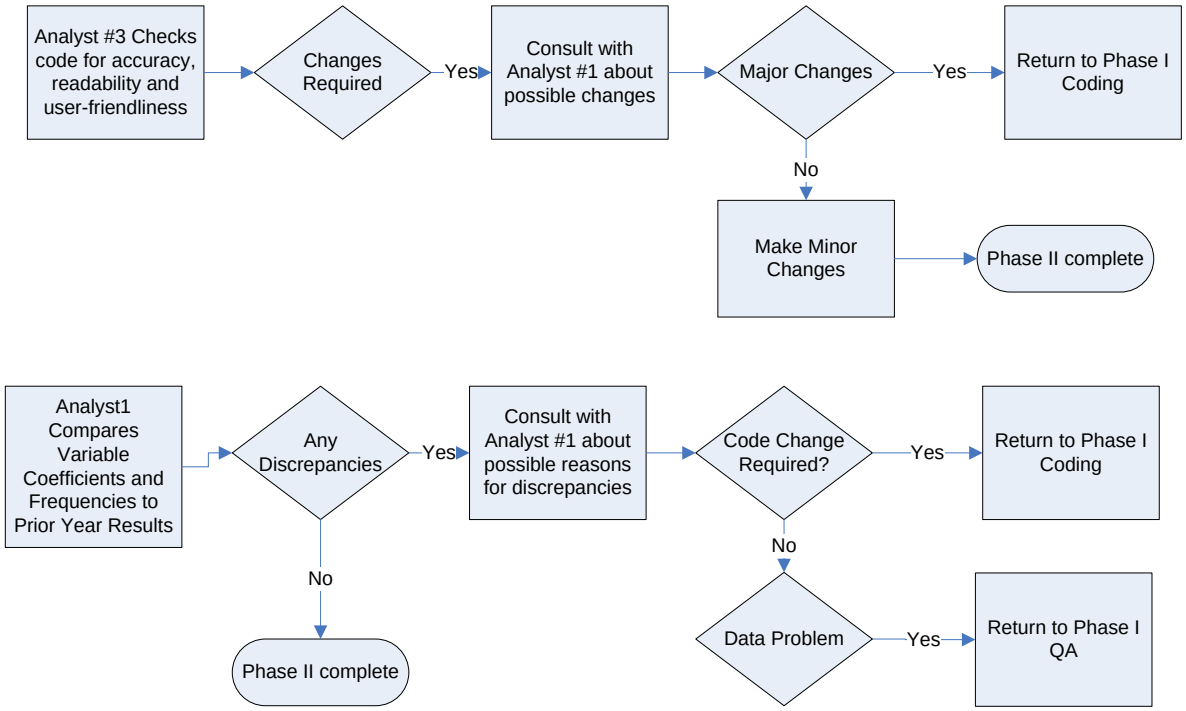


Figure 8 – YNHHSC/CORE QA Phase II

Phase II

Results Testing – Alpha Version



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7. APPENDICES

Appendix A. Measure Specifications

1. Cohort ICD-9-CM Codes by Measure

AMI Cohort Codes

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

Heart Failure Cohort Codes

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
428.0 Congestive heart failure, unspecified
428.1 Left heart failure
428.20 Systolic heart failure, unspecified
428.21 Systolic heart failure, acute
428.22 Systolic heart failure, chronic
428.23 Systolic heart failure, acute or chronic
428.30 Diastolic heart failure, unspecified
428.31 Diastolic heart failure, acute
428.32 Diastolic heart failure, chronic
428.33 Diastolic heart failure, acute or chronic

428.40 Combined systolic and diastolic heart failure, unspecified
428.41 Combined systolic and diastolic heart failure, acute
428.42 Combined systolic and diastolic heart failure, chronic
428.43 Combined systolic and diastolic heart failure, acute or chronic
428.9 Heart failure, unspecified

Pneumonia Cohort Codes

480.0 Pneumonia due to adenovirus
480.1 Pneumonia due to respiratory syncytial virus
480.2 Pneumonia due to parainfluenza virus
480.3 Pneumonia due to SARS-associated coronavirus
480.8 Viral pneumonia: pneumonia due to other virus not elsewhere classified
480.9 Viral pneumonia unspecified
481 Pneumococcal pneumonia [streptococcus pneumoniae pneumonia]
482.0 Pneumonia due to klebsiella pneumoniae
482.1 Pneumonia due to pseudomonas
482.2 Pneumonia due to hemophilus influenzae (h. influenzae)
482.30 Pneumonia due to streptococcus unspecified
482.31 Pneumonia due to streptococcus group a
482.32 Pneumonia due to streptococcus group b
482.39 Pneumonia due to other streptococcus
482.40 Pneumonia due to staphylococcus unspecified
482.41 Pneumonia due to staphylococcus aureus
482.42 Methicillin resistant pneumonia due to Staphylococcus aureus
482.49 Other staphylococcus pneumonia
482.81 Pneumonia due to anaerobes
482.82 Pneumonia due to escherichia coli [e.coli]
482.83 Pneumonia due to other gram-negative bacteria
482.84 Pneumonia due to legionnaires' disease
482.89 Pneumonia due to other specified bacteria
482.9 Bacterial pneumonia unspecified
483.0 Pneumonia due to mycoplasma pneumoniae
483.1 Pneumonia due to chlamydia
483.8 Pneumonia due to other specified organism
485 Bronchopneumonia organism unspecified
486 Pneumonia organism unspecified
487.0 Influenza with pneumonia
488.11 Influenza due to identified novel H1N1 influenza virus with pneumonia

2. **Outcome Definition Criteria for AMI, HF and pneumonia mortality measures**

30-day time frame

Rationale: Outcomes occurring within 30 days of discharge can be influenced by hospital care and the early transition to the outpatient setting. The use of the 30-day time frame is a clinically meaningful period for hospitals to collaborate with their communities in an effort to reduce mortality.

All-cause mortality

Rationale: From a patient perspective, death is the most critical outcome regardless of cause.

3. **Cohort Inclusion Criteria for AMI, HF and pneumonia mortality measures**

Principal discharge diagnosis of AMI, HF, or pneumonia

Rationale: AMI, HF, and pneumonia are the conditions targeted for measurement in this report.

Enrolled in Part A and Part B Medicare for the 12 months prior to the date of admission, and enrolled in Part A during the index admission

Rationale: The 12 month prior enrollment ensures a full year of administrative data for risk adjustment (requirement is dropped for patients with an index admission within a VA hospital). Part A is required during the index admission to ensure no Medicare Advantage patients are included in the measures.

Aged 65 or older

Rationale: Medicare patients younger than 65 are not included in the measure because they are considered to be too clinically different from patients 65 and over as they often qualify for Medicare at a younger age because of disabilities.

4. **Cohort Exclusion Criteria for AMI, HF and pneumonia mortality measures**

Discharged alive on the day of admission or the following day (and not transferred or AMA)

Rationale: It is unlikely that these patients had a clinically significant AMI, HF, or pneumonia.

Transfers from another acute care facility

Rationale: Death is attributed to the hospital where the patient was initially admitted. These patients are still included in the measure cohort, but the initial admitting hospital is accountable for the outcome (thus the "transfer-in" hospitalization is excluded as an index admission).

Inconsistent or unknown vital status or other unreliable data

Rationale: We do not include stays for patients where the age is greater than 115, where the gender is neither male nor female, where the admission date is after the date of death in the Medicare Enrollment Database, or where the date of death occurs before the date of discharge but the patient was discharged alive.

Enrolled in the Medicare hospice program or used VA hospice services any time in the 12 months prior to the index admission, including the first day of the index admission

Rationale: These patients are likely continuing to seek comfort measures only, so mortality is not necessarily an adverse outcome or signal of poor quality care for these patients.

Discharged against medical advice (AMA)

Rationale: Providers did not have the opportunity to deliver full care and prepare the patient for discharge.

Subsequent admissions within 30 days prior to or on the death date for a patient

Rationale: This exclusion only applies to the three-year combined data, when two randomly selected admissions occur during the transition months (December and January for calendar year data) and the patient subsequently dies. This prevents attributing the death to two separate admissions.

For patients with more than one admission in a given year for a given condition, only one admission for that condition is randomly selected to include in the cohort of index admissions

Rationale: Each episode of care must be mutually independent with the same probability of the outcome. The probability of death increases with each subsequent admission and therefore the episodes of care are not mutually independent.

Table A1 – Risk Variables

Variable	Codes	AMI	HF	Pneumonia
Age-65 (years above 65, continuous)	n/a	x	x	x
Male	n/a	x	x	x
History of PTCA	ICD-9-CM V45.82, 00.66, 36.01, 36.02, 36.05, 36.06, 36.07	x		
History of CABG	ICD-9-CM V45.81, 36.10–36.16	x	x	x
Congestive heart failure	CC 80	x	x	x
Acute coronary syndrome	CC 81, 82	x	x	x
Angina pectoris/old myocardial infarction	CC 83	x	x	x
Coronary atherosclerosis/other chronic ischemic heart disease	CC 84	x	x	x
Valvular and rheumatic heart disease	CC 86	x	x	x
Arrhythmias	CC 92, 93	x	x	x
Vascular or circulatory disease	CC 104-106	x	x	x
Cardio-respiratory failure and shock	CC 79	x	x	x
Other and unspecified heart disease	CC 94		x	
Anterior myocardial infarction	ICD-9-CM 410.00-410.19	x		
Other location of myocardial infarction	ICD-9-CM 410.20-410.69	x		
Metastatic cancer and acute leukemia	CC 7	x	x	x
Lung, upper digestive tract, and other severe cancers	CC 8			x
Lymphatic, head and neck, brain, and other major cancers; breast, prostate, colorectal and other cancers and tumors	CC 9-10			x
Cancer	CC 8-12	x	x	
Diabetes and DM complications	CC 15-20, 119, 120	x	x	x
Protein-calorie malnutrition	CC 21	x	x	x
Disorders of fluid/electrolyte/acid-base	CC 22, 23	x	x	x
Iron deficiency and other/unspecified anemias and blood disease	CC 47	x	x	x
Dementia and senility	CC 49, 50	x	x	x
Hemiplegia, paraplegia, paralysis, functional disability	CC 67-69, 100-102, 177, 178	x	x	x
Stroke	CC 95, 96	x	x	x
COPD	CC 108	x	x	x
Asthma	CC 110			x
Pneumonia	CC 111-113	x	x	x
End-stage renal disease or dialysis	CC 129, 130	x	x	x
Renal failure	CC 131	x	x	x
Other urinary tract disorders	CC 136	x	x	x
Decubitus ulcer or chronic skin ulcer	CC 148, 149	x	x	x

History of infection	CC 1, 3-6	x		x
Other gastrointestinal disorders	CC 36		x	x
Drug/alcohol abuse/dependence/psychosis	CC 51-53		x	x
Major psychiatric disorders	CC 54-56		x	x
Other psychiatric disorders	CC 60		x	x
Fibrosis of lung and other chronic lung disorders	CC 109		x	x
Severe hematological disorders	CC 44		x	x
Cerebrovascular disease	CC 97-99, 103			
Peptic ulcer, hemorrhage, other specified gastrointestinal disorders	CC 34		x	
Nephritis	CC 132		x	
Liver and biliary disease	CC 25-30		x	
Depression	CC 58		x	
Septicemia/shock	CC 2			x
Pleural effusion/pneumothorax	CC 114			x
Other lung disorders	CC 115			x
Urinary tract infection	CC 135			x
Vertebral fractures	CC 157			x
Other injuries	CC 162			x

Table A2 – Risk Variables Considered Complications of Care During the Index Admission*

CC	Description	AMI	HF	Pneumonia
2	Septicemia/Shock			x
6	Other Infectious Diseases	x		x
17	Diabetes with Acute Complications	x	x	x
23	Disorders of Fluid/Electrolyte/Acid-Base	x	x	x
28	Acute Liver Failure/Disease		x	
34	Peptic Ulcer, Hemorrhage, Other Specified Gastrointestinal Disorders		x	
79	Cardio-Respiratory Failure and Shock	x	x	x
80	Congestive Heart Failure	x	x	x
81	Acute Myocardial Infarction	x	x	x
82	Other Acute/subacute forms of Ischemic Heart Disease	x	x	x
92	Specified Heart Arrhythmias	x	x	x
93	Other Heart Rhythm and Conduction Disorders	x	x	x
95	Cerebral Hemorrhage	x	x	x
96	Ischemic or Unspecified Stroke	x	x	x
97	Precerebral Arterial Occlusion and Transient Cerebral Ischemia	x		
100	Hemiplegia/Hemiparesis	x	x	x
101	Diplegia (Upper), Monoplegia, and Other Paralytic Syndromes	x	x	x
102	Speech, Language, Cognitive, Perceptual	x	x	x
104	Vascular Disease with Complications	x	x	x
105	Vascular Disease	x	x	x
106	Other Circulatory Disease	x	x	x
111	Aspiration and Specified Bacterial Pneumonias	x	x	x
112	Pneumococcal Pneumonia, Emphysema, Lung Abscess	x	x	x
114	Pleural Effusion/Pneumothorax			x
129	End Stage Renal Disease	x	x	x
130	Dialysis Status	x	x	x
131	Renal Failure	x	x	x
132	Nephritis		x	
135	Urinary Tract Infection			x
148	Decubitus Ulcer of Skin	x	x	x
164	Major Complications of Medical Care and Trauma			x
177	Amputation Status, Lower Limb/Amputation	x	x	x
178	Amputation Status, Upper Limb	x	x	x

* The selected CC's are considered complications of care and are not risk-adjusted for if they only occur during the index admission.

5. Statistical Approach to Risk-Standardized Mortality Rates

We estimate the hospital-specific risk-standardized mortality rates using hierarchical generalized linear models. This strategy accounts for within-hospital correlation of the observed outcome and accommodates the assumption that underlying differences in quality across hospitals lead to systematic differences in outcomes. We model the probability of mortality as a function of patient age, sex, clinically relevant comorbidities, and history of PCI and/or CABG with an intercept for the hospital-specific random effect.

We use the following strategy to calculate the hospital-specific mortality rates. We calculate these rates as the ratio of a hospital's "predicted" mortality to "expected" mortality multiplied by the national observed mortality rate. The expected mortality for each hospital is estimated using its patient-mix and the average hospital-specific intercept (that is, the average intercept among all hospitals in the sample). The predicted mortality for each hospital is estimated given the same patient-mix but an estimated hospital-specific intercept. Operationally, the expected mortality for each hospital is obtained by summing the expected probabilities of mortality for all patients in the hospital. The expected probability of mortality for each patient is calculated via the hierarchical model which applies the estimated regression coefficients to the observed patient characteristics and adds the average of the hospital-specific. The predicted mortality for each hospital is calculated by summing the predicted probabilities for all patients in the hospital. The predicted probability for each patient is calculated through the hierarchical model which applies the estimated regression coefficients to the patient characteristics observed and adding the hospital-specific intercept.

More specifically, we use a hierarchical generalized linear model, in this case, a hierarchical logistic regression, to account for the natural clustering of observations within hospitals. The model employs a logit link function to link the risk factors to the outcome with a hospital-specific random effect as follows:

$$h(Y_{ij}) = \alpha_i + \beta \mathbf{Z}_{ij} \quad (1)$$

$$\alpha_i = \mu + \omega_i; \qquad \omega_i \sim N(0, \tau^2) \quad (2)$$

Where h(.) is a logit link, Y_{ij} is whether the j^{th} patient in the i^{th} hospital died (1: death, 0 otherwise); α_i represents the hospital-specific intercept, $\mathbf{Z}_{ij} = (Z_{1ij}, Z_{2ij}, \ldots, Z_{pij})$ the patient-specific covariates, μ is the average hospital intercept across all hospitals in the sample, and τ^2 is the between-hospital variance component[1]. This model separates within-hospital variation from between-hospital variation. The hierarchical generalized linear models are estimated using the SAS software system (SAS 9.2 GLIMMIX).

Hospital performance reporting

Using the selected set of risk factors, we fit the hierarchical generalized linear model defined by Equations (1) - (2) and estimate the parameters, $\hat{\mu}$, $\{\hat{\alpha}_i, \hat{\alpha}_2, \ldots, \hat{\alpha}_I\}$, $\hat{\beta}$, and $\hat{\tau}^2$ where i is the total number of hospitals. We calculate a standardized outcome measure, RSMR, for each hospital by

[1] Daniels M, Gatsonic C. Hierarchical Generalized Linear Models in the Analysis of Variations in Health Care Utilization. *Journal of the American Statistical Association.* 1999;94(445):14

computing the ratio of the predicted mortality to the expected mortality, multiplied by the national observed mortality rate, $\bar{y}$. Specifically, we calculate

Predicted $$\hat{y}_{ij}(Z_{ij}) = h^{-1}(\hat{\alpha}_i + \hat{\beta}\mathbf{Z}_{ij}) \quad (3)$$

Expected $$\hat{e}_{ij}(Z_{ij}) = h^{-1}(\hat{\mu} + \hat{\beta}\mathbf{Z}_{ij}) \quad (4)$$

$$\widehat{RSMR}_i = \frac{\sum_{j=1}^{n_i} \hat{y}_{ij}(Z_{ij})}{\sum_{j=1}^{n_i} \hat{e}_{ij}(Z_{ij})} \times \bar{y} \quad (5)$$

Above, n_i is the number of index hospitalizations for the i^{th} hospital.

If the "predicted" mortality is higher (or lower) than the "expected" mortality for a given hospital, then its $\widehat{RSMR}$ will be higher (or lower) than the national observed mortality rate. For each hospital, we compute an interval estimate of $RSMR_i$ to characterize the level of uncertainty around the point estimate using bootstrapping simulations as described below. The point estimate and interval estimate are used to characterize and compare hospital performance (for example, higher than expected, as expected, or lower than expected).

Creating Interval Estimates

Because the statistic described in Equation 5**,** that is, $\widehat{RSMR}_i$ is a complex function of parameter estimates, we use the re-sampling technique, bootstrapping, to derive an interval estimate. Bootstrapping has the advantage of avoiding unnecessary distributional assumptions.

Algorithm:

Let *I* denote the total number of hospitals in the sample. We repeat steps 1-4 below for B times, where *B* is the number of bootstrap samples desired:

1. Sample *I* hospitals with replacement.
2. Fit the hierarchical generalized linear model using all patients within each sampled hospital. If some hospitals are selected more than once in a bootstrapped sample, we treat them as distinct so that we have *I* random effects to estimate the variance components. At the conclusion of Step 2, we have:
    a. $\hat{\beta}^{(b)}$ (the estimated regression coefficients of the risk factors).
    b. The parameters governing the random effects, hospital adjusted outcomes, distribution, $\hat{\mu}^{(b)}$ and $\hat{\tau}^{2(b)}$.

c. The set of hospital-specific intercepts and corresponding variances,

$$\{\hat{\alpha}_i^{(b)}, \widehat{var}\left(\alpha_i^{(b)}\right); i = 1,2,\ldots,I\}$$

3. We generate a hospital random effect by sampling from the distribution of the hospital-specific distribution obtained in Step 2c. We approximate the distribution for each random effect by a normal distribution. Thus, we draw $\alpha_i^{(b*)} \sim N(\hat{\alpha}_i^{(b)}, \widehat{var}(\hat{\alpha}_i^{(b)}))$ for the unique set of hospitals sampled in Step 1.

4. Within each unique hospital *i* sampled in Step 1, and for each case *j* in that hospital, we calculate $\hat{y}_{ij}^{(b)}$, $\hat{e}_{ij}^{(b)}$, and $\widehat{RSMR}_i(Z)^{(B)}$ where $\hat{\beta}^{(b)}$ and $\hat{\mu}^{(b)}$ are obtained from Step 2 and $\hat{\alpha}_i^{(b*)}$ is obtained from Step 3.

Ninety-five percent interval estimates (or alternative interval estimates) for the hospital-standardized outcome can be computed by identifying the 2.5th and 97.5th percentiles of the B estimates (or the percentiles corresponding to the alternative desired intervals)[2].

[2] Normand S, Wang Y, Krumholz H. Assessing surrogacy of data sources for institutional comparisons. *Health Services and Outcomes Research Methodology.* 2007;7:79-96.

Appendix B. Annual Updates

Prior annual updates for the measures can be found in the annual maintenance reports available on QualityNet. For convenience, we have listed all prior updates here under the reporting year and corresponding report. In 2013, CMS began assigning version numbers to its measures. The measure specifications in the original methodology reports are considered Version 1.0 for each measure. The measures receive a new version number for each subsequent year of updates.

2008 Measures Maintenance Report (Version 2.0)

1. Added three viral pneumonia codes (480.0, 480.1, and 480.2)
    a. Rationale: Viral pneumonias are common causes of pneumonia in the elderly.
2. Excluded patients with a history of Medicare hospice enrollment in the 12 months prior to or on the index admission date
    a. Rationale: These patients are likely continuing to seek comfort measures only, so mortality is not necessarily an adverse outcome or signal of poor quality care for these patients.
3. Added checks for cases with unreliable mortality, vital status, age, and gender data and exclude such cases
    a. Additional checks include: patients over 115 years of age; date of discharge is before the date of admission; unknown gender; two hospitals have conflicting death information for the same patient.
4. Modified list of complications
    a. Rationale: The models do not adjust for risk factors present on an index admission if the conditions may represent complications of care.
5. Discontinued use of hierarchical component of the HCC system
    a. Rationale: The hierarchical logic is meant to predict expenditures, not to estimate prevalence of comorbidities. Dropping the hierarchy allowed the risk factor coefficients to better reflect the true disease burden.
6. Updated CC map
    a. Rationale: The ICD-9-CM CC map is updated annually to capture all relevant comorbidities coded in patient administrative claims data.

2009 Measures Maintenance Report (Version 3.0)

1. Randomly selected one AMI admission per patient per year for inclusion in the cohort
    a. Rationale: Three-year data increased the number of multiple AMI admissions, which would be statistically correlated. Randomly selecting one AMI admission per year aligned the measure with HF and PN.
2. Used three years of claims and enrollment data for public reporting
    a. Rationale: Three years of data increased the precision of the hospital RSMR estimates by increasing the number of admissions used to calculate the rates. CMS developed the measures using one year of data.
3. Excluded patients discharged against medical advice (AMA)
    a. Rationale: Providers are not able to deliver full care and prepare the patient for discharge when patients leave AMA.
4. Updated CC map
    a. Rationale: The ICD-9-CM CC map is updated annually to capture all relevant comorbidities coded in patient administrative claims data.

2010 Measures Maintenance Report (Version 4.0)

1. Revised period for collecting comorbidities from claims codes
    a. Rationale: The revised models use comorbidities coded within 365 days of admission rather than 365 days of discharge. This includes more clinical covariates for risk adjustment.
2. Updated CC map
    a. Rationale: The ICD-9-CM CC map is updated annually to capture all relevant comorbidities coded in patient administrative claims data.

2011 Measures Maintenance Report (Version 5.0)

1. Added two additional pneumonia codes (482.42 and 488.11)
    a. Rationale: CMS updated ICD-9 cohort codes to distinguish between Methicillin susceptible and resistant Staphylococcus aureus pneumonia (482.41 and 482.42), and added a new code for viral pneumonia cases (488.11) to reflect the emergence of H1N1 influenza virus.
2. Included VA Hospitals
    a. Rationale: Created a more inclusive perspective of the relative quality of US hospitals.
3. Updated CC map
    a. Rationale: The ICD-9-CM CC map is updated annually to capture all relevant comorbidities coded in patient administrative claims data.

2012 Measures Maintenance Report (Version 6.0)

1. Included VA one-day stays
    a. Rationale: Stays of less than 24 hours that result in death, discharge against medical advice, transfer (or follow a transfer) are not likely to be observation stays because the time frame of the admissions was determined not by clinical necessity but by other factors such as death or transfer. These stays had been previously excluded from the measure.
2. Excluded patients based on enrollment in VA hospice (as well as CMS hospice)
    a. Rationale: VA patients who have a history of VA hospice care in the 12 months prior to the index admission are now excluded.
3. Incorporated of Version 5010 format
    a. Rationale: Version 5010 increased the number of diagnoses and procedures hospitals could code on Medicare claims. The inclusion of 15 additional codes for diagnoses and 19 additional codes for procedures allows us to identify additional comorbidities, thereby increasing the accuracy of risk-adjustment.
4. Updated CC map
    a. Rationale: The ICD-9-CM CC map is updated annually to capture all relevant comorbidities coded in patient administrative claims data.

2013 Measures Maintenance Report (Version 7.0)

1. Updated CC map
    a. Rationale: The ICD-9-CM CC map is updated annually to capture all relevant comorbidities coded in patient administrative claims data.

Appendix C. Common Terms

Cohort: The index admissions included in the measure after the inclusion and exclusion criteria have been applied.

Complications: Medical conditions that likely occurred as a consequence of care rendered, rather than as an expected outcome of the patient's condition or a condition that the patient had upon presentation to the hospital.

Comorbidities: Medical conditions that the patient had in addition to their primary disease.

Condition Categories (CCs): Groupings of ICD-9-CM diagnosis codes in clinically relevant categories, from the Hierarchical Condition Categories (HCCs) system. CMS uses the grouping but not the hierarchical logic of the system to create risk factor variables. Description of the Condition Categories can be found at http://www.cms.hhs.gov/Reports/downloads/pope_2000_2.pdf.

Expected mortality: The number of deaths expected on the basis of average hospital performance with a given hospital's case mix.

Hierarchical model: A widely accepted statistical method that enables fair evaluation of relative hospital performance by taking into account patient risk factors as well as the number of patients that a hospital treats. This statistical model accounts for the structure of the data (patients clustered within hospitals) and calculates: (1) how much variation in hospital mortality rates overall is accounted for by patients' individual risk factors (such as age and other medical conditions); and (2) how much variation is accounted for by hospital contribution to mortality risk.

Hospital-specific intercept: A measure of the hospital quality of care. It is calculated based on the hospital's actual mortality rate relative to hospitals with similar patients – considering how many patients it served, what its patients' risk factors were, and how many died. The hospital-specific effect will be negative for a better-than-average hospital, positive for a worse-than-average hospital, and close to zero for an average hospital. The hospital-specific effect is used in the numerator to calculate "predicted" mortality.

Index admission: Any admission included in the measure calculation as the initial admission for an episode of AMI, HF, or pneumonia care and evaluated for the outcome.

Interval estimate: Similar to a confidence interval. The interval estimate is a range of probable values for the estimate that characterizes the amount of uncertainty associated with the estimate. For example, a 95% interval estimate for a mortality rate indicates that CMS is 95% confident that the true value of the rate lies between the lower limit and the upper limit of the interval.

Medicare fee-for-service (FFS): Original Medicare plan. Only beneficiaries in Medicare FFS, not in managed care (Medicare Advantage), are included in the measures.

National observed mortality rate: All included hospitalizations with the outcome divided by all included hospitalizations.

Outcome: The result of a broad set of healthcare activities that affect patients' well-being. For the mortality measures, the outcome is mortality within 30 days of admission.

Predicted mortality: The number of deaths within 30 days predicted on the basis of the hospital's performance with its observed case mix, also referred to as "adjusted actual" mortality.

Risk-adjustment variables: Patient demographics and comorbidities that are used to standardize rates for differences in case mix across hospitals.

Appendix D. Memorandum

MEMORANDUM

From: RTI International
To: CMS/CCSQ
Date: December 24, 2012

Subject: Overview of update of mappings of ICD-9-CM codes to CC groups for risk adjustment of hospital mortality and readmission models, changes related to FY2012 codes. This is in the context of creating a mapping covering FY2008 – FY2012 to the CC diagnosis clusters.

Overview

Each year the CDC National Center for Health Statistics and the Centers for Medicare & Medicaid Services oversee the changes and modifications to the ICD-9-CM system made through the Coordination and Maintenance Committee. The committee is a joint public-private effort to update and improve the coding system.

RTI has developed and supported a classification system that uses these codes as the basis for risk adjustment systems. The Hierarchical Condition Category (HCC) system groups the ICD-9-CM codes into larger groups that are used in a model to predict medical care utilization, spending, mortality or other related measures. The condition categories (CCs) may also be used without applying the hierarchies that are used to categorize a person's medical conditions into the highest severity category of a set of related conditions. For this project the full set of 189 CCs in version 12 were updated for FY2012 changes and the changes were documented.

New ICD-9 codes generally become effective October 1 of each year, though there is a round of changes that may be made in an April announcement. Each calendar year of diagnosis data encompasses 2 years of codes. In the new mappings codes valid in FY2008 through FY2012 are all mapped to CCs. This allows the mapping to fully cover data from October 1, 2007 through September 30, 2012. These codes span CY2008 through CY2011 and the first nine months of 2012. The last three months of 2012 fall into FY2013.

Method

Additions and deletions

When the code changes are announced each year there may be both additions, deletions and changes to the descriptions of codes. We map only the valid codes, those of highest specificity, each year. ICD-9-CM codes have a minimum of three characters, mostly digits, and a maximum of five characters. The form is XXX, XXX.X or XXX.XX. [3] Code numbers after the decimal point are subclasses of the 3-digit main classes. An addition of new codes may be at any level from a new 3-digit class to new 4 and 5 digit subclasses. Deletions from ICD-9 may be explicit, the removal of a code from the code book. But deletions from our mapping occur more often because new, more specific, subcodes are introduced.

[3] In the Medicare data and our mappings the decimal points are omitted and all codes are left justified to remove ambiguity. The first character of a code may be an E or V as well as a digit.

Introduction of a new code of higher specificity than the code it sprang from does not remove the original 3- or 4- digit code from the ICD-9 book, but since coding is supposed to be done to the highest specificity, we remove the more general code from the mapping in the year it is superseded. If the new high specificity code is just an addition to an existing subset of codes of similar specificity, the new code is added but there would be no change in the status of the more general code. That code would have previously been superseded by higher specificity codes.

As an example, in 2012, code 0414, Bacterial infection in conditions classified elsewhere and of unspecified site, Escherichia coli [E.coli] was split into:

ICD-9	Short ICD-9 label
04141	Shiga txn-produce E.coli
04142	Shiga txn prod E.coli NEC
04143	Shiga txn prod E.coli NOS
04149	E.coli infection NEC/NOS

The new 5-digit codes were added to our mapping and were assigned to the same CC that 0414 was assigned to. The old 4-digit code would have been removed, except that 0414 was valid in 2008, 2009, 2010 and 2011. Since our mapping is intended to allow valid codes from those years, 0414 was retained.

In 2012 there were 168 codes added to ICD-9-CM. None were new 3-digit codes. Although there were a few 4-digit codes, the majority were of 5-digit specificity. The new 4-digit code groups were added with 5-digit detail. Among these there were 17 V-codes added but no E-codes. The V codes are for medical encounters but are not actual diagnoses of current conditions. The new 5-digit codes added more specificity within existing diagnostic code groups. In addition to the 0414 changes above another example is the 5 new codes in the ICD-9 code 5128 group, specifying particular types of pneumothorax. These were all mapped to the CC for "Pleural Effusion/Pneumothorax," where the nonspecific code was mapped previously. A more complicated situation is described in the *Mapping* section, below.

In FY 2012 there were 45 4-digit codes that were no longer at the highest specificity and are invalid starting that year. There was also one 3-digit code removed. However, the 46 codes are retained in our mapping because they were valid in the prior years covered by this mapping.

Mapping

Mapping of the new codes is done by review of the annual changes by RTI staff and clinical consultants. In most cases the codes of higher specificity are mapped to the same CC as the more general code that was split. This does not always occur. For example the ICD-9 code 9980 4-digit group was made invalid by the creation of 5-digit more specific codes. These are:

ICD-9	Short ICD-9 label	New CC	CC label
99800	Postoperative shock, NOS	164	Major Complications of Medical Care and Trauma
99801	Postop shock, cardiogenic	79	Cardio-Respiratory Failure and Shock
99802	Postop shock, septic	2	Septicemia/Shock
99809	Postop shock, other	164	Major Complications of Medical Care and Trauma

The original 4-digit code was assigned to CC 164. The more specific codes are not all assigned to that same CC. There is enough specificity to assign them to more specific CCs.

The general practice in maintaining the mappings for this work has been to maintain the existing structure of the CCs and to map the new codes to the location they would have gone to in prior years. However, sometimes the new specificity makes clear enough distinctions that new related codes do not all logically go to one place. Some new codes require judgment calls to be made. Our decision committee brings together both the people who maintain the integrity of the system and the people who provide the clinical expertise. The changes for FY2012 did not create a need for major changes but there were a few new 5-digit splits that did not all get assigned to the same CC.