2016 Procedure-Specific Measure Updates and Specifications Report Hospital-Level 30-Day Risk-Standardized Mortality Measure

Isolated Coronary Artery Bypass Graft (CABG) Surgery – Version 3.0

Submitted By:

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1. HOW TO USE THIS REPORT

This report describes the Centers for Medicare & Medicaid Services' (CMS's) procedure-specific mortality measure used in the Hospital Inpatient Quality Reporting program and publicly reported on *Hospital Compare*. The measure reports hospital-level 30-day risk-standardized mortality rate (RSMR) following isolated coronary artery bypass graft (CABG) surgery. This report provides a single source of information about this measure for a wide range of readers. Reports describing CABG surgery readmission, condition-specific mortality, and other outcome measures can be found on *QualityNet.*

This report provides an overview of the measure methodology, methodology updates for 2016 public reporting, and the national results for 2016 public reporting. The appendices provide detailed specifications for the measure, including tables of the codes used for cohort derivation and risk adjustment, as well as a history of annual updates.

Specifically, the report includes:

- **Section 2 - An overview of the CABG surgery mortality measure:**
  - Background
  - Cohort inclusions and exclusions
    - included and excluded hospitalizations
    - how transferred patients are handled
  - Outcome
  - Risk-adjustment variables
  - Data sources
  - Mortality rate calculation
  - Categorization of hospitals' performance score
- **Section 3 - 2016 measure updates**
- **Section 4 - 2016 measure results**
- **Section 5 - Glossary**

The Appendices contain detailed measure information, including:

- Appendix A: Statistical approach to calculating RSMRs;
- Appendix B: Data quality assurance (QA);
- Appendix C: Annual updates to the measure since measure development; and,
- Appendix D: Measure specifications.

For additional references, the original CABG surgery measure methodology report, as well as prior updates and specifications reports, are available in the Measure Methodology and Archived Resources sections under the claims-based mortality measures page of *QualityNet*:

- Hospital-Level 30-Day All-Cause Mortality Following Coronary Artery Bypass Graft Surgery Measure Technical Report[1]
- 2015 Measure Updates and Specifications Report: Hospital-Level 30-Day Risk-Standardized Coronary Artery Bypass Graft (CABG) Surgery Mortality Measure[2]

2. BACKGROUND AND OVERVIEW OF MEASURE METHODOLOGY

2.1 Background on Mortality Measure

In 2015, CMS began publicly reporting 30-day RSMRs for CABG surgery for the nation's non-federal short-term acute care hospitals (including Indian Health Services hospitals) and critical access hospitals.

Results for this measure are posted on *Hospital Compare*, which CMS updates annually.

CMS contracted with the Yale-New Haven Health Services Corporation/Center for Outcomes Research & Evaluation (CORE) to update the CABG surgery mortality measure for 2016 public reporting through a process of measure reevaluation. Measures are reevaluated annually in order to improve them by responding to stakeholder input and incorporating advances in science or changes in coding.

2.2 Overview of Measure Methodology

The 2016 risk-adjusted CABG surgery mortality measure uses specifications from the initial measure methodology report with refinements to the measure, as listed in Appendix C and described in prior measures updates and specifications reports[1,2]. An overview of the methodology is presented in this section.

2.2.1 Cohort

Index Admissions Included in the Measure

An index admission is the hospitalization to which the mortality outcome is attributed and includes admissions for patients:

- Having a qualifying isolated CABG surgery during the index admission;
- Enrolled in Medicare fee-for-service (FFS) Part A and Part B for the 12 months prior to the date of the index admission, and enrolled in Part A during the index admission; and,
- Aged 65 or over.

Isolated CABG surgeries are defined as those CABG procedures performed *without* the following concomitant valve or other major cardiac, vascular, or thoracic procedures:

  - Valve procedures;
  - Atrial and/or ventricular septal defects;
  - Congenital anomalies;
  - Other open cardiac procedures;
  - Heart transplants;
  - Aorta or other non-cardiac arterial bypass procedures;
  - Head, neck, intracranial vascular procedures; or,
  - Other chest and thoracic procedures

International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) codes used to define the cohort for the measure are listed in Appendix D, in Tables D.1.1 and D.1.2.

Index Admissions Excluded from the Measure

The CABG surgery mortality measure excludes index admissions for patients:

- With inconsistent or unknown vital status or other unreliable demographic (age and gender) data; or,
- Discharged against medical advice (AMA).

For patients with more than one qualifying CABG surgery admission in the measurement period, the first CABG admission is selected for inclusion in the measure and the subsequent CABG admission(s) are excluded from the cohort.

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 database, as well as records for providers with invalid provider IDs.

The percentage of admissions excluded based on each criterion is shown in Section 4 in Figure 4.2.1.

Patients Transferred Between Hospitals

Transfer patients are identified by tracking claims for inpatient short-term acute care hospitalizations over time. To qualify as a transfer, the second inpatient admission must occur on the same day or the next calendar day following discharge from the first inpatient admission at a short-term acute care hospital. Cases that meet this criterion are considered transfers regardless of whether or not the first institution indicates intent to transfer the patient in the discharge disposition code, and regardless of the diagnoses and procedures in the transfer chain.

A transfer to another acute care facility after CABG surgery is most likely due to a complication of the CABG procedure or the peri-operative care the patient received, and as such, the care provided by the hospital performing the CABG procedure likely dominates mortality risk, even among transferred patients. This is true also for patients that are transferred in from another hospital for their CABG surgery. Therefore, in a series of one or more transfers, the first admission where an eligible CABG procedure was done is included in the cohort, regardless of whether the patient is transferred in or transferred out. Furthermore, the measure assigns a death that occurs within 30 days to the hospital that performed the first ("index") CABG surgery. For example, if a patient is admitted to Hospital A and undergoes CABG surgery, and then transfers to Hospital B, the Hospital A admission would be included in the cohort, and death within 30 days of the Hospital A admission would be captured in Hospital A's mortality outcome. This is different than the other mortality measures that always consider the first hospitalization

as the index admission and always assign a death to the hospital that initially admitted the patient.

2.2.2 Outcome

All-Cause Mortality

All deaths are considered an outcome, regardless of cause. There are a number of reasons for capturing deaths from any cause in the CABG surgery mortality measure. First, from a patient perspective, a death from any cause is an adverse event. In addition, making inferences about quality issues based solely on the documented cause of death is difficult. For example, a patient hospitalized for CABG surgery who develops a hospital-acquired infection may ultimately die of sepsis and multi-organ failure. In this context, considering the patient's death to be unrelated to the care the patient received for the CABG surgery during the index admission would be inappropriate.

30-Day Time Frame

The measure assesses mortality within a 30-day period from the procedure date. The procedure date is used because some patients who undergo CABG surgery might be admitted during the days before the procedure date rather than on the day of the procedure. For those patients, dating the measurement period from the day of admission would underestimate the period of risk.

The measure uses a 30-day time frame because older adult patients are more vulnerable to adverse health outcomes occurring during this time. Death within 30 days of the CABG surgery can be influenced by hospital care and the early transition to the non-acute care setting. The 30-day time frame is a clinically meaningful period for hospitals to collaborate with their communities in an effort to reduce mortality[3].

2.2.3 Risk-Adjustment Variables

In order to account for differences in patient mix among hospitals, the measure adjusts for variables (for example, age, sex, comorbid diseases, and indicators of patient frailty) that are clinically relevant and have relationships with the outcome. For each patient, risk-adjustment variables are obtained from inpatient, outpatient, and physician Medicare administrative claims data extending 12 months prior to, and including, the index admission.

The measure adjusts 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 measure does 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 healthcare that groups of patients with varying SES receive. The intent is for the measure to adjust for patient demographic and clinical characteristics while illuminating

important quality differences. 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[4]. Please note that the Office of the Assistant Secretary for Planning and Evaluation (ASPE) is conducting research to examine the impact of SES on quality measures, resource use, and other measures under the Medicare program as directed by the IMPACT Act. ASPE will issue an initial report to Congress by October 2016 and a final report to Congress by October 2019. The findings in these reports will be considered in future reevaluation of this measure.

Refer to Table D.1.3 in Appendix D of this report for the list of comorbidity risk-adjustment variables and the list of complications that are excluded from risk adjustment if they occur during the index admission.

2.2.4 Data Sources

The data sources for these analyses are Medicare administrative claims data and enrollment information for patients with hospitalizations between July 1, 2012 and June 30, 2015. The datasets also contain associated inpatient, outpatient, and physician Medicare administrative claims for the 12 months prior to the index admission for patients admitted in this time period. See the original methodology report for further descriptions of these data sources and an explanation of the three-year measurement period[1].

2.2.5 Measure Calculation

The measure estimates hospital-level 30-day all-cause RSMRs for CABG surgery using a hierarchical logistic regression models. In brief, the approach simultaneously models data at the patient and hospital levels to account for variance in patient outcomes within and between hospitals[5]. At the patient level, it models the log-odds of mortality within 30 days of the procedure date using age, sex, selected clinical covariates, and a hospital-specific effect. At the hospital level, the approach models the hospital-specific effects as arising from a normal distribution. The hospital effect represents the underlying risk of mortality at the hospital, after accounting for patient risk. The hospital-specific effects are given a distribution to account for the clustering (non-independence) of patients within the same hospital[5]. If there were no differences among hospitals, then after adjusting for patient risk, the hospital effects 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 based on the hospital's performance with its observed case mix, and the denominator is the number of deaths expected based on 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 a particular hospital's performance, given its case mix, to be compared to an average hospital's performance with the same case mix. Thus, a lower ratio indicates lower-than-expected

mortality rates or better quality, while a higher ratio indicates higher-than-expected mortality rates or worse quality.

The "predicted" number of deaths (the numerator) is calculated by using the coefficients estimated by regressing the risk factors (Table D.1.3) and the hospital-specific effect on the risk of mortality. The estimated hospital-specific effect is added to the sum of the estimated regression coefficients multiplied by the patient characteristics. The results are log transformed and summed over all patients attributed to a hospital to get a predicted value. The "expected" number of deaths (the denominator) is obtained in the same manner, but a common effect using all hospitals in our sample is added in place of the hospital-specific effect. The results are log transformed and summed over all patients in the hospital to get an expected value. To assess hospital performance for each reporting period, we re-estimate the model coefficients using the years of data in that period.

This calculation transforms the ratio of predicted over expected into a rate that is compared to the national observed mortality rate. The hierarchical logistic regression models are described fully in Appendix A and in the original methodology report[1].

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 the National Rate" if the 95% interval estimate surrounding the hospital's rate includes the national observed mortality rate.
- "Worse than the National Rate" if the entire 95% interval estimate surrounding the hospital's rate is higher than the national observed mortality rate.
- "Better than the 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: "Number of Cases Too Small". This category is used when 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 4.2.5 describes the distribution of hospitals by performance category in the U.S. for this reporting period.

3. UPDATES TO MEASURES FOR 2016 PUBLIC REPORTING

3.1 Rationale for Measure Updates

Measure reevaluation ensures that the risk-standardized mortality models are continually assessed and remain valid, given possible changes in clinical practice and coding standards over time, while allowing for model refinements. Modifications made to the measure cohort, risk models, and outcomes are informed by review of the most recent literature related to measure conditions or outcomes, feedback from various stakeholders, and empirical analyses including assessment of coding trends that reveal shifts in clinical practice or billing patterns. In addition, each year we assess measure characteristics and revise the statistical software code used to calculate measure results. As a part of these annual reevaluation activities, we undertook the following activities for 2016 public reporting:

- Validated the performance of the model and risk-adjustment variables in three recent one-year periods (July 2012-June 2013, July 2013-June 2014, and July 2014-June 2015);
- Evaluated and validated model performance for the three years combined (July 2012-June 2015); and,
- Updated the measure's SAS analytic package (SAS pack) and documentation.

No methodological changes to the measure were made for 2016 public reporting.

Although hospitals are using International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10) coding for discharges effective on or after October 1, 2015, ICD-10 codes for use in defining the cohort and ICD-10-based Condition Category (CC) Groups for use in risk adjustment were not incorporated into the measure specifications this year, as the measurement period for 2016 public reporting does not include claims data after June 30, 2015.

3.2 Changes to SAS Pack

We made minor refinements to the measure calculation SAS pack. The new SAS pack 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) to this address.**

The SAS pack describes the data files and data elements that feed the model software. Please be aware that CMS does not provide training or technical support for the software. CMS has made the SAS pack available to be completely transparent regarding the measure calculation methodology. However, note that even with the SAS pack it is not possible to replicate the RSMR calculation without the data files which contain longitudinal patient data from the entire national sample of acute care hospitals to estimate the individual hospital-specific effects, the average hospital-specific effect, and the risk-adjustment coefficients used in the equations.

4. RESULTS FOR 2016 PUBLIC REPORTING

4.1 Assessment of Updated Models

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

We evaluated the performance of the models using the July 2012 to June 2015 data for 2016 public reporting. We examined differences in the frequency of patient risk factors and the model variable coefficients.

We assessed logistic regression model performance in terms of discriminant ability for each year of data and for the three-year combined period. We computed two summary statistics to assess 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 the procedure date. Potential values range from 0.5, meaning no better than chance, to 1.0, an indication of perfect prediction. Perfect prediction implies patients' outcomes can be predicted completely by their risk factors, and physicians and hospitals play no role in patients' outcomes.

The results of these analyses for the measure are presented in Section 4.2.

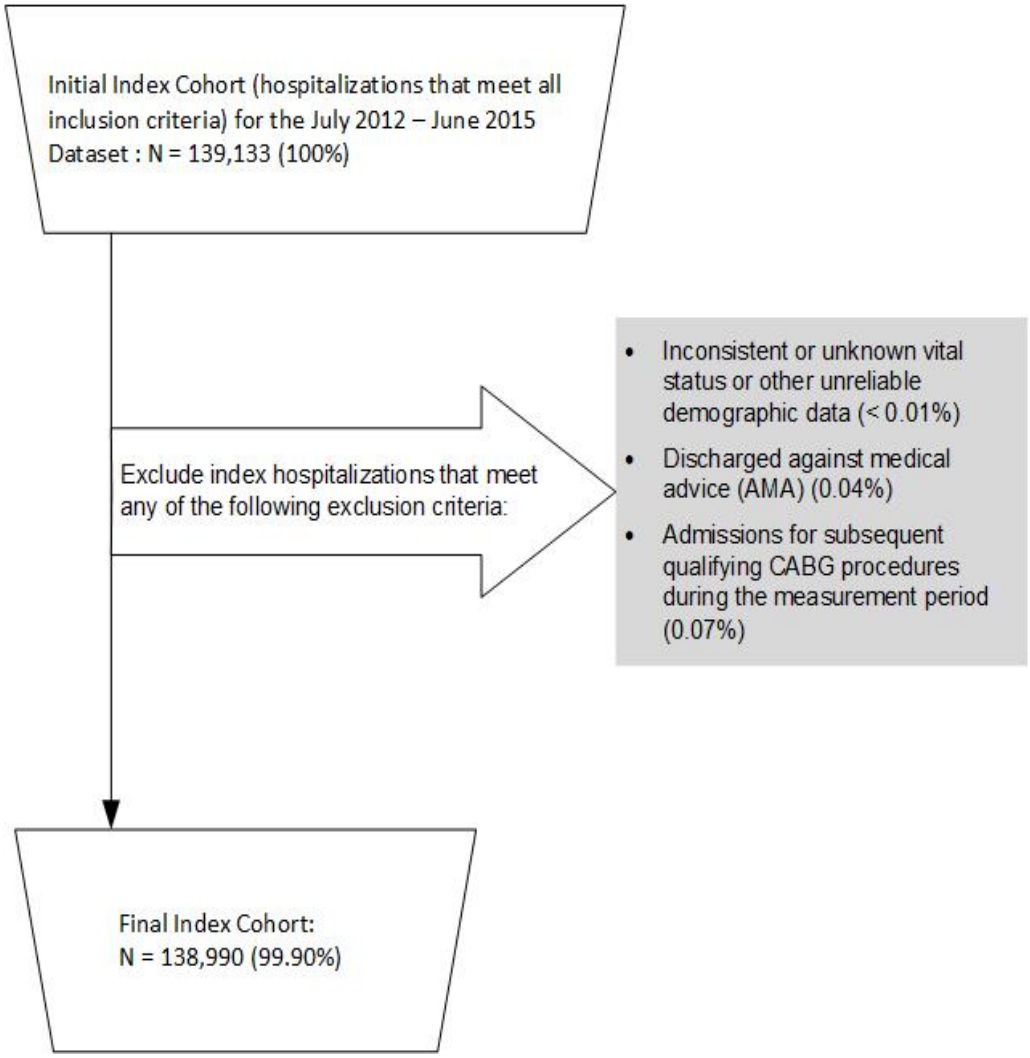
4.2 CABG Surgery Mortality 2016 Model Results

4.2.1 Index Cohort Exclusions

The exclusion criteria for the measure are presented in Section 2.2.1. The percentage of CABG surgery admissions meeting each exclusion criterion in the July 2012-June 2015 dataset is presented in Figure 4.2.1.

Admissions may have been counted in more than one exclusion category because they are not mutually exclusive. The index cohort includes short-term acute care hospitalizations for Medicare patients aged 65 or over with a qualifying isolated CABG procedure; and enrolled in Medicare FFS Part A and Part B for the 12 months prior to the date of admission, and enrolled in Part A during the index admission.

Figure 4.2.1– CABG Surgery Cohort Exclusions in the July 2012-June 2015 Dataset



4.2.2 Frequency of CABG Surgery Model Variables

We examined the change in both observed mortality rate and frequency of clinical and demographic variables. Between July 2012-June 2013 and July 2014-June 2015, the observed mortality rate remained relatively constant at 3.3%. Notable changes in the frequencies for model variables include:

- Decrease in Chronic Obstructive Pulmonary Disease (COPD) (26.4% to 25.4%)
- Increases in Male % (70.2% to 71.8%), Cardiogenic shock (5.2% to 6.3%), Other endocrine/metabolic/nutritional disorders (93.4% to 94.4%), Renal failure (17.5% to 19.1%), and Other gastrointestinal disorders (55.2% to 56.6%)

Refer to Table 4.2.1 for more detail.

4.2.3 CABG Surgery Model Parameters and Performance

Table 4.2.2 shows hierarchical regression model variable coefficients by individual year and for the combined three-year dataset. Table 4.2.3 shows the risk-adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for the CABG surgery mortality model by individual year and for the combined three-year dataset. Overall, the variable effect sizes were relatively constant across years. In addition, model performance was stable over the three-year time period; the c-statistic increased slightly from 0.77 to 0.79 (Table 4.2.4).

4.2.4 Distribution of Hospital Volumes and RSMRs for CABG Surgery

Table 4.2.5 shows the distribution of hospital admission volumes and Table 4.2.6 shows the distribution of hospital RSMRs. The mean RSMR increased slightly over the three years, from 3.3% between July 2012 and June 2013 to 3.4% between July 2014 and June 2015. The median hospital RSMR in the combined three-year dataset was 3.2% (Interquartile Range [IQR] 2.8% - 3.8%). Table 4.2.7 shows the between-hospital variance by individual year and for the combined three-year dataset. Between-hospital variance in the combined dataset was 0.206 (Standard Error [SE]: 0.022). If there were no systematic differences between hospitals, the between-hospital variance would be 0.

Figure 4.2.2 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 (SD) above the national rate were 2.48 times higher than odds of all-cause mortality if treated at a hospital one SD below the national rate. If there were no systematic differences between hospitals, the OR would be 1.0[5].

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

Of 1,194 hospitals in the study cohort, 14 performed “Better than the National Rate,” 1,015 performed “No Different from the National Rate,” and 21 performed “Worse than the National Rate.” 144 were classified as “Number of Cases Too Small” (fewer than 25) to reliably tell how well the hospital is performing.

Table 4.2.1 – Frequency of CABG Surgery Model Variables Over Different Time Periods

Variable	07/2012-06/2013	07/2013-06/2014	07/2014-06/2015	07/2012-06/2015
Total N	46,798	46,240	45,952	138,990
Observed mortality rate (%)	3.3	3.1	3.3	3.2
Mean age minus 65 (SD)	8.9 (5.8)	8.8 (5.7)	8.7 (5.7)	8.8 (5.7)
Male (%)	70.2	71.4	71.8	71.1
Cardiogenic shock (ICD-9 diagnosis code 785.51)	5.2	5.6	6.3	5.7
History of Coronary Artery Bypass Graft (CABG) or valve surgery (ICD-9 diagnosis codes: V42.2, V43.3, V45.81, 414.02, 414.03, 414.04, 414.05, 414.06, 414.07, 996.02, 996.03; ICD-9 procedure code: 39.61)	5.5	5.2	5.1	5.3
Pneumonia (CC 111-113)	13.2	12.7	12.7	12.9
Other endocrine/metabolic/nutritional disorders (CC 24)	93.4	93.8	94.4	93.9
Protein-calorie malnutrition (CC 21)	5.0	4.6	4.4	4.7
Renal failure (CC 131)	17.5	18.1	19.1	18.2
Chronic Obstructive Pulmonary Disease (COPD) (CC 108)	26.4	26.0	25.4	25.9
Dialysis status (CC 130)	2.1	2.0	2.1	2.1
Liver or biliary disease (CC 25-30)	6.6	6.5	6.8	6.6
Congestive heart failure (CC 80)	20.2	20.6	20.3	20.4
Other gastrointestinal disorders (CC 36)	55.2	55.8	56.6	55.8
Other acute/subacute forms of ischemic heart disease (CC 82)	42.0	42.2	41.6	42.0
Coronary atherosclerosis (ICD-9 diagnosis codes 414.2, 414.3, 414.8, 414.9, 414.00, 414.01, 414.10, 414.11, 414.12, 414.19, 746.85)	86.2	86.7	86.9	86.6
Hypertension (CC 91)	88.7	89.1	89.0	88.9
Acute myocardial infarction (CC 81)	17.6	17.6	17.5	17.6
Angina pectoris/old myocardial infarction (CC 83)	42.2	42.3	42.2	42.2
Vascular or circulatory disease (CC 104-106)	33.3	33.9	33.4	33.5
Decubitus ulcer or chronic skin ulcer (CC 148-149)	3.5	3.7	3.7	3.6
Cancer; metastatic cancer and acute leukemia (CC 7-12)	19.1	18.9	18.9	19.0
Stroke (CC 95-96)	4.7	4.7	5.0	4.8
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177-178)	3.4	3.5	3.6	3.5
Dementia or other specified brain disorders (CC 49-50)	5.8	5.7	5.6	5.7

Table 4.2.2 – Hierarchical Logistic Regression Model Variable Coefficients for CABG Surgery Over Different Time Periods

Variable	07/2012-06/2013	07/2013-06/2014	07/2014-06/2015	07/2012-06/2015
Intercept	-3.652	-3.833	-3.922	-3.829
Age minus 65 (years above 65, continuous)	0.059	0.064	0.064	0.063
Male	-0.421	-0.271	-0.446	-0.374
Cardiogenic shock (ICD-9 diagnosis code 785.51)	1.873	1.817	2.027	1.930
History of Coronary Artery Bypass Graft (CABG) or valve surgery (ICD-9 diagnosis codes: V42.2, V43.3, V45.81, 414.02, 414.03, 414.04, 414.05, 414.06, 414.07, 996.02, 996.03; ICD-9 procedure code: 39.61)	0.315	0.368	0.467	0.390
Pneumonia (CC 111-113)	0.390	0.254	0.441	0.357
Other endocrine/metabolic/nutritional disorders (CC 24)	-0.525	-0.331	-0.181	-0.342
Protein-calorie malnutrition (CC 21)	0.417	0.587	0.467	0.494
Renal failure (CC 131)	0.152	0.269	0.189	0.204

Variable	07/2012-06/2013	07/2013-06/2014	07/2014-06/2015	07/2012-06/2015
Chronic Obstructive Pulmonary Disease (COPD) (CC 108)	0.407	0.317	0.281	0.324
Dialysis status (CC 130)	0.531	0.637	0.483	0.553
Liver or biliary disease (CC 25-30)	0.260	0.388	0.479	0.379
Congestive heart failure (CC 80)	0.148	0.180	0.171	0.173
Other gastrointestinal disorders (CC 36)	-0.286	-0.243	-0.245	-0.258
Other acute/subacute forms of ischemic heart disease (CC 82)	-0.215	-0.146	-0.292	-0.213
Coronary atherosclerosis (ICD-9 diagnosis codes 414.2, 414.3, 414.8, 414.9, 414.00, 414.01, 414.10, 414.11, 414.12, 414.19, 746.85)	0.191	0.095	0.107	0.144
Hypertension (CC 91)	-0.179	-0.335	-0.310	-0.271
Acute myocardial infarction (CC 81)	0.280	0.244	0.155	0.236
Angina pectoris/old myocardial infarction (CC 83)	-0.223	-0.188	-0.091	-0.165
Vascular or circulatory disease (CC 104-106)	0.144	0.125	0.144	0.141
Decubitus ulcer or chronic skin ulcer (CC 148-149)	0.211	0.100	0.134	0.158
Cancer; metastatic cancer and acute leukemia (CC 7-12)	-0.017	-0.170	-0.019	-0.060
Stroke (CC 95-96)	-0.014	0.001	0.180	0.057
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177-178)	0.083	0.300	0.200	0.206
Dementia or other specified brain disorders (CC 49-50)	0.223	0.206	0.296	0.235

Table 4.2.3 – Adjusted OR and 95% CIs for the CABG Surgery Hierarchical Logistic Regression Model Over Different Time Periods

Variable	07/2012-06/2013 OR (95% CI)	07/2013-06/2014 OR (95% CI)	07/2014-06/2015 OR (95% CI)	07/2012-06/2015 OR (95% CI)
Age minus 65 (years above 65, continuous)	1.06 (1.05 - 1.07)	1.07 (1.06 - 1.08)	1.07 (1.06 - 1.08)	1.07 (1.06 - 1.07)
Male	0.66 (0.59 - 0.73)	0.76 (0.68 - 0.86)	0.64 (0.57 - 0.72)	0.69 (0.64 - 0.73)
Cardiogenic shock (ICD-9 diagnosis code 785.51)	6.51 (5.71 - 7.42)	6.15 (5.40 - 7.01)	7.59 (6.70 - 8.59)	6.89 (6.40 - 7.43)
History of Coronary Artery Bypass Graft (CABG) or valve surgery (ICD-9 diagnosis codes: V42.2, V43.3, V45.81, 414.02, 414.03, 414.04, 414.05, 414.06, 414.07, 996.02, 996.03; ICD-9 procedure code: 39.61)	1.37 (1.11 - 1.69)	1.45 (1.16 - 1.80)	1.60 (1.29 - 1.98)	1.48 (1.31 - 1.67)
Pneumonia (CC 111-113)	1.48 (1.29 - 1.69)	1.29 (1.12 - 1.48)	1.55 (1.36 - 1.78)	1.43 (1.32 - 1.55)
Other endocrine/metabolic/nutritional disorders (CC 24)	0.59 (0.49 - 0.71)	0.72 (0.59 - 0.87)	0.83 (0.68 - 1.03)	0.71 (0.64 - 0.79)
Protein-calorie malnutrition (CC 21)	1.52 (1.27 - 1.81)	1.80 (1.51 - 2.14)	1.60 (1.34 - 1.90)	1.64 (1.48 - 1.81)
Renal failure (CC 131)	1.16 (1.01 - 1.34)	1.31 (1.14 - 1.50)	1.21 (1.05 - 1.39)	1.23 (1.13 - 1.33)
Chronic Obstructive Pulmonary Disease (COPD) (CC 108)	1.50 (1.34 - 1.68)	1.37 (1.22 - 1.55)	1.32 (1.18 - 1.49)	1.38 (1.29 - 1.48)
Dialysis status (CC 130)	1.70 (1.29 - 2.24)	1.89 (1.45 - 2.46)	1.62 (1.23 - 2.13)	1.74 (1.49 - 2.03)
Liver or biliary disease (CC 25-30)	1.30 (1.08 - 1.56)	1.47 (1.22 - 1.77)	1.61 (1.35 - 1.93)	1.46 (1.31 - 1.62)
Congestive heart failure (CC 80)	1.16 (1.02 - 1.32)	1.20 (1.05 - 1.37)	1.19 (1.04 - 1.36)	1.19 (1.10 - 1.28)
Other gastrointestinal disorders (CC 36)	0.75 (0.67 - 0.84)	0.78 (0.70 - 0.88)	0.78 (0.70 - 0.88)	0.77 (0.72 - 0.82)
Other acute/subacute forms of ischemic heart disease (CC 82)	0.81 (0.72 - 0.91)	0.86 (0.77 - 0.97)	0.75 (0.66 - 0.84)	0.81 (0.76 - 0.87)
Coronary atherosclerosis (ICD-9 diagnosis codes 414.2, 414.3, 414.8, 414.9, 414.00, 414.01, 414.10, 414.11, 414.12, 414.19, 746.85)	1.21 (1.01 - 1.46)	1.10 (0.91 - 1.33)	1.11 (0.92 - 1.35)	1.15 (1.04 - 1.29)
Hypertension (CC 91)	0.84 (0.72 - 0.98)	0.72 (0.61 - 0.84)	0.73 (0.63 - 0.86)	0.76 (0.70 - 0.84)
Acute myocardial infarction (CC 81)	1.32 (1.16 - 1.50)	1.28 (1.12 - 1.46)	1.17 (1.02 - 1.34)	1.27 (1.17 - 1.37)
Angina pectoris/old myocardial infarction (CC 83)	0.80 (0.71 - 0.90)	0.83 (0.74 - 0.93)	0.91 (0.81 - 1.03)	0.85 (0.79 - 0.91)
Vascular or circulatory disease (CC 104-106)	1.15 (1.03 - 1.30)	1.13 (1.00 - 1.28)	1.15 (1.02 - 1.30)	1.15 (1.08 - 1.23)
Decubitus ulcer or chronic skin ulcer (CC 148-149)	1.24 (0.98 - 1.56)	1.11 (0.87 - 1.41)	1.14 (0.90 - 1.45)	1.17 (1.02 - 1.34)
Cancer; metastatic cancer and acute leukemia (CC 7-12)	0.98 (0.86 - 1.13)	0.84 (0.73 - 0.98)	0.98 (0.85 - 1.13)	0.94 (0.87 - 1.02)
Stroke (CC 95-96)	0.99 (0.77 - 1.26)	1.00 (0.78 - 1.28)	1.20 (0.96 - 1.50)	1.06 (0.92 - 1.21)
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177-178)	1.09 (0.83 - 1.42)	1.35 (1.05 - 1.74)	1.22 (0.95 - 1.56)	1.23 (1.06 - 1.42)
Dementia or other specified brain disorders (CC 49-50)	1.25 (1.03 - 1.51)	1.23 (1.01 - 1.50)	1.34 (1.11 - 1.63)	1.27 (1.13 - 1.41)

Table 4.2.4 – CABG Surgery Generalized Linear Modeling (Logistic Regression) Performance Over Different Time Periods

Characteristic	07/2012-06/2013	07/2013-06/2014	07/2014-06/2015	07/2012-06/2015
Predictive ability, % (lowest decile – highest decile)	0.6 - 13.6	0.5 - 13.3	0.4 - 15.0	0.5 - 14.0
c-statistic	0.77	0.77	0.79	0.77

Table 4.2.5 – Distribution of Hospital CABG Surgery Admission Volumes Over Different Time Periods

Characteristic	07/2012-06/2013	07/2013-06/2014	07/2014-06/2015	07/2012-06/2015
Number of hospitals	1,164	1,157	1,150	1,194
Mean number of admissions (SD)	40.2 (35.5)	40.0 (35.1)	40.0 (35.5)	116.4 (104.6)
Range (min. – max.)	1 - 249	1 - 268	1 - 277	1 - 794
25th percentile	16	16	15	45
50th percentile	29.5	30	29.5	86
75th percentile	55	53	54	158

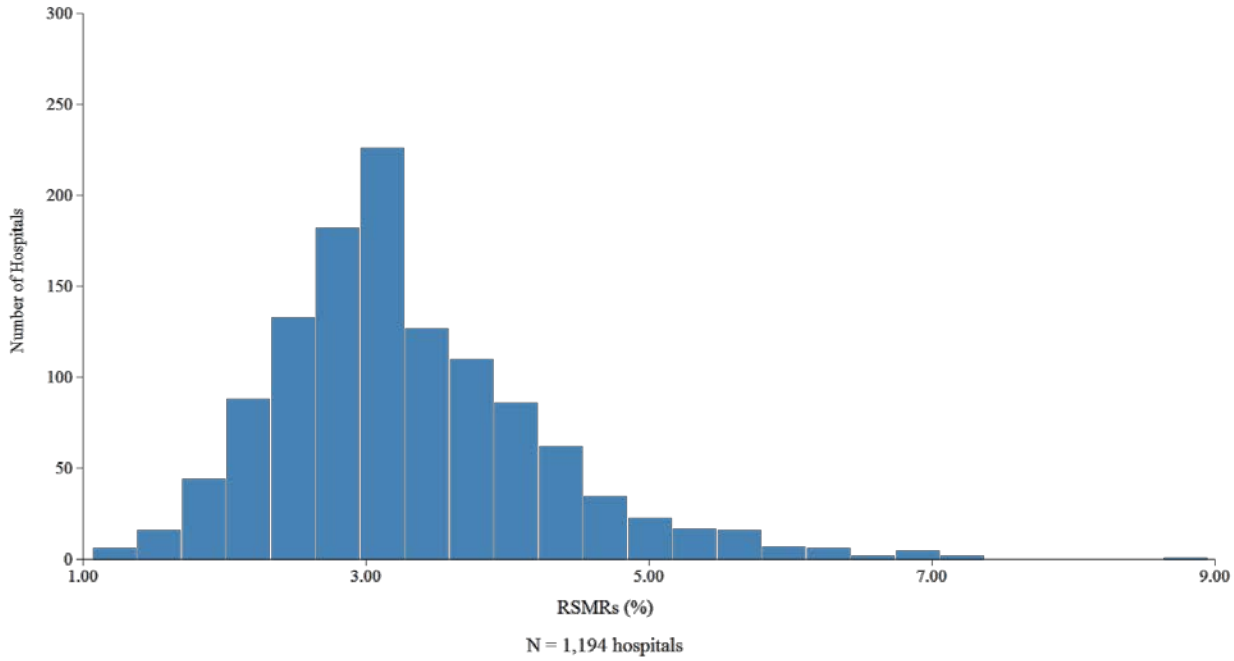
Table 4.2.6 – Distribution of Hospital CABG Surgery RSMRs Over Different Time Periods

Characteristic	07/2012-06/2013	07/2013-06/2014	07/2014-06/2015	07/2012-06/2015
Number of hospitals	1,164	1,157	1,150	1,194
Mean (SD)	3.3 (0.7)	3.2 (0.4)	3.4 (0.7)	3.3 (0.8)
Range (min. – max.)	1.9 - 8.5	2.0 - 5.9	1.8 - 6.6	1.4 - 8.3
25th percentile	2.9	2.9	2.9	2.8
50th percentile	3.2	3.1	3.2	3.2
75th percentile	3.7	3.4	3.7	3.8

Table 4.2.7 – Between-Hospital Variance for CABG Surgery

	07/2012-06/2013	07/2013-06/2014	07/2014-06/2015	07/2012-06/2015
Between-hospital variance (SE)	0.234 (0.042)	0.154 (0.040)	0.235 (0.043)	0.206 (0.022)

Figure 4.2.2 – Distribution of Hospital 30-Day CABG Surgery RSMRs Between July 2012 and June 2015



5. GLOSSARY

Case mix: The particular illness severity and age characteristics of patients with index admissions at a given hospital.

Cohort: The index admissions used to calculate the measure after inclusion and exclusion criteria have been applied.

Comorbidities: Medical conditions the patient had in addition to his/her primary reason for admission to the hospital.

Complications: Medical conditions that may have occurred as a consequence of care rendered during hospitalization.

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 CCs can be found at http://www.cms.hhs.gov/Reports/downloads/pope_2000_2.pdf.

Confidence Interval (CI): A CI is a range of values that describes the uncertainty surrounding an estimate. It is indicated by its endpoints; for example, a 95% CI for the OR associated with protein-calorie malnutrition noted as "1.09 – 1.15" would indicate that there is 95% confidence that the OR lies between 1.09 and 1.15.

Expected mortality: The number of deaths expected based on 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 accounting for patient risk factors and 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 effect: A measure of the hospital quality of care calculated through hierarchical logistic regression, taking into consideration how many patients were eligible for the cohort, these patients' risk factors, and how many died. The hospital-specific effect is the calculated random effect intercept for each hospital. 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 CABG surgery and evaluated for the outcome.

Interval estimate: Similar to a CI, the interval estimate is a range of probable values for the estimate that characterizes the amount of associated uncertainty. 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 and the upper limit of the interval.

Medicare fee-for-service (FFS): Original Medicare plan in which providers receive a fee or payment for each individual service provided directly from Medicare. 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.

Odds ratio (OR): The ORs express the relative odds of the outcome for each of the predictor variables. For example, the OR for Protein-calorie malnutrition (CC 21) represents the odds of the outcome for patients with that risk variable present relative to those without the risk variable present. The model coefficient for each risk variable is the log (odds) for that variable.

Outcome: The result of a broad set of healthcare activities that affect patients' well-being. For the CABG surgery mortality measure, the outcome is mortality within 30 days of the procedure date.

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

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

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7. APPENDICES

Appendix A. Statistical Approach to RSMRs for CABG Surgery Measure

We estimate the hospital-specific RSMRs 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 CABG surgery with an intercept for the hospital-specific random effect.

We use the following strategy to calculate the hospital-specific RSMRs, which we calculate 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 effect (that is, the average effect among all hospitals in the sample). The predicted mortality for each hospital is estimated given the same patient mix but an estimated hospital-specific effect. Operationally, the expected number of deaths 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 effect. The predicted number of deaths 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 adds the hospital-specific effect.

More specifically, we use a hierarchical logistic regression model 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:

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

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

Where h(.) is a logit link, Y_{ij} is whether the j^{th} patient in the i^{th} hospital died (equal to 1 if death within 30 days, zero 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 adjusted average hospital intercept across all hospitals in the sample, and τ^2 is the between-hospital variance component[6]. This model separates within-hospital variation from between-hospital variation. The hierarchical logistic regression models are estimated using the SAS software system (SAS 9.3 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 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 $$\hat{e}_{ij}(Z_{ij}) = h^{-1}(\hat{\mu} + \hat{\beta}\mathbf{Z}_{ij}) \quad (4)$$

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

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, 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 in the next section. 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,

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

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 $\widehat{RSMR}(Z)^{(B)}$ 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)[7].

Appendix B. Data QA

We use a two-phase approach to internal QA for the mortality measure reevaluation process. Refer to Figure B.1 for a detailed outline of phase I and Figure B.2 for a detailed outline of phase II.

This section represents QA for the subset of the work CORE conducted to maintain and report the CABG surgery mortality measure. 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.

Phase I

The first step in the QA process is to ensure the validity of the input data files. No new variables that impacted the measures were added to the input files; thus, our main task was to ensure that variable frequencies and distributions in the newly created input data files were consistent with data from the prior time period.

In general, we use both manual scan and descriptive analyses to conduct data validity checks, including cross-checking of mortality information, distributions of ICD-9-CM codes, and frequencies of key variables. The results are reviewed for accuracy and changes compared to data from prior data sources. Any new variable constructs and other changes in formatting to the input files are also verified. 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 CABG surgery mortality measure: 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.

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 compares prior years' risk-adjustment coefficients and variable frequencies, to enable us to check for potential inconsistencies in the data and the impact of any changes to the SAS pack.

Figure B.1 – CORE QA Phase I

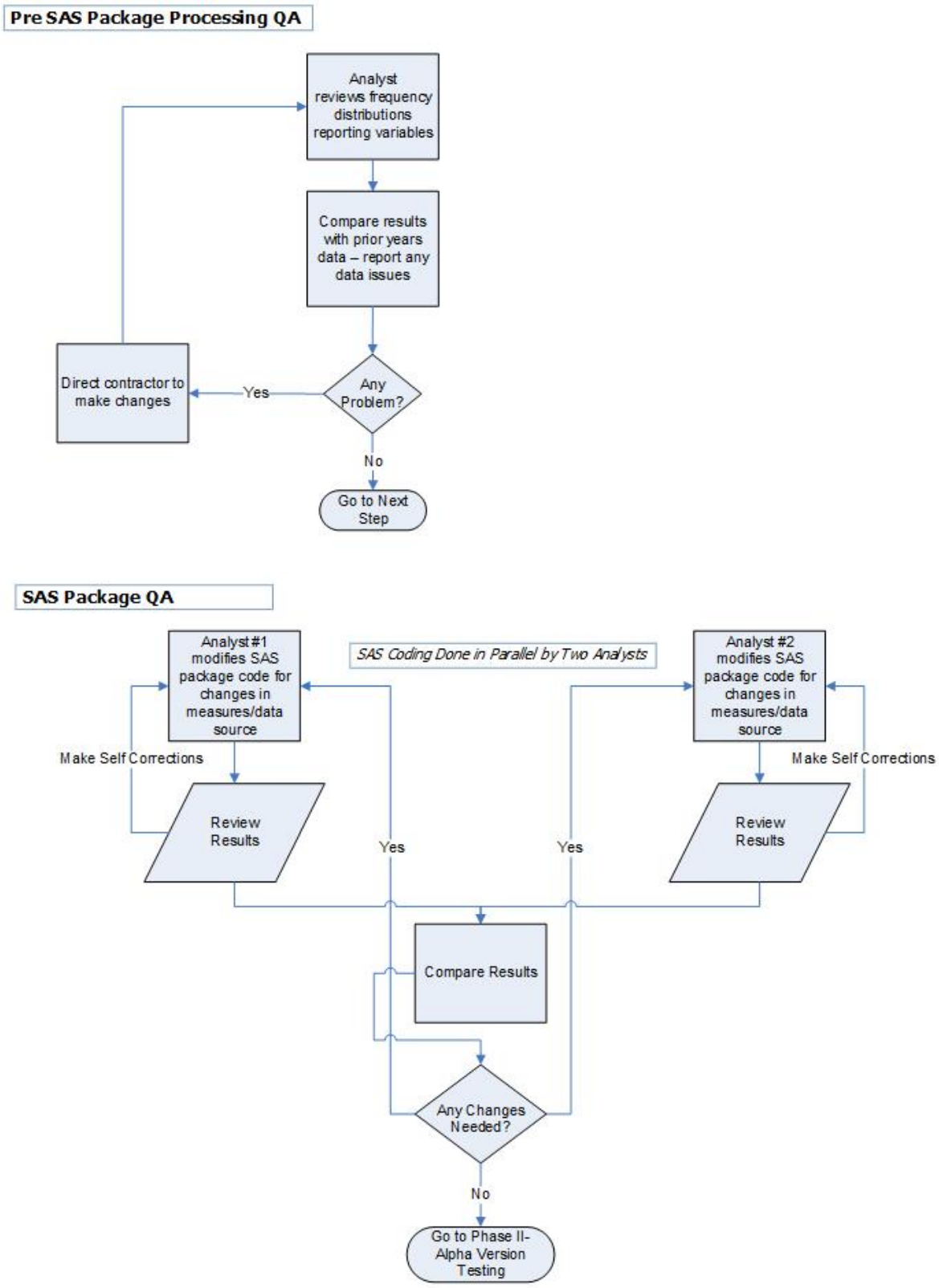
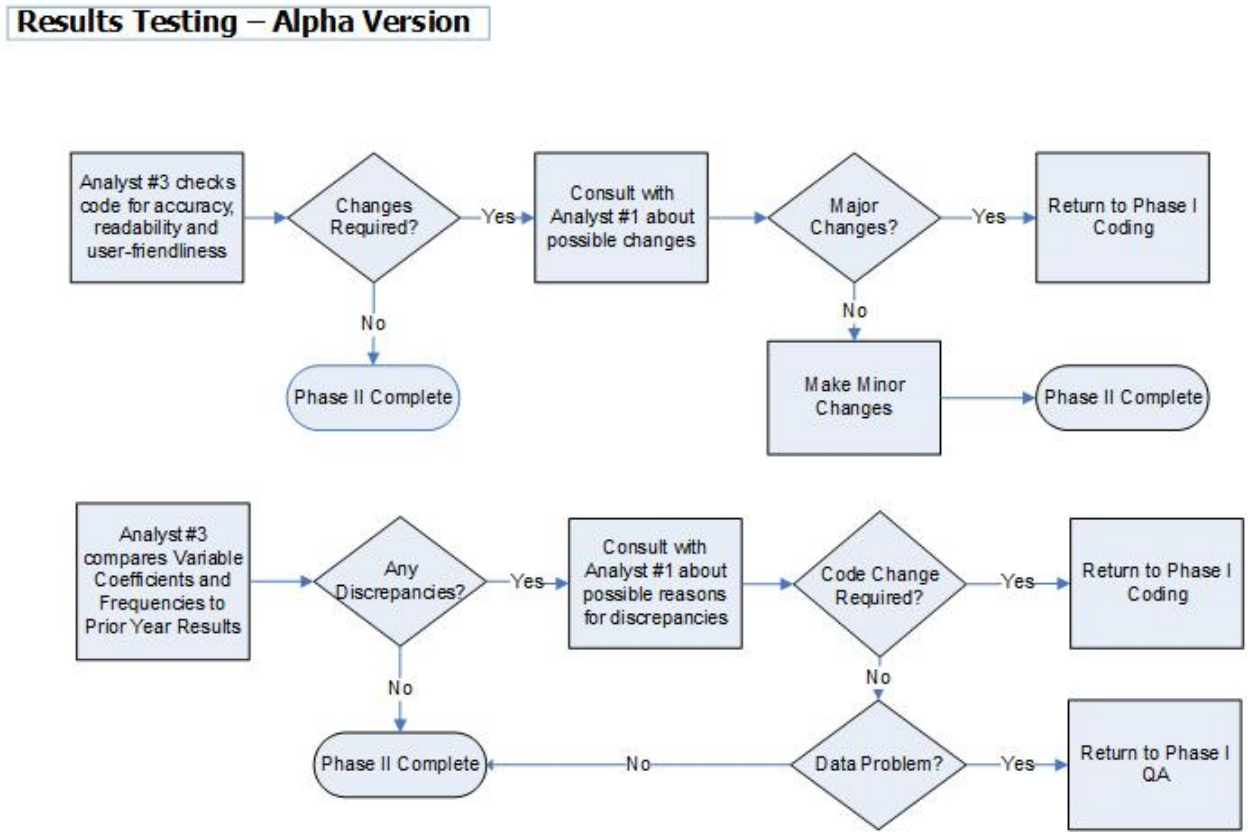


Figure B.2 – CORE QA Phase II



Appendix C. Annual Updates

Prior annual updates for the measure can be found in the annual updates and specifications 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 public reporting.

2016

2015 Measures Updates and Specifications Report (Version 3.0-CABG)

No updates were made to the specifications of the CABG surgery mortality measure for 2016 public reporting.

2015

2015 Measures Updates and Specifications Report (Version 2.0-CABG)

No updates were made to the specifications of the CABG surgery mortality measure for 2015 public reporting.

Appendix D. Measure Specifications

Appendix D.1 Hospital-Level 30-Day RSMR Following CABG Surgery (NQF #2558)

Cohort

Inclusion Criteria for CABG Surgery Measure

1. **Enrolled in Medicare FFS Part A and Part B for the 12 months prior to the date of admission, and enrolled in Part A during the index admission**
   Rationale: Claims data are consistently available only for Medicare FFS beneficiaries. The 12-month prior enrollment criterion ensures that patients were Medicare FFS beneficiaries and that their comorbidities are captured from claims for risk adjustment. Medicare Part A is required at the time of admission to ensure no Medicare Advantage patients are included in the measure.
2. **Aged 65 or over**
   Rationale: Medicare patients younger than 65 usually qualify for the program due to severe disability. They are not included in the measure because Medicare patients younger than 65 are considered to be too clinically distinct from Medicare patients 65 and over.
3. **Having a qualifying isolated CABG procedure during the index admission**
   Rationale: Isolated CABG surgery is the procedure targeted for measurement (Table D.1.1). Isolated CABG procedures are defined as those CABG procedures performed without concomitant valve or other major cardiac, vascular, or thoracic procedures, because they represent a population of patients with higher risk. These procedure groups include (Table D.1.2):
   - **Valve procedures;**
   - **Atrial and/or ventricular septal defects;**
   - **Congenital anomalies;**
   - **Other open cardiac procedures;**
   - **Heart transplants;**
   - **Aorta or other non-cardiac arterial bypass procedures;**
   - **Head, neck, intracranial vascular procedures; and,**
   - **Other chest and thoracic procedures.**

Exclusion Criteria for CABG Surgery Measure

1. **Inconsistent or unknown vital status or other unreliable demographic 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.
2. **Discharged against medical advice (AMA)**
   Rationale: Providers did not have the opportunity to deliver full care and prepare the patient for discharge.
3. **Admissions for subsequent qualifying CABG procedures during the measurement period**
   Rationale: CABG procedures are expected to last for several years without the need for revision or repeat revascularization. A repeat CABG procedure during the measurement period likely represents a complication of the original CABG procedure and is a clinically more complex and

higher risk surgery. Therefore, we select the first CABG surgery admission for inclusion in the measure and exclude subsequent CABG surgery admissions from the cohort.

Table D.1.1 – ICD-9-CM Codes Used to Identify Eligible CABG Procedures

ICD-9-CM Procedure Codes	Description
36.10	Aortocoronary bypass for heart revascularization, not otherwise specified
36.11	(Aorto) coronary bypass of one coronary artery
36.12	(Aorto) coronary bypass of two coronary arteries
36.13	(Aorto) coronary bypass of three coronary arteries
36.14	(Aorto) coronary bypass of four or more coronary arteries
36.15	Single internal mammary- coronary artery bypass
36.16	Double internal mammary- coronary artery bypass
36.17	Abdominal- coronary artery bypass
36.19	Other bypass anastomosis for heart revascularization

The CABG surgery mortality measure excludes admissions where any of the following ICD-9-CM procedure codes occur with one of the ICD-9 procedure codes in Table D.1.1 above:

Table D.1.2 – ICD-9-CM Codes Used to Identify Non-Isolated CABG Procedures Not Included in Final Cohort

ICD-9-CM Procedure Code	Description	Category
00.61	Percutaneous angioplasty or atherectomy of precerebral (extracranial) vessel(s)	Head, neck, intracranial vascular procedures
00.62	Percutaneous angioplasty or atherectomy of intracranial vessel(s)	Head, neck, intracranial vascular procedures
00.63	Percutaneous insertion of carotid artery stent(s)	Head, neck, intracranial vascular procedures
00.64	Percutaneous insertion of other precerebral (extracranial) artery stent(s)	Head, neck, intracranial vascular procedures
00.65	Percutaneous insertion of intracranial vascular stent(s)	Head, neck, intracranial vascular procedures
32.41	Thoracoscopic lobectomy of lung	Other chest and thoracic procedures
32.49	Other lobectomy of lung	Other chest and thoracic procedures
33.50	Lung transplantation, not otherwise specified	Other chest and thoracic procedures
33.51	Unilateral lung transplantation	Other chest and thoracic procedures
33.52	Bilateral lung transplantation	Other chest and thoracic procedures
33.6	Combined heart-lung transplantation	Other chest and thoracic procedures
35.00	Closed heart valvotomy, unspecified valve	Valve procedures
35.01	Closed heart valvotomy, aortic valve	Valve procedures
35.02	Closed heart valvotomy, mitral valve	Valve procedures
35.03	Closed heart valvotomy, pulmonary valve	Valve procedures
35.04	Closed heart valvotomy, tricuspid valve	Valve procedures
35.10	Open heart valvuloplasty without replacement, unspecified valve	Valve procedures

ICD-9-CM Procedure Code	Description	Category
35.11	Open heart valvuloplasty of aortic valve without replacement	Valve procedures
35.12	Open heart valvuloplasty of mitral valve without replacement	Valve procedures
35.13	Open heart valvuloplasty of pulmonary valve without replacement	Valve procedures
35.14	Open heart valvuloplasty of tricuspid valve without replacement	Valve procedures
35.20	Replacement of unspecified heart valve	Valve procedures
35.21	Replacement of aortic valve with tissue graft	Valve procedures
35.22	Other replacement of aortic valve	Valve procedures
35.23	Replacement of mitral valve with tissue graft	Valve procedures
35.24	Other replacement of mitral valve	Valve procedures
35.25	Replacement of pulmonary valve with tissue graft	Valve procedures
35.26	Other replacement of pulmonary valve	Valve procedures
35.27	Replacement of tricuspid valve with tissue graft	Valve procedures
35.28	Other replacement of tricuspid valve	Valve procedures
35.31	Operations on papillary muscle	Valve procedures
35.32	Operations on chordae tendineae	Valve procedures
35.33	Annuloplasty	Valve procedures
35.34	Infundibulectomy	Valve procedures
35.35	Operations on trabeculae carneae cordis	Valve procedures
35.39	Operations on other structures adjacent to valves of heart	Valve procedures
35.41	Enlargement of existing atrial septal defect	Atrial and/or ventricular septal defects
35.42	Creation of septal defect in heart	Atrial and/or ventricular septal defects
35.50	Repair of unspecified septal defect of heart with prosthesis	Atrial and/or ventricular septal defects
35.51	Repair of atrial septal defect with prosthesis, open technique	Atrial and/or ventricular septal defects
35.52	Repair of atrial septal defect with prosthesis, closed technique	Atrial and/or ventricular septal defects
35.53	Repair of ventricular septal defect with prosthesis, open technique	Atrial and/or ventricular septal defects
35.54	Repair of endocardial cushion defect with prosthesis	Atrial and/or ventricular septal defects
35.55	Repair of ventricular septal defect with prosthesis, closed technique	Atrial and/or ventricular septal defects
35.60	Repair of unspecified septal defect of heart with tissue graft	Atrial and/or ventricular septal defects
35.61	Repair of atrial septal defect with tissue graft	Atrial and/or ventricular septal defects
35.62	Repair of ventricular septal defect with tissue graft	Atrial and/or ventricular septal defects

ICD-9-CM Procedure Code	Description	Category
35.63	Repair of endocardial cushion defect with tissue graft	Atrial and/or ventricular septal defects
35.70	Other and unspecified repair of unspecified septal defect of heart	Atrial and/or ventricular septal defects
35.71	Other and unspecified repair of atrial septal defect	Atrial and/or ventricular septal defects
35.72	Other and unspecified repair of ventricular septal defect	Atrial and/or ventricular septal defects
35.73	Other and unspecified repair of endocardial cushion defect	Atrial and/or ventricular septal defects
35.81	Total repair of tetralogy of Fallot	Congenital anomalies
35.82	Total repair of total anomalous pulmonary venous connection	Congenital anomalies
35.83	Total repair of truncus arteriosus	Congenital anomalies
35.84	Total correction of transposition of great vessels, not elsewhere classified	Congenital anomalies
35.91	Interatrial transposition of venous return	Congenital anomalies
35.92	Creation of conduit between right ventricle and pulmonary artery	Congenital anomalies
35.93	Creation of conduit between left ventricle and aorta	Congenital anomalies
35.94	Creation of conduit between atrium and pulmonary artery	Congenital anomalies
35.95	Revision of corrective procedure on heart	Congenital anomalies
35.96	Percutaneous valvuloplasty	Valve procedures
35.98	Other operations on septa of heart	Atrial and/or ventricular septal defects
35.99	Other operations on valves of heart	Valve procedures
37.31	Pericardiectomy	Other open cardiac procedures
37.32	Excision of aneurysm of heart	Other open cardiac procedures
37.33	Excision or destruction of other lesion or tissue of heart, open approach	Other open cardiac procedures
37.35	Partial ventriculectomy	Other open cardiac procedures
37.51	Heart transplantation	Heart transplants
37.52	Implantation of total internal biventricular heart replacement system	Other open cardiac procedures
37.53	Replacement or repair of thoracic unit of (total) replacement heart system	Other open cardiac procedures
37.54	Replacement or repair of other implantable component of (total) replacement heart system	Other open cardiac procedures
37.55	Removal of internal biventricular heart replacement system	Other open cardiac procedures
37.63	Repair of heart assist system	Other open cardiac procedures
37.67	Implantation of cardiomyostimulation system	Other open cardiac procedures
38.11	Head and neck endarterectomy	Head, neck, intracranial vascular procedures
38.12	Endarterectomy, other vessels of head and neck	Head, neck, intracranial vascular procedures

ICD-9-CM Procedure Code	Description	Category
38.14	Endarterectomy of Aorta	Aorta or other non-cardiac arterial bypass procedures
38.15	Thoracic endarterectomy	Aorta or other non-cardiac arterial bypass procedures
38.16	Endarterectomy: Excision of tunica intima of artery to relieve arterial walls thickened by plaque or chronic inflammation. Location includes abdominal arteries excluding abdominal aorta: Celiac, Gastric, Hepatic, Iliac, Mesenteric, Renal, Splenic, Umbilical	Aorta or other non-cardiac arterial bypass procedures
38.17	Endarterectomy - abdominal veins: Iliac, Portal, Renal, Splenic, Vena cava.	Aorta or other non-cardiac arterial bypass procedures
38.34	Resection of vessel with replacement: Angiectomy, excision of aneurysm (arteriovenous), blood vessel (lesion) with anastomosis (4=aorta, abdominal)	Aorta or other non-cardiac arterial bypass procedures
38.42	Resection of vessel with replacement: Angiectomy, excision of aneurysm with replacement (2= other vessels of head and neck; carotid, jugular)	Head, neck, intracranial vascular procedures
38.44	Resection of vessel with replacement, aorta, abdominal	Aorta or other non-cardiac arterial bypass procedures
38.45	Resection of vessel with replacement, thoracic vessels	Aorta or other non-cardiac arterial bypass procedures
39.21	Caval-pulmonary artery anastomosis	Aorta or other non-cardiac arterial bypass procedures
39.22	Aorta-subclavian-carotid bypass	Aorta or other non-cardiac arterial bypass procedures
39.23	Other intrathoracic vascular shunt or bypass	Aorta or other non-cardiac arterial bypass procedures
39.24	Aorta-renal bypass	Aorta or other non-cardiac arterial bypass procedures
39.25	Aorta-iliac-femoral bypass	Aorta or other non-cardiac arterial bypass procedures
39.26	Other intra-abdominal vascular shunt or bypass	Aorta or other non-cardiac arterial bypass procedures
39.28	Extracranial-intracranial (EC-IC) vascular bypass	Head, neck, intracranial vascular procedures
39.29	Other (peripheral) vascular shunt or bypass	Aorta or other non-cardiac arterial bypass procedures
39.71	Endovascular implantation of graft in abdominal aorta	Aorta or other non-cardiac arterial bypass procedures
39.72	Endovascular embolization or occlusion of head and neck vessels	Head, neck, intracranial vascular procedures
39.73	Endovascular implantation of graft in thoracic aorta	Aorta or other non-cardiac arterial bypass procedures
39.74	Endovascular removal of obstruction from head and neck vessel(s)	Head, neck, intracranial vascular procedures

ICD-9-CM Procedure Code	Description	Category
39.75	Endovascular embolization or occlusion of vessel(s) of head or neck using bare coils	Head, neck, intracranial vascular procedures
39.76	Endovascular embolization or occlusion of vessel(s) of head or neck using bioactive coils	Head, neck, intracranial vascular procedures
39.79	Other endovascular procedures on other vessels	Aorta or other non-cardiac arterial bypass procedures
85.22	Resection of quadrant of breast	Other chest and thoracic procedures
85.23	Subtotal mastectomy, which excludes quadrant resection (85.22)	Other chest and thoracic procedures
85.41	Unilateral simple mastectomy	Other chest and thoracic procedures
85.42	Bilateral simple mastectomy	Other chest and thoracic procedures
85.43	Unilateral extended simple mastectomy	Other chest and thoracic procedures
85.44	Bilateral extended simple mastectomy	Other chest and thoracic procedures
85.45	Unilateral radical mastectomy	Other chest and thoracic procedures
85.46	Bilateral radical mastectomy	Other chest and thoracic procedures
85.47	Unilateral extended radical mastectomy	Other chest and thoracic procedures
85.48	Bilateral extended radical mastectomy	Other chest and thoracic procedures

Risk Adjustment

Table D.1.3 – Risk Variables for CABG Surgery Measure

Description	Variable	Variables Not Used in Risk Adjustment if Occurred Only During Index Admission (indicated by "X")
Age minus 65 (years above 65, continuous)	n/a	
Male	n/a	
Cardiogenic shock	ICD-9 diagnosis code 785.51	
History of Coronary Artery Bypass Graft (CABG) or valve surgery	ICD-9 diagnosis codes: V42.2, V43.3, V45.81, 414.02, 414.03, 414.04, 414.05, 414.06, 414.07, 996.02, 996.03; ICD-9 procedure code: 39.61	X
Coronary atherosclerosis	ICD-9 diagnosis codes 414.2, 414.3, 414.8, 414.9, 414.00, 414.01, 414.10, 414.11, 414.12, 414.19, 746.85	
Pneumonia	CC 111 Aspiration and specified bacterial pneumonias	X
	CC 112 Pneumococcal pneumonia, emphysema, lung abscess	X
	CC 113 Viral and unspecified pneumonia, pleurisy	
Other endocrine/metabolic/nutritional disorders	CC 24 Other endocrine/metabolic/nutritional disorders	
Protein-calorie malnutrition	CC 21 Protein-calorie malnutrition	
Renal failure	CC 131 Renal failure	X

Description	Variable	Variables Not Used in Risk Adjustment if Occurred Only During Index Admission (indicated by "X")
Chronic Obstructive Pulmonary Disease (COPD)	CC 108 Chronic Obstructive Pulmonary Disease (COPD)	
Dialysis status	CC 130 Dialysis status	X
Liver or biliary disease	CC 25 End-stage liver disease	
	CC 26 Cirrhosis of liver	
	CC 27 Chronic hepatitis	
	CC 28 Acute liver failure/disease	X
	CC 29 Other hepatitis and liver disease	
	CC 30 Gallbladder and biliary tract disorders	
Congestive heart failure	CC 80 Congestive heart failure	X
Other gastrointestinal disorders	CC 36 Other gastrointestinal disorders	
Other acute/subacute forms of ischemic heart disease	CC 82 Other acute/subacute forms of ischemic heart disease	
Hypertension	CC 91 Hypertension	
Acute myocardial infarction	CC 81 Acute myocardial infarction	
Angina pectoris/old myocardial infarction	CC 83 Angina pectoris/old myocardial infarction	
Vascular or circulatory disease	CC 104 Vascular disease with complications	X
	CC 105 Vascular disease	X
	CC 106 Other circulatory disease	X
Decubitus ulcer or chronic skin ulcer	CC 148 Decubitus ulcer of skin	X
	CC 149 Chronic ulcer of skin, except decubitus	
Cancer; metastatic cancer and acute leukemia	CC 7 Metastatic cancer or acute leukemia	
	CC 8 Lung, upper digestive tract, and other severe cancers	
	CC 9 Lymphatic, head and neck, brain, and other major cancers	
	CC 10 Breast, prostate, colorectal and other cancers and tumors	
	CC 11 Other respiratory and heart neoplasms	
	CC 12 Other digestive and urinary neoplasms	
Stroke	CC 95 Cerebral hemorrhage	X
	CC 96 Ischemic or unspecified stroke	X
Hemiplegia, paraplegia, paralysis, functional disability	CC 67 Quadriplegia, other extensive paralysis	
	CC 68 Paraplegia	
	CC 69 Spinal cord disorders/injuries	
	CC 100 Hemiplegia/hemiparesis	X
	CC 101 Diplegia (upper), monoplegia, and other paralytic syndromes	X
	CC 102 Speech, language, cognitive, perceptual	X
	CC 177 Amputation status, lower limb/amputation complications	X
	CC 178 Amputation status, upper limb	X
Dementia or other specified brain disorders	CC 49 Dementia	

Description	Variable	Variables Not Used in Risk Adjustment if Occurred Only During Index Admission (indicated by "X")
	CC 50 Senility, nonpsychotic organic brain syndromes/conditions	

Outcome

Outcome Criteria for CABG Surgery Measure

Death, from any cause, within 30 days from the index admission.
Rationale: From a patient perspective, death is the most critical outcome regardless of cause. Outcomes occurring within 30 days of the procedure date can be influenced by hospital care and early transition to the non-acute care setting. The 30-day time frame is a clinically meaningful period for hospitals to collaborate with their communities to reduce mortality.