Hospital-level 30-day All-Cause Unplanned Readmission Following Coronary Artery Bypass Graft Surgery

Updated Measure Methodology Report

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1. INTRODUCTION

1.1 Background

CMS has contracted with Yale New Haven Health Services Corporation/Center for Outcomes Research and Evaluation (YNHHSC/CORE) to develop two administrative-based, risk-adjusted CABG outcomes measures suitable for public reporting that reflect the quality of care for hospitalized patients undergoing CABG in the United States: 1) Hospital-level 30-day Readmission Following Coronary Artery Bypass Graft Surgery, and 2) Hospital-level 30-day Mortality Following Coronary Artery Bypass Graft Surgery. The goal of the measures is to improve the quality of care delivered to patients undergoing CABG procedures. They are complementary measures that assess different domains of quality. The mortality measure will both document short-term survival and inform quality improvement efforts targeted toward maximizing survival in the post-operative period. As readmission following CABG is likely a signal of both peri-operative complications and suboptimal transitional care, the readmission measure offers the additional benefit of assisting hospitals in minimizing medical and surgical complications during surgery and the postoperative period and improving the care provided in the transition to outpatient settings. The premise is that improved quality of care, including coordination and communication among providers and with patients and their caregivers, can favorably influence performance on these measures.

In this technical report, we provide detailed information on the development of the administrative-based CABG readmission measure. The measure detailed in this report was developed by YNHHSC/CORE in collaboration with the Society of Thoracic Surgeons (STS), which was contracted by CMS to develop a clinical registry-based, risk-adjusted CABG readmission measure for public reporting. Each measure developer had representatives on the other developer's working group. Important methodological decisions were made jointly and the measures were similarly presented to a combined Technical Expert Panel (TEP) and submitted for public comment together. To the extent possible, the measure specifications of the administrative-based CABG readmission measure are fully harmonized with those of the registry-based CABG readmission measure, given the limitations of both data sources. The CABG readmission measure described in this report complies with accepted standards for outcomes measure development, including appropriate risk adjustment and transparency of specifications. Although we developed the measure using Medicare data, the measure was also tested in and adapted for all-payer datasets. We also validated the measure cohort and risk-adjustment model using STS registry data.

1.2 Importance of CABG Readmission

CABG is a priority area for outcomes measure development because it is a common procedure associated with considerable morbidity, mortality, and health care spending. In 2007, there were 114,028 hospitalizations for CABG surgery and 137,721 hospitalizations for combined surgeries for CABG and valve procedures ("CABG plus valve" surgeries) in the U.S.[1]

Readmission rates following CABG surgery are high and vary across hospitals. For example, in January 2009-September 2011 Medicare Fee-for-Service (FFS) data, the median hospital-level risk-standardized readmission rate after CABG was 16.8% and ranged from 12.0% to 23.1%. This is consistent with published data as the average 30-day all-cause, hospital-level readmission rate in New York state was 16.5% and ranged from 8.3% to 21.1% among all patients who underwent CABG surgery between January 1, 2005 and November 30, 2007.[2] Among patients readmitted within 30 days, 87.3% of readmissions were for reasons related to CABG surgery, with a 30-day rate of readmissions due to complications of CABG surgery of 14.4%. Patients readmitted within 30 days also experienced a 2.8% in-hospital mortality rate during their readmission(s), three-fold higher than the 30-day mortality rate for patients without readmissions.[2] Hence, addressing the causes of readmission will improve outcomes for patients.

Readmissions after CABG also impose significant health care costs. In 2007, the Medicare Payment Advisory Committee (MedPAC) published a report to Congress in which it identified the seven conditions associated with the most costly potentially preventable readmissions in the U.S.[3] Among these seven, CABG ranked as having the highest potentially preventable readmission rate within 15 days following discharge (13.5%) and the second highest average Medicare payment per readmission ($8,136).[3] The annual cost to Medicare for potentially preventable CABG readmissions was estimated at $151 million.

High readmission rates and wide variation in these rates suggest that there is room for improvement. Reducing readmissions after CABG surgery has been identified as a target for quality measurement. An all-cause readmission measure for patients who undergo CABG surgery will provide hospitals with an incentive to reduce readmissions through prevention and/or early recognition and treatment of postoperative complications, and improved coordination of peri-operative care and discharge planning. Finally, CABG surgery has been identified as a potential applicable condition for use in the Affordable Care Act's Hospital Readmission Reduction Program.[4]

1.3 CABG Readmission as a Measure of Quality

Outcome measures can focus attention on a broad set of healthcare activities that affect patients' well-being. Moreover, improving patient outcomes is the ultimate goal of quality improvement, so outcomes are a direct measure of success in quality improvement. Two statutes[4,5] direct the Department of Health and Human Services to develop outcomes measures. The Deficit Reduction Act (DRA) of 2005 mandated that the Secretary of Health and Human Services publicly report quality measures that include measures of hospital outcomes and efficiency under the Hospital Inpatient Quality Reporting (IQR) Program (formerly the Reporting Hospital Quality Data for Annual Payment Update Program). In addition, the Affordable Care Act of 2010 promotes the further development and use of outcomes measures.

Hospital readmission is an important outcome for patients, as it is disruptive to patients and caregivers, costly to the healthcare system, and puts patients at additional risk of hospital-acquired infections and complications. Research has shown that readmission rates are influenced by the quality of inpatient and outpatient care, as well as hospital system characteristics, such as the bed capacity of the local healthcare system.[6] In

addition, specific hospital processes such as discharge planning,[7] medication reconciliation, and coordination of outpatient care have been shown to affect readmission rates.[3,6,8-20]

Randomized controlled trials have shown that improvement in the following areas can directly reduce readmission rates: quality of care during the initial admission; improvement in communication with patients, their caregivers and their clinicians; patient education; pre-discharge assessment; and coordination of care after discharge.[21-36] Successful randomized trials have reduced 30-day readmission rates by 20-40%. Since 2008, 14 Medicare Quality Improvement Organizations have been funded to focus on care transitions, applying lessons learned from clinical trials. Several have been notably successful in reducing readmissions within 30 days.[37] Evidence that hospitals have been able to reduce readmission rates through these quality-of-care initiatives illustrates the degree to which hospital practices can affect readmission rates.

Although data documenting readmission reductions in CABG is limited, there are data that support CABG readmission as an important quality metric.[38] Studying readmission after CABG surgery in New York, Hannan, et. al.[2] found wide variation in readmission rates; that the most common cause of readmission after CABG is complications; and that hospital-level variables such as use of cardiac rehabilitation and length of stay influenced readmission rates. The authors also noted that readmission rates were not closely correlated to mortality rates and thus readmission likely offers a complementary metric to measuring mortality for evaluating hospitals. Together, this data suggest that readmission reduction following CABG surgery is a viable and important target for quality improvement.

The goal of outcomes measurement is to evaluate patient outcomes after accounting for patients' conditions at the time of hospital admission (hospital case-mix). This readmission measure was developed to identify hospitals that perform better or worse than would be expected based on their patient case-mix, and therefore to promote hospital quality improvement and to better inform consumers about care quality.

Measuring and reporting readmission rates will inform healthcare providers about opportunities to improve care, strengthen incentives for quality improvement, and ultimately improve the quality of care received by Medicare patients. Improvements in care transitions for this condition are likely to reduce costly readmissions.

1.4 Approach to Measure Development

We developed this measure in accordance with national guidelines for publicly reported outcomes measures, and in consultation with clinical and measurement experts, key stakeholders, and the public. The proposed measure is consistent with the technical approach to outcomes measurement set forth in National Quality Forum (NQF) guidance for outcomes measures,[39] CMS's Measure Management System (MMS) guidance, and the guidance articulated in the American Heart Association scientific statement, "Standards for Statistical Models Used for Public Reporting of Health Outcomes.[40] Throughout measure development, we obtained expert and stakeholder input via three mechanisms: first, through regular discussions with an advisory working group, and second, through regular discussions with STS members concurrently developing a registry-based readmission measure, and three, through meetings with a national Technical Expert Panel (TEP).

The working group was comprised of two cardiothoracic surgeons in addition to the development team. The working group meetings addressed key issues surrounding measure development, including detailed discussions regarding the appropriate cohort for inclusion in the measure. The working group provided a forum for focused expert review and discussion of technical issues during measure development prior to consideration by the broader TEP.

In addition to the working group, and in alignment with the CMS MMS, we convened a TEP of diverse perspectives and backgrounds, including clinicians, consumers, hospitals, purchasers, and experts in quality improvement.

To recruit the TEP, we posted a call for TEP nominations on the CMS website, which included a brief description of the measures being developed, the measure development process, and information on expected TEP member involvement. We also identified potential TEP members and relevant organizations and notified them of the call. All nominations (comprised of a signed nomination/disclosure/agreement form, a statement of interest, and a CV) were compiled, reviewed with STS, and confirmed by CMS in order to conduct a joint TEP for the measures. The final TEP consisted of 15 members, although one member recused himself after being appointed to the NQF Consensus Standards Approval Committee.

We convened three TEP conference calls during the course of measure development. In contrast to the working group meetings, the TEP meetings followed a more structured format. We presented key methods decisions, relevant data and analysis, and our proposed approach. Presentations were followed by open discussions of issues with TEP members.

Using STS CABG registry data and in collaboration with STS, we performed a clinical data validation study of the administrative cohort definition, risk adjustment model and hospital performance assessment, detailed in Appendix E.

Finally, we publicly posted the preliminary measure specifications and a summary of the TEP discussions and made a widely distributed call for public comments. We collected comments through the CMS Measure Management System (MMS) Web site (https://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/MMS/CallforPublicComment.html), and took the comments into consideration during the final stages of measure development. In addition, we summarized the public comments for CMS and posted the verbatim comments and a summary of public comments on the publicly accessible CMS MMS Web site.

2. METHODS

2.1 Overview

We developed a hospital-level all-cause unplanned readmission measure for patients aged 65 years and over admitted for a qualifying CABG procedure to a non-Federal acute care hospital in the U.S. (including U.S. Virgin Islands, Puerto Rico, Guam, Northern Mariana Islands, and American Samoa). The measure does not count planned readmissions in the measure outcome, since they are generally not a signal of quality of care.

To develop the measure, we used Medicare administrative datasets that contain hospitalization data for Medicare FFS beneficiaries hospitalized in calendar year 2009 for a qualifying CABG procedure. The datasets also include administrative data on each patient for the 12 months prior to the index admission and the 30 days following it. An index admission is the hospitalization considered for the outcome. We subsequently updated some results in this report using CABG admissions from January 1, 2009 – September 30, 2011.

The measure calculates hospital-level risk-standardized readmission rates (RSRRs) using a hierarchical logistic regression model to account for the clustering of patients within hospitals while risk-adjusting for differences in patient case-mix. We risk-adjusted for patients' comorbid conditions, as identified in both inpatient and outpatient claims for the 12 months prior to the index hospitalization, as well as those present at admission. The model does not risk-adjust for diagnoses that may have been a complication of the index admission.

The measure developed in 2009 data was validated using Medicare FFS data from 2008 and 2010 and additionally validated using STS CABG registry data. The measure was also tested in an all-payer dataset and shown to be applicable to all-payer data for patients 18 years and older. Where relevant, references are made to the STS registry-based CABG Readmission measure specifications.

2.2 Data Sources

Part A inpatient data (to identify the cohort and comorbidities for risk adjustment) - contains final action claims data submitted by inpatient hospital providers for Medicare FFS beneficiaries for reimbursement of facility costs. Information in this file includes diagnoses (The International Classification of Diseases, 9th Revision, Clinical Modification or ICD-9 diagnosis codes), procedures (ICD-9 procedure codes), dates of service, hospital provider, and beneficiary demographic information.

Part A outpatient data (to identify comorbidities for risk adjustment) - contains final action claims submitted by inpatient hospital providers for Medicare FFS claims paid for the facility component of surgical or diagnostic procedures, emergency room care, and other non-inpatient services performed in a hospital outpatient department or ambulatory surgical/diagnostic center.

Part B data (to identify comorbidities for risk adjustment) – contains final action claims for physician services (regardless of setting) and other outpatient care, services, and supplies for Medicare FFS beneficiaries. For purposes of this project, Part B services included only face-to-face encounters between a care provider and patient. We, thus, do not include services such as laboratory tests, medical supplies, or other ambulatory services.

Medicare Enrollment Database (EDB) (to determine the outcome) – contains Medicare beneficiary demographic, benefit/coverage, enrollment status, and vital status information.

STS Adult Cardiac Surgery Database (to validate administrative cohort definition and risk adjustment model) – contains comprehensive clinical data (patient demographics and clinical information, hospital length of stay, current and prior cardiac procedures, operative and post-operative information, complications and mortality) on patients undergoing CABG procedures at participating hospitals and represents 95% penetration of US cardiac surgery programs.

California Patient Discharge Data (to test the measure in all-payer data) – contains linked administrative data for approximately 3 million adult discharges from more than 450 non-Federal acute care hospitals (2006 data), including readmission and mortality outcomes (via linking with California vital statistics records).

2.3 Outcome Definition

The outcome for this measure is 30-day all-cause readmission. We define a readmission as a subsequent unplanned acute care hospital inpatient admission within 30 days of the discharge date for the index admission (an index admission is the hospitalization during which the qualifying CABG procedure was performed).

2.3.1 30-Day Timeframe

Clinical experts concur that a 30-day timeframe is clinically sensible for measuring outcomes following CABG surgery, and is a meaningful timeframe for hospitals because readmissions are more likely attributable to care received within the index hospitalization and during the transition to the outpatient setting. For example, hospitals, in collaboration with their medical communities, take actions to reduce readmission, such as: ensure patients are clinically ready at discharge; reduce risk of infection; reconcile medications; improve communications among providers involved in transition of care; encourage strategies that promote disease management principles; and educate patients about symptoms to monitor, whom to contact with questions, and where and when to seek follow-up care.

Monitoring for readmissions for fewer than 30 days following discharge may be inadequate to capture all relevant outcomes and may provide insufficient power to capture meaningful hospital performance variation. Extending the assessment period beyond 30 days may capture events more heavily impacted by extraneous

factors. Furthermore, this outcome period is consistent with other NQF-endorsed CMS publicly reported readmission measures, including those publicly reported for AMI, heart failure, and pneumonia, and technical experts agreed that the timeframe was reasonable to assess readmissions following a CABG procedure.

2.3.2 All-Cause Readmission

We used all-cause readmission, rather than CABG surgery-related readmissions for several reasons. First, from the patient perspective, readmission for any reason is likely to be an undesirable outcome of care. Second, there is no reliable way to determine whether a readmission is related to CABG based on the documented cause of readmission. For example, a CABG patient who develops pneumonia post-operatively may ultimately be readmitted for respiratory distress. It would be inappropriate to treat this readmission as unrelated to the care the patient received for CABG. Third, the range of potentially avoidable readmissions also includes those not directly related to the CABG procedure, such as those resulting from medication reconciliation errors, poor communication at discharge, or inadequate follow-up post-discharge. Creating a comprehensive list of potentially avoidable readmissions related to CABG would be arbitrary and, ultimately, challenging to implement. Fourth, all existing CMS readmission measures report all-cause readmission, making this approach consistent with existing measures. Finally, research shows that readmission reduction interventions can reduce all-cause readmission, not only condition-specific readmission.[6-10,15-18]

2.3.3 Planned Readmission

Planned readmissions are scheduled admissions for elective procedures or for planned care such as chemotherapy or rehabilitation. Because planned readmissions are not necessarily a signal of quality of care, we chose to exclude planned readmissions from being considered as an outcome in this readmission measure. Although clinical experts agree that planned readmissions are rare after CABG, they likely do occur. Therefore, to identify these planned readmissions we have adapted and applied an algorithm originally created to identify planned readmissions for a hospital-wide (i.e., not condition-specific) readmission measure. This algorithm underwent two rounds of public comment, a validation study using data from a medical record review, and was finalized based upon technical input of 17 surgeons nominated by 9 surgical societies as well as 10 other expert surgeons.

In brief, the algorithm identifies a short list of always planned readmissions (those where the principal discharge diagnosis is major organ transplant, obstetrical delivery, or maintenance chemotherapy) as well as those readmissions with a *potentially* planned procedure (e.g., total hip replacement) AND a non-acute principle discharge diagnosis code. For example, a readmission for colon resection is considered planned if the principal diagnosis is colon cancer but unplanned if the principal diagnosis is abdominal pain, as this might represent a complication of the CABG procedure or hospitalization. Readmissions that

included potentially planned procedures with acute diagnoses or procedures that might represent specific complications of CABG, such as PTCA or repeat CABG are *not* excluded from the measure outcome as they are not considered planned in this measure. The algorithm flowchart and related tables providing detailed specifications for identifying planned readmissions is provided in Appendix A
The Planned Readmission Algorithm uses a flowchart and four tables to classify readmissions as planned. As illustrated in the flowchart (Figure PR1), readmissions are considered planned if any of the following occurs during the readmission:

1. A procedure is performed that is in one of the procedure categories that are always planned regardless of diagnosis (Table PR1);
2. The principal diagnosis is in one of the diagnosis categories that are always planned (Table PR2); or,
3. A procedure is performed that is in one of the potentially planned procedure categories (Table PR3) and the principal diagnosis is not in the list of acute discharge diagnoses (Table PR4).

Only the first readmission following an index hospital stay is counted in the numerator of this measure. If a patient has two or more readmissions within 30 days of discharge from the index hospital stay, only the first will be considered an outcome of interest; the second or later readmissions are not counted in the outcome.

It should be noted that this approach differs from that adopted by STS for their registry-based measure, in which all 30-day readmissions were considered to be unplanned.

2.4 Cohort Definition

The cohort includes patients aged 65 years and over who received a qualifying CABG procedure at a non-federal acute care facility. Patients are eligible for inclusion if they had a qualifying CABG procedure and continuous enrollment in Medicare FFS one year prior to the first day of the index hospital stay and through 30 days post discharge. All patients in the cohort are alive at discharge (i.e., no in-hospital death). The cohort is defined using the ICD-9-Clinical Modification (ICD-9-CM) procedure codes identified in Medicare Part A inpatient claims data. Table 1 below provides the final CABG measure cohort codes.

Table 1. Qualifying CABG Measure Cohort Codes

ICD-9 Code	Description
36.1x	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

ICD-9 Code	Description
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

2.4.1 Isolated CABG Cohort Definition

In order to include a clinically-coherent set of patients in the measure, we sought input from clinical experts regarding the inclusion of other concomitant cardiac and non-cardiac procedures, such as valve replacement and carotid endarterectomy. Clinical outcomes following such procedures are higher than those following "isolated" CABG procedures[2], that is, CABG procedures performed without concomitant high-risk cardiac and non-cardiac procedures. All of the measures developed by STS, including the NQF-endorsed STS Risk-Adjusted Operative Mortality for CABG measure,[41] consider isolated CABG patients separate from those undergoing CABG plus valve procedures. Limiting the measure cohort to "isolated" CABG patients is consistent with published reports of CABG outcomes[2]. In addition, our clinical experts, consultants and TEP members agreed that an isolated CABG cohort is a clinically coherent cohort for quality measurement.

We defined isolated CABG patients as those undergoing CABG procedures without concomitant valve or other major cardiac, vascular or thoracic procedures (Table 2). We also considered excluding a number of cardiac procedures that we ultimately decided to include in the measure cohort if they occurred concomitantly with CABG procedures. These procedures did not represent the same increased risk of morbidity as those listed in Table 3 and were more discretionary in nature. While we do not anticipate that hospitals might perform or code for additional procedures in order to avoid measurement, we did not want to provide any incentive or opportunity for such behaviors.

The administrative CABG readmission measure isolated CABG cohort is as harmonized with that of the STS registry-based CABG readmission measure cohort as the limitations of the two data sources allow. The only clinical difference is that this measure includes only epicardial MAZE procedures while the STS measure cohort excluded all MAZE procedures at the time of measure development. This is because the current version of the STS data collection form did not differentiate between open and epicardial MAZE procedures, limiting their ability to include epicardial MAZE procedures. Appendix B provides ICD-9 codes and CMS's Hierarchical Condition Categories (CCs, see Section 2.9 for additional information on CCs) excluded from the isolated CABG cohort.

Table 2. Concurrent procedure groups that exclude patients from isolated CABG cohort

Procedure groups excluded from isolated CABG[1]:	**Rationale**
• 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	• Represent higher risk population of patients • Aligned with STS

Table 3. Concurrent procedure groups considered, but rejected, as criteria for excluding patients (CABG patients with these procedures are retained in the measure)

Procedure groups considered for exclusion but ultimately included in isolated CABG:	**Rationale**
• Computer Assisted Surgery • Placement of circulatory assist devices (includes Ventricular assist devices [VADs], excludes implantation of cardiomyostimulation system, often planned) • Lead removal/revision/replacement • Pacemaker implantation • Implantable Cardioverter Defibrillator (ICD) implantation • Transmyocardial revascularization (TMR) procedures • Miscellaneous (e.g., other revascularization, cardiac massage, epicardial “maze” procedures intended to eliminate atrial fibrillation)	• Do not represent higher patient risk categories • Rare procedures that are discretionary and, as such, may provide additional hospital performance information • Aligned with STS (to the extent possible given data limitations)

[1] Refer to full list of codes in Appendix B.

2.5 Inclusion/Exclusion Criteria

Admissions eligible for inclusion in the measure are those for patients aged 65 years or older admitted to non-federal acute care hospitals for CABG procedures AND continuously enrolled in Medicare FFS one year prior to the first day of the index hospitalization. All patients in the cohort are alive at discharge (i.e., no in-hospital death). The flow chart depicting eligible admissions is presented in Figure 2 in the Results Section. An index admission is any eligible admission to a non-federal acute care hospital assessed in the measure for the outcome (readmitted within 30 days of the date of discharge). Eligible index admissions are identified using the ICD-9 codes listed in Table 1 above.

We excluded the following admissions from the measure:

- Patients who leave hospital against medical advice (AMA).

  Rationale: We exclude hospital stays for patients who are discharged AMA because providers did not have the opportunity to deliver full care and prepare the patient for discharge.

- 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 very likely represents a complication of the original CABG procedure and is a clinically more complex and higher risk surgery. We, therefore, select the first CABG admission for inclusion in the measure and exclude subsequent CABG admissions from the cohort.

- Patients without at least 30 days post-discharge enrollment in Medicare FFS

  Rationale: We exclude these hospital stays because the 30-day readmission outcome cannot be assessed in this group.

2.6 Transferred Patients and Attribution of Readmission Outcome

Among medical conditions, such as AMI, heart failure and pneumonia, transfers between acute care facilities can occur for a variety of different reasons and it is likely that the discharging hospital has the most influence over a patient's risk of readmission and therefore the readmission outcome is appropriately assigned to the hospital that discharges the patient. For that reason, the currently publicly reported AMI, heart failure and pneumonia readmission measures attribute the readmission outcome to the hospital discharging the patient, even if that is not the hospital that initially admitted the patient.

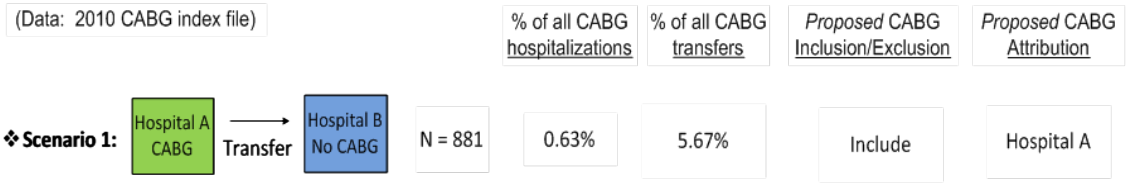
In contrast, following CABG surgery, transfer to another acute care facility after CABG is most likely due to a complication of the CABG procedure or the peri-operative care the patient received and as such the care provided by the hospital performing the CABG procedure likely dominates readmission risk, even among transferred patients. This viewpoint is supported by the high proportion of CABG readmissions for diagnoses such

as heart failure, pleural effusion, and pneumonia and is endorsed by the clinical experts on both the YNHHHSC/CORE and STS CABG measure development working groups and the combined TEP. Therefore, for this measure, the readmission outcome is attributed to the hospital performing the first ("index") CABG, even if this is not the discharging hospital. For example, a patient may be admitted to hospital A for a CABG that qualifies them for inclusion in the measure and is then transferred to hospital B. The initial admission to hospital A and the admission to hospital B are considered one acute episode of care, made up of two inpatient admissions. The measure identifies transferred patients as those who are admitted to an acute care hospital on the same day or following day of discharge from an eligible admission.

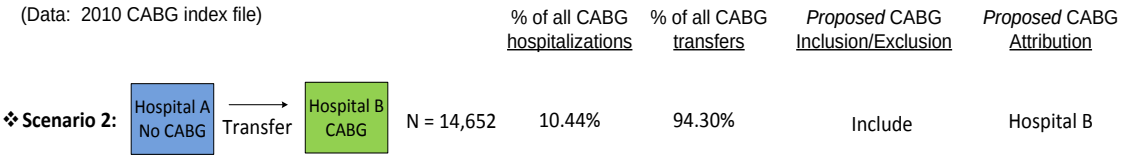
Below we summarize the most common transfer scenarios arising in the CABG measure development cohort and the attribution of the readmission outcome in each scenario. The following decisions are based upon the fact that transfer following a CABG procedure almost always reflects one or more serious complication(s) (and/or its sequelae) arising at the index hospital.

CABG Transfer Scenarios:

Transfer Scenario 1 (below) indicates that a patient undergoes a CABG procedure at Hospital A and then is transferred to hospital B (but does not receive additional CABG procedures). The measure attributes the readmission outcome to Hospital A, which performed the index CABG procedure, and starts the 30-day window from the day of discharge from Hospital B. This scenario is included in the measure because excluding it might miss important care quality information. Clinical experts in both the YNHHHSC/CORE and STS working groups uniformly supported that transfer following CABG is an indication of complications and thus impacts readmission risk. In addition, excluding this scenario might provide hospitals with an incentive to transfer sicker patients to other hospitals in order to avoid measurement.



Transfer Scenario 2 (below) indicates that a patient is admitted to Hospital A (but does not receive a CABG procedure at hospital A) and is transferred to hospital B to receive a CABG procedure. The measure attributes the readmission outcome to Hospital B, which performed the index CABG procedure, and starts the 30-day window from the day of discharge from Hospital B. This is a common scenario arising in the CABG measure development cohort and attributing the outcome to the second hospital is consistent with other measures.[42-44]



Transfer Scenario 3 (below) indicates that a patient undergoes a CABG procedure at Hospital A and then is transferred to hospital B, to receive a second CABG procedure. The measure attributes the readmission outcome to Hospital A, which performed the index CABG procedure, and starts the 30-day window from the day of discharge from Hospital B. Similar to Scenario 1, this rare scenario is included in the measure as excluding it might miss important care quality information. Clinical experts in both the YNHHHSC/CORE and STS working groups unanimously agreed that transfer following CABG is an indication of complications and thus impacts readmission risk. In addition, excluding this scenario might provide hospitals with an incentive to transfer sicker patients to other hospitals in order to avoid measurement.

(Data: 2010 CABG index file)				% of all CABG hospitalizations	% of all CABG transfers	*Proposed* CABG Inclusion/Exclusion	*Proposed* CABG Attribution
❖ **Scenario 3:**	Hospital A CABG	→ Transfer	Hospital B CABG	N = 4	0.00%	0.03%	Include	Hospital A

2.7 Model Development and Validation Samples

To create the model development and validation samples, we applied the inclusion and exclusion criteria to all 2008-2010 admissions. We used CABG admissions in 2009 that met the inclusion and exclusion criteria to create the model development sample and used the remaining admissions (2008 and 2010) as our model validation sample. Our approach to validation is outlined in Section 2.12 Measure Testing below. We subsequently updated select results in this report using CABG admissions in January 1, 2009 – September 30, 2011. Measure results using the 33-month sample are reported in Section 3.1 below.

2.8 Approach to Risk Adjustment

The goal of risk adjustment is to account for patient demographic and clinical characteristics in order to identify differences in care quality. The model adjusts for case-mix differences based on the clinical status of the patient at the time of admission. Conditions that may represent adverse outcomes due to care received during the index admission are not considered for inclusion in the risk-adjusted model. Although they may increase the risk of readmission, including them as covariates in a risk-adjusted model could attenuate the measure's ability to characterize the quality of care delivered by hospitals. Appendix C lists the conditions not adjusted for if they only appear in the index admission and not in the 12 months prior to admission. This methodology is consistent with NQF guidelines (http://www.qualityforum.org/docs/measure_evaluation_criteria.aspx).

The model does not adjust for socioeconomic status (SES), race, or ethnicity. Variation in quality associated with these characteristics may be indicative of disparities[45] in the quality of the care provided to vulnerable populations, and adjusting for these factors in a model would obscure these disparities. The model does not adjust for hospital characteristics either (e.g., teaching status) since this would hold different types of

hospitals to different quality standards, and because such characteristics may exist on a causal pathway to the outcome, rather than act as confounders.

2.9 Candidate and Final Risk-Adjustment Variables

Our goal was to develop a parsimonious model that included clinically relevant variables that are associated with risk of readmission. The candidate variables for the model were derived from: the index admission, with comorbidities identified from the index admission secondary diagnoses (excluding potential complications), 12-month pre-index inpatient Part A data, outpatient hospital data, and Part B physician data.

For administrative model development, we started with 189 Condition Categories (CCs) which are part of CMS's Hierarchical Condition Categories. The Hierarchical Condition Category (HCC) system groups the ICD-9-CM codes into larger groups that are used in models to predict medical care utilization, mortality or other related measures. CCs are clinically relevant diagnostic groups of the more than 15,000 ICD-9 codes.[46] We used the ICD-9 to CC assignment map, which is maintained by CMS.

To select candidate variables, a team of clinicians reviewed all 189 CCs and excluded those that were not relevant to the Medicare population (Appendix D) or that were not clinically relevant to the readmission outcome (e.g., attention deficit disorder, female infertility). Clinically relevant CCs were selected as candidate variables and some of those CCs were then combined into clinically coherent CC groupings. Other candidate variables included age, gender, and cardiogenic shock (Table 4). Gender was included in risk adjustment due to the fact that women have smaller vessels and thus represent more technically challenging CABG procedures compared to men.[47]

Table 4. Candidate Model Variables for Risk Adjustment

Category	Variable	CC
Demographics	Age	
	Gender	
Comorbidities	Cardiogenic Shock	ICD-9 code 785.51
	History of Infection	CC 1, 3-6
	Septicemia/Shock	CC 2
	Cancer (Metastatic Cancer and Acute Leukemia; Lung, Upper Digestive Tract, and Other Severe Cancers; Lymphatic, Head and Neck, Brain and Other Major Cancers; Breast, Prostate, Colorectal and Other Cancers and Tumors; Other Respiratory and Heart Neoplasms; Other Digestive and Urinary Neoplasms)	CC 7-12
	Other Neoplasms	CC 13
	Benign Neoplasms of Skin, Breast, Eye	CC 14
	Diabetes and DM Complications	CC 15-20, 119-120
	Protein-Calorie Malnutrition	CC 21
	Disorders of Fluid/Electrolyte/Acid-Base	CC 22-23
	Obesity/Disorders of Thyroid, Cholesterol, Lipids	CC 24
	Liver and Biliary Disease	CC 25-30
	Intestinal Obstruction/Perforation	CC 31
	Pancreatic Disease	CC 32
	Inflammatory Bowel Disease	CC 33
	Peptic Ulcer, Hemorrhage, Other Specified Gastrointestinal Disorders	CC 34
	Other Gastrointestinal Disorders	CC 36
	Bone/Joint/Muscle Infections/Necrosis	CC 37
	Rheumatoid Arthritis and Inflammatory Connective Tissue Disease	CC 38
	Disorders of the Vertebrae and Spinal Discs	CC 39
	Osteoarthritis of Hip or Knee	CC 40
	Osteoporosis and Other Bone/Cartilage Disorders	CC 41
	Other Musculoskeletal and Connective Tissue Disorders	CC 43
	Severe Hematological Disorders	CC 44
	Disorders of Immunity	CC 45
	Coagulation Defects and Other Specified Hematological Disorders	CC 46
	Iron Deficiency and Other/Unspecified Anemia and Blood Disease	CC 47
	Delirium and Encephalopathy	CC 48
	Dementia or Senility	CC 49-50
	Drug/Alcohol Abuse/Dependence/Psychosis (Drug/Alcohol Induced Dependence/Psychosis; Drug/Alcohol Dependence; Drug/Alcohol Abuse, without Dependence)	CC 51-53
	Major Psychiatric Disorders	CC 54-56
	Depression	CC 58

Category	Variable	CC
	Anxiety Disorders	CC 59
	Other Psychiatric Disorders	CC 60
	Hemiplegia, Paraplegia, Paralysis, Functional Disability	CC 67-69, 100-102, 177-178
	Polyneuropathy	CC 71
	Parkinson's and Huntington's Diseases	CC 73
	Seizure Disorders and Convulsions	CC 74
	Mononeuropathy, Other Neurological Conditions/Injuries	CC 76
	Respiratory Arrest/Cardio-Respiratory Failure and Shock	CC 78-79
	Congestive Heart Failure	CC 80
	Acute Myocardial Infarction	CC 81
	Unstable Angina and Other Acute Ischemic Heart Disease	CC 82
	Angina Pectoris/Old Myocardial Infarction	CC 83
	Coronary Atherosclerosis/Other Chronic Ischemic Heart Disease	CC 84
	Heart Infection/Inflammation, Except Rheumatic; Valvular and Rheumatic Heart Disease	CC 85-86
	Congenital Cardiac/Circulatory Defect (Major Congenital Cardiac/Circulatory Defect; Other Congenital Heart/Circulatory Disease)	CC 87-88
	Hypertensive Heart and Renal Disease or Encephalopathy	CC 89
	Hypertensive Heart Disease	CC 90
	Hypertension	CC 91
	Arrhythmias	CC 92-93
	Other and Unspecified Heart Disease	CC 94
	Stroke	CC 95-96
	Cerebrovascular Disease	CC 97-99, 103
	Vascular or Circulatory Disease	CC 104-106
	Chronic Obstructive Pulmonary Disease	CC 108
	Fibrosis of Lung and Other Chronic Lung Disorder	CC 109
	Asthma	CC 110
	Pneumonia	CC 111-113
	Pleural Effusion/Pneumothorax	CC 114
	Other Lung Disorders	CC 115
	Retinal Detachment/Retinal Disorders (Retinal Detachment; Retinal Disorders, Except Detachment and Vascular Retinopathies)	CC 118, 121
	Glaucoma	CC 122
	Other Eye Disorders	CC 124
	Significant Ear, Nose, and Throat Disorders	CC 125
	Hearing Loss	CC 126
	Other Ear, Nose, Throat, and Mouth Disorders	CC 127
	End-stage Renal Disease or Dialysis	CC 130
	Renal Failure	CC 131
	Nephritis	CC 132

Category	Variable	CC
	Urinary Obstruction and Retention	CC 133
	Incontinence	CC 134
	Urinary Tract Infection	CC 135
	Other Urinary Tract Disorders	CC 136
	Pelvic Inflammatory Disease	CC 138
	Other Female Genital Disorders	CC 139
	Male Genital Disorders	CC 140
	Decubitus Ulcer or Chronic Skin Ulcer	CC 148-149
	Cellulitis, Local Skin Infection	CC 152
	Other Dermatological Disorders	CC 153
	Trauma	CC 154-156, 158-161
	Vertebral Fractures	CC 157
	Other Injuries	CC 162
	Poisoning and Allergic Reactions	CC 163
	Major Complications of Medical Care and Trauma	CC 164
	Other Complications of Medical Care	CC 165
	Major Symptoms, Abnormalities	CC 166
	Minor Symptoms, Signs, Findings	CC 167

To inform final variable selection, a modified approach to stepwise logistic regression was performed. The development sample was used to create 1,000 "bootstrap" samples. For each sample, we ran a logistic stepwise regression that included the candidate variables. The results (not shown in this report) were summarized to show the percentage of times that each of the candidate variables was significantly associated with readmission ($p<0.001$) in each of the 1,000 repeated samples (e.g., 90 percent would mean that the candidate variable was selected as significant at $p<0.001$ in 90 percent of the estimations). We also assessed the direction and magnitude of the regression coefficients.

The clinical team reviewed these results and decided to retain the majority of risk-adjustment variables above a 70% cutoff, because they demonstrated a relatively strong and stable association with risk for readmission and were clinically relevant. Additionally, specific variables with particular clinical relevance to the risk of readmission were forced into the model (regardless of percent selection) to ensure appropriate risk adjustment for CABG. These included:

Clinical variables associated with CABG:

- History of Prior CABG or Valve Surgery (ICD-9 procedure codes: V42.2, V43.3, V45.81, 414.02, 414.03, 414.04, 414.05, 414.06, 414.07, 996.02, 996.03, 39.61)[48]

Markers for end of life/frailty:

- Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)
- Dementia and Senility (CC 49 and CC 50, respectively)
- Metastatic Cancer and Acute Leukemia (CC 7)
- Protein-calorie Malnutrition (CC 21)
- Hemiplegia, Paraplegia, Paralysis, Functional disability (CC 67-69, 100-102, 177-178)
- Stroke (CC 95-96)

Diagnoses with potential asymmetry among hospitals that would impact the validity of the model:

- Lung, Upper Digestive Tract, and Other Severe Cancers (CC 8)
- Lymphatic, Head and Neck, Brain, and Other Major Cancers; Breast, Prostate, Colorectal and Other Cancers and Tumors; Other Respiratory and heart Neoplasms (CC 9-11)
- Other Digestive and Urinary Neoplasms (CC 12)

The final model variables are shown in Table 5.

Table 5. Final Model Variables

Category	Variable	CC
Demographics	Age	
	Gender	
Comorbidities	History of Prior 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 codes: 39.61
	Cardiogenic Shock	ICD-9 code 785.51
	Cancer	CC 7-12
	Diabetes and DM Complications	CC 15-20, 119, 120
	Protein-Calorie Malnutrition	CC 21
	Disorders of Fluid/Electrolyte/Acid-Base	CC 22-23
	Obesity/Disorders of Thyroid, Cholesterol, Lipids	CC 24
	Severe Hematological Disorders	CC 44
	Dementia or Senility	CC 49-50
	Major Psychiatric Disorders	CC 54-56
	Hemiplegia, Paraplegia, Paralysis, Functional Disability	CC 67-69, 100-102, 177-178
	Polyneuropathy	CC 71
	Congestive Heart Failure	CC 80
	Arrhythmias	CC 92-93
	Stroke	CC 95-96
	Cerebrovascular Disease	CC 97-99, 103
	Vascular or Circulatory Disease	CC 104-106
	Chronic Obstructive Pulmonary Disease	CC 108
	Fibrosis of Lung and Other Chronic Lung Disorders	CC 109
	Pneumonia	CC 111-113
	Other Lung Disorders	CC 115
	End-stage Renal Disease or Dialysis	CC 130
	Renal Failure	CC 131
	Decubitus Ulcer or Chronic Skin Ulcer	CC 148-149

2.10 Statistical Approach to Measure Calculation

The measure calculates readmission rates using a hierarchical logistic regression model to account for the clustering of patients within hospitals while risk-adjusting for differences in patient case-mix. We modeled the log-odds of readmission within 30 days of discharge from an index CABG admission as a function of patient demographic and clinical characteristics, and a random hospital-specific intercept. This strategy accounts for within-hospital correlation of the observed outcomes and models the assumption that underlying differences in quality among the health care groups being evaluated lead to systematic differences in outcomes.

We then calculate hospital-specific readmission rates. These rates are obtained as the ratio of predicted to expected readmissions, multiplied by the national unadjusted rate. The expected number of readmissions in each hospital is estimated using its patient mix and the average hospital-specific intercept. The predicted number of readmissions in each hospital is estimated given the same patient mix but the hospital-specific intercept. Operationally, the expected number of readmissions for each hospital is obtained by regressing the risk factors on the 30-day readmission using all hospitals in our sample, applying the subsequent estimated regression coefficients to the patient characteristics observed in the hospital, adding the average of the hospital-specific intercepts, summing over all patients in the hospital, and then transforming to get a count. This is a form of indirect standardization. The predicted hospital outcome is the number of expected readmissions in the "specific" hospital and not at a reference hospital. Operationally this is accomplished by estimating a hospital-specific intercept that represents baseline readmission risk within the hospital, applying the estimated regression coefficients to the patient characteristics in the hospital, summing over all patients in the hospital, and then transforming to get a count. To assess hospital performance in any given year, we re-estimate the model coefficients using that year's data.

More specifically, we estimate 2 types of regression models using the administrative data (Figure 1). First, we fit a logistic regression model linking the outcome to the risk factors.[49] Let Y_{ij} denote the outcome (equal to 1 if patient is readmitted within 30-days, zero otherwise) for the j^{th} patient discharged from the i^{th} hospital; $\mathbf{Z}_{ij}$ denotes a set of risk factors based on the administrative data. Let I denote the total number of hospitals and n_i the number of index admissions to hospital i. We assume the outcome is related linearly to the covariates via a known linked function, h, where

$$\text{Logistic Regression Model} \qquad h(Y_{ij}) = \alpha + \beta \mathbf{Z}_{ij} \qquad (1)$$

and $\mathbf{Z}_{ij} = (Z_{1ij}, Z_{2ij}, \ldots, Z_{pij})$ is a set of p patient-specific covariates. In our case, h = the logit link.

To account for the natural clustering of observations within hospitals, we estimate a hierarchical logistic regression model that links the risk factors to the same outcomes and a hospital-specific random effect,

$$\text{Hierarchical logistic regression model} \quad h(Y_{ij}) = \alpha_i + \beta \mathbf{Z}_{ij} \qquad (2)$$

$$\alpha_i = \mu + \omega_i; \qquad \omega_i \sim N(0, \tau^2) \qquad (3)$$

where α_i represents the hospital-specific intercept, $\mathbf{Z}_{ij}$ is defined as above, μ the adjusted average outcome over all hospitals in the sample, and τ^2 the between-hospital variance component.[50] This model separates within-hospital variation from between-hospital variation. Both hierarchical logistic regression models and logistic regression models are estimated using the SAS software system (GLIMMIX and LOGISTIC procedures respectfully).

We first fit the logistic regression model described in Equation (1) using the logit link. Having identified the covariates that remained, we next fit the hierarchical logistic regression model described in Equations (2) and (3), again using the logit link function; e.g.

$$\text{Logit}\left(P\left(Y_{ij}=1\right)\right)=\alpha_i+\beta\,\mathbf{Z}_{ij}$$
$$\alpha_i=\mu+\omega_i \quad \omega_i \sim N\left(0,\tau^2\right)$$

where $\mathbf{Z}_{ij}$ consisted of the covariates retained in the logistic regression model. As before, Y_{ij} = 1 if patient *j* treated at hospital *i* had the event; 0 otherwise.

2.11 Hospital Performance Reporting

For each hospital, bootstrapping simulations were used to compute a 95% interval estimate of the RSRR to characterize the level of uncertainty around the specific point estimate. The point estimate and interval estimate can be used to characterize and compare a hospital's performance (e.g., higher than expected, as expected, or lower than expected) to an average hospital with a similar case-mix.

Using the set of risk factors in the logistic regression model, we fit the hierarchical logistic regression model defined by Equations (2) - (3) and estimate the parameters, $\hat{\mu}$, $\{\hat{\alpha}_i,\hat{\alpha}_2,...,\hat{\alpha}_I\}$, $\hat{\beta}$, and $\hat{\tau}^2$. We calculate a standardized outcome, s_i, for each hospital by computing the ratio of the number of predicted readmissions to the number of expected readmissions, multiplied by the unadjusted overall readmission rate, $\bar{y}$. Specifically, we calculate

Predicted $\quad \hat{y}_{ij}(Z) = h^{-1}(\hat{\alpha}_i + \hat{\beta}\,\mathbf{Z}_{ij})$ (4)

Expected $\quad \hat{e}_{ij}(Z) = h^{-1}(\hat{\mu} + \hat{\beta}\,\mathbf{Z}_{ij})$ (5)

$$\hat{s}_i(Z) = \frac{\sum_{j=1}^{n_i}\hat{y}_{ij}(Z)}{\sum_{j=1}^{n_i}\hat{e}_{ij}(Z)} \times \bar{y} \quad (6)$$

If the number of "predicted" readmissions is higher (lower) than the "expected" number of readmissions, then that hospital's $\hat{s}_i$ will be higher (lower) than the unadjusted average. For each hospital, we compute an interval estimate of s_i to characterize the level of uncertainty around the point estimate using bootstrapping simulations. The point estimate and interval estimate can be used to characterize and compare hospital performance (e.g., higher than expected, as expected, or lower than expected).

2.11.1 Creating Interval Estimates

Because the statistic described in Equation (6) is a complex function of parameter estimates, we use re-sampling and simulation techniques to derive an interval estimate. In particular, we use bootstrapping procedures to compute confidence intervals. Because the theoretical-based standard errors are not easily derived, and to avoid making unnecessary assumptions, we use the bootstrap to empirically construct the sampling distribution for each hospital-specific RSRR.

2.11.2 Algorithm

Let *I* denote the total number of hospitals in the sample. We repeat steps 1 – 4 below for b = 1,2,…B times:

1. Sample *I* hospitals with replacement.

2. Fit the hierarchical logistic regression model using all patients within each sampled hospital. We use as starting values the parameter estimates obtained by fitting the model to all hospitals. 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:

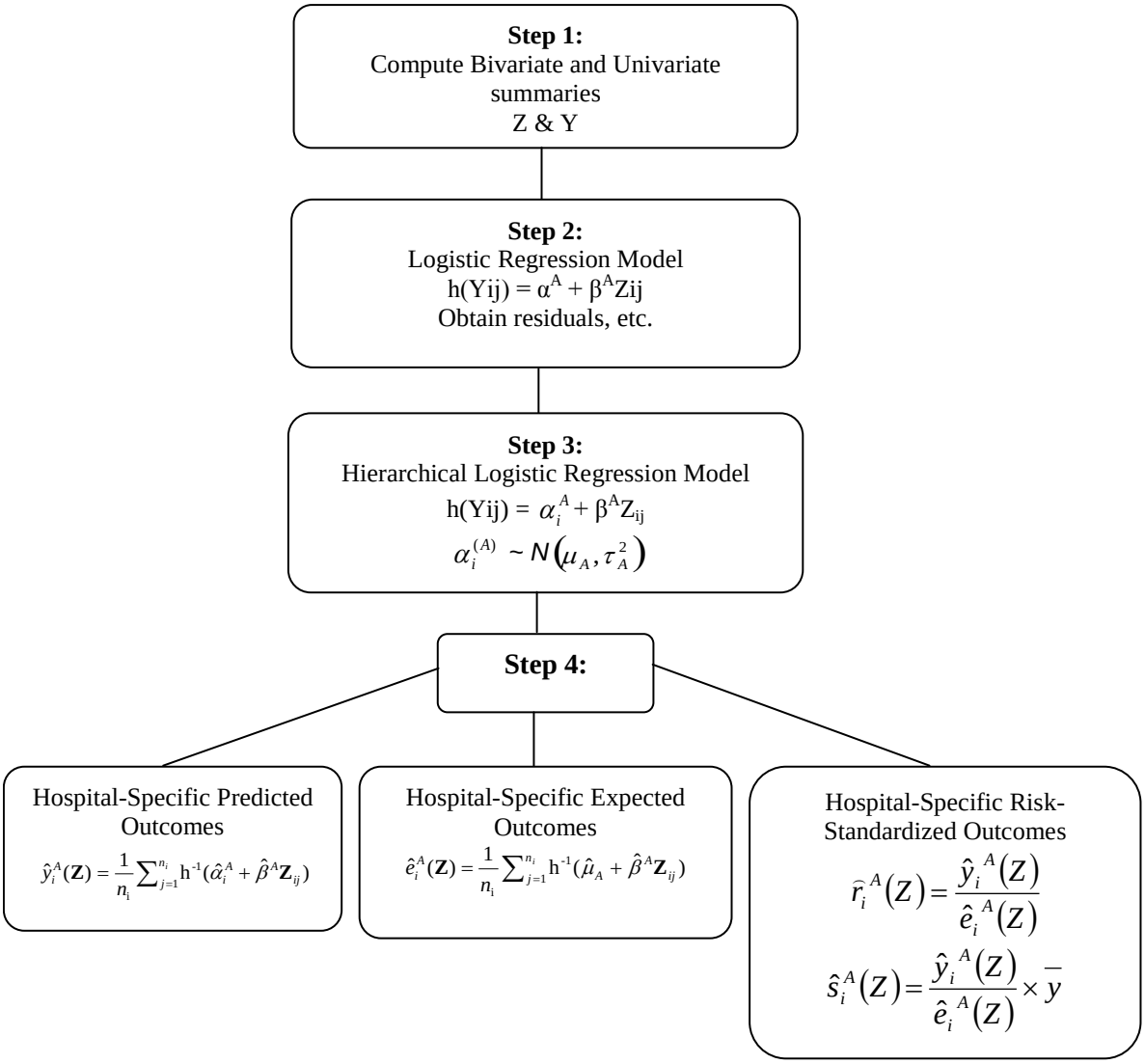
   a. $\hat{\beta}^{(b)}$ (the estimated regression coefficients of the risk factors)
   b. The parameters governing the random effects, hospital-adjusted outcomes, distribution, $\hat{\mu}^{(b)}$ and $\hat{\tau}^{2(b)}$.
   c. The set of hospital-specific intercepts and corresponding variances, $\{\hat{\alpha}_i^{(b)}, \hat{\text{var}}\left(\alpha_i^{(b)}\right); i = 1,2,\ldots,I\}$.

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 $\alpha_i^{(b^*)} \sim N\left(\hat{\alpha}_i^{(b)}, \hat{\text{var}}\left(\hat{\alpha}_i^{(b)}\right)\right)$ 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 $\hat{s}_i(Z)^{(b)}$ 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 randomly half of the B estimates (or the percentiles corresponding to the alternative desired intervals).[51]

Figure 1. Analysis Steps



2.12 Measure Testing

2.12.1 Reliability of Data Elements

For measure development, we only use data elements in claims that have both face validity and reliability. We do not use fields that are inconsistently coded across providers. We also only use fields that are consequential for payment and which are audited. We identify these variables through empiric analyses and our understanding of CMS auditing and billing policies and do not use variables which do not meet these standards. For example, "discharge disposition" is a variable in Medicare claims data that is not consistently coded across hospitals. Thus, we construct an indicator variable as a surrogate for "discharge disposition" to identify patients that are transferred using variables in the claims data with greater reliability, including admit date and discharge date.

In addition, CMS has in place several hospital auditing programs used to assess overall claims code accuracy, ensure appropriate billing, and recoup overpayments. CMS routinely conducts data analysis to identify potential problem areas and detect fraud, and audits important data fields used in our measures, including diagnosis and procedure codes, and other elements that are consequential to payment.

2.12.2 Reliability of Model

To test the reliability of the model, we assessed model performance and the effect of the risk-adjustment variables on the outcome across the years of data. We computed several summary statistics for assessing model performance which included:[52] over-fitting indices,[b] predictive ability, area under the (ROC) curve, distribution of residuals, and model chi-square.[c]

2.12.3 Measure Results Reliability

The reliability of a measurement is the degree to which repeated measurements of the same entity agree with each other. For measures of hospital performance,

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[b] Over-fitting (γ_0, γ_1) provides evidence of over-fitting and requires several steps to calculate. Let *b* denote the *estimated vector* of regression coefficients. *Predicted Probabilities* ($\hat{p}$) = 1/(1+exp{-Xb}), and *Z* = *Xb* (e.g., the linear predictor that is a scalar value for everyone). A new logistic regression model that includes only an intercept and a slope by regressing the logits on Z is fitted in the validation sample; e.g., Logit(P(Y=1|Z)) = γ_0 + γ_1Z. Estimated values of γ_0 far from 0 and estimated values of γ_1 far from 1 provide evidence of over-fitting.

[c] Chi-Square – A test of statistical significance usually employed for categorical data to determine whether there is a good fit between the observed data and expected values; i.e., whether the differences between observed and expected values are attributable to true differences in characteristics or instead the result of chance variation. The formula for computing the chi-square is as follows:

$$\sum \frac{(O-E)^2}{E}$$

where O = observed value
E = expected value, and
degrees of freedom (df) = (rows-1)(columns-1)

the measured entity is the hospital, and reliability is the extent to which repeated measurements of the same hospital give similar results. Accordingly, our approach to assessing reliability is to consider the extent to which assessments of a hospital using different but randomly selected subsets of patients produce similar measures of hospital performance. That is, we take a "test-retest" approach in which hospital performance is measured once using a random subset of patients, then measured again using a second random subset exclusive of the first, and the agreement of the two resulting performance measures compared across hospitals.[53]

For test-retest reliability of the measure in Medicare FFS patients aged 65 and older, we combined index admissions from successive measurement periods into one dataset, randomly sampled half of patients within each hospital, calculated the measure for each hospital, and repeated the calculation using the second half. Thus, each hospital is measured twice, but each measurement is made using an entirely distinct set of patients. To the extent that the calculated measures of these two subsets agree, we have evidence that the measure is assessing an attribute of the hospital, not of the patients.

As a metric of agreement, we calculated the intra-class correlation coefficient[54] and assessed the values according to conventional standards[55]. Specifically, we used a combined 2008-2010 sample, randomly split it into two approximately equal subsets of patients, and calculated the RSRR for each hospital for each sample. The agreement of the two RSRRs was quantified for hospitals in each sample using the intra-class correlation as defined by ICC (2,1) by Shrout and Fleiss.[54]

Using two non-overlapping random samples provides an honest estimate of the measure's reliability, compared with using two random but potentially overlapping samples which would exaggerate the agreement. Moreover, because our final measure is derived using hierarchical logistic regression, and a known property of hierarchical logistic regression models is that smaller volume hospitals contribute less 'signal', a split sample from a single three year measurement period will introduce extra noise, potentially underestimating the actual test-retest reliability that would be achieved if the measure were reported using the full three years of data.

2.12.4 Validity

To assess face validity, we surveyed the Technical Expert Panel and asked each member to rate the following statement using a six-point scale (1=Strongly Disagree, 2=Moderately Disagree, 3=Somewhat Disagree, 4=Somewhat Agree, 5=Moderately Agree, and 6=Strongly Agree): "The readmission rates obtained from the readmission measure as specified will provide an accurate reflection of quality."

In addition, in collaboration with STS, we performed a validation study of the CABG readmission measure using the national STS Adult Cardiac Surgery Database. The validation study performed included three separate validation components and is detailed in Appendix E.

2.12.4.1 Validation of the administrative isolated CABG cohort

Validation of the administrative isolated CABG cohort consisted of a probabilistic matching, at the patient and hospital level, of the administrative CABG cohort for the administrative readmission measure detailed in this report and the measure cohort for the STS clinical data-based CABG readmission measure. Non-matching patients were identified as either Claims Only (i.e., the administrative cohort defined them as isolated CABG patients while the STS registry did not) or Registry Only (i.e., the administrative cohort defined them as non-isolated CABG patients while the registry defined them as isolated CABG patients). This information was reviewed to identify inclusion/exclusion criteria and/or codes used to define the administrative readmission cohort that might be changed in order to improve the claims-based cohort definition and to align as much as possible with the registry definition of isolated CABG procedures.

2.12.4.2 Validation of the administrative risk adjustment model

Validation of the administrative risk adjustment model consisted of measuring the correlation of the hospital-level performance assigned by the administrative CABG readmission measure detailed in this report in the matched cohort of CABG patients to that assigned by the STS clinical data-based CABG readmission measure (also in the matched cohort). In addition, we performed a reclassification analysis to determine how many hospitals might be reclassified to a different performance category ("better" or "worse than expected" or "as expected", according to the methodology used for the currently publicly reported CMS readmission measures for Acute Myocardial Infarction, Heart Failure and Pneumonia)[56] if assessed by the administrative as compared to the registry measure.

2.12.4.3 "Real world" comparison of the administrative readmission measure

In order to understand the implications of implementing the registry-based versus the claims-based readmission measures, we performed a "real world" comparison. In this analysis, the hospital-level performance results of applying the administrative CABG readmission measure in the administrative isolated CABG measure cohort were compared to the results of applying the STS clinical data-based CABG readmission measure in the STS isolated CABG cohort. There is no accepted gold standard for this comparison.

2.13 Testing of Measure in All-Payer Data

Using 2006 California Patient Discharge Data, we created a measure cohort with up to one year of hospital admission claims history and 30-days follow-up data. We then created the patient cohort using the CABG measure inclusion and exclusion criteria (with the exception of including all patients 18+), and compared the FFS 65+, non-FFS 65+, all 65+, and all-payer 18-64 year-old patient subgroups with respect to the distribution of risk factors and the crude outcome rate. We fit the model in all patients 18+ and (a) examined overall model performance in terms of the c-statistic; (b) compared performance (c-statistic, predictive ability) across patient subgroups (FFS 65+, non-FFS 65+, all 65+, and all-payer 18-64); and (c) compared the distribution of Pearson residuals (model fit) across the patient subgroups. To help determine whether the measure could be applied to a population of patients aged 18+ (i.e., including younger patients aged 18-64), we examined the interaction terms between age (18-64 vs. 65+) and each of the other risk factors in 2006 California Patient Discharge Data. Specifically, we fit the model in all patients 18+ with and without interaction terms and (a) conducted a reclassification analysis to compare risk prediction at the patient level; (b) compared the C statistic; and (c) compared hospital-level risk-standardized rates (scatterplot, ICC) to assess whether the model with interactions is different from the current model in profiling hospital rates. Details of all-payer data testing are provided in Appendix F.

3. RESULTS

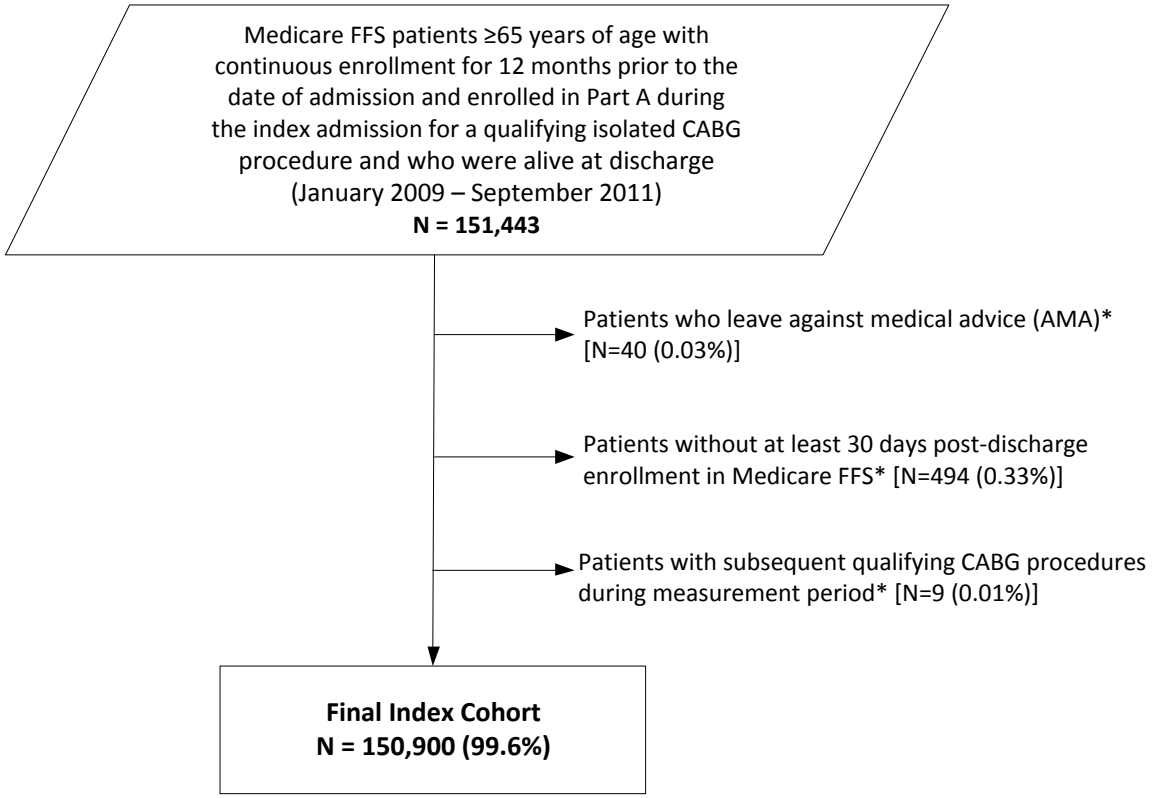
3.1 Model Results

3.1.1 January 2009-September 2011 Sample

The 33-month sample included 151,443 isolated CABG admissions from 1,195 hospitals. Additional results tables for the 2009 development sample are presented at the end of Section 4. The results are similar when using the January 2009-September 2011 sample. The flow chart depicting eligible admissions and exclusions is presented in Figure 2.

Table 6 conveys the risk factor frequencies, parameter estimates, standard errors, odds ratios (OR), and 95% confidence intervals for the model risk factors in the development sample.

Figure 2. Cohort Flow Chart for January 2009-September 2011 Sample



*Categories are not mutually exclusive

3.1.2 Hierarchical Logistic Regression Model

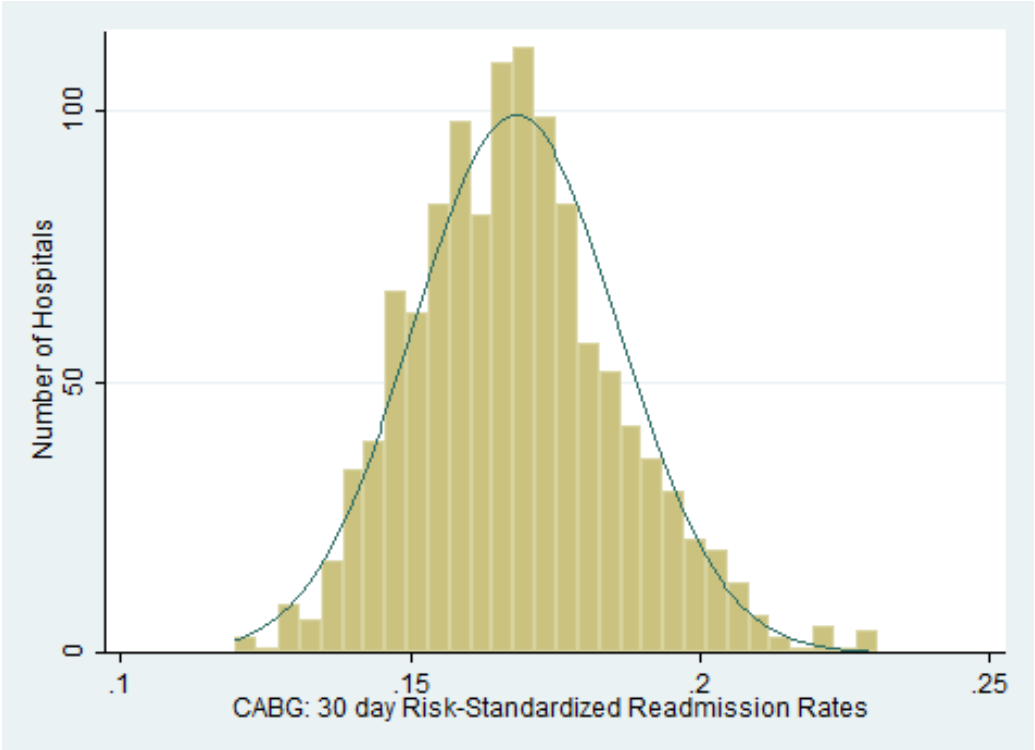
Table 7 conveys the adjusted odds ratios for the development sample calculated via the hierarchical logistic regression model. The odds ratios are nearly identical to those calculated using the logistic regression model (Table 6). The results are similar when using the January 1, 2009-September 30, 2011 sample.

3.1.3 Unadjusted and Adjusted Readmission Rates

The unadjusted mean hospital readmission rate is 17.7% and ranges from 0%-100% with a median of 16.8% (25th and 75th percentiles are 13.1% and 20.8%, respectively). Figure 3 displays the hospital risk-standardized rates for the January 2009-September 2011 sample calculated via the hierarchical logistic regression model. The rates have a mean of 16.8%, and range from 12.0% - 23.1%. The median risk-standardized rate is 16.8% (25th and 75th percentiles are 15.6% and 17.9%, respectively).

In the hierarchical model, each hospital has its own intercept (random intercept model), which is used to measure the differences in readmission between hospitals while adjusting for case-mix (patient risk factors).

Figure 3. Distribution of Hospital-Level Risk-Standardized Readmission Rates (January 2009-September 2011 Sample; n= 150,900 Admissions from 1,195 Hospitals)



3.2 Measure Testing

3.2.1 Reliability of Data Elements

We used data from 2008, 2009, and 2010 to assess the rates of the data elements over time: 62,811 admissions from 1,163 hospitals in 2008, 58,676 admissions from 1,160 hospitals in 2009 and 54,404 admissions from 1,164 hospitals in 2010. Table 8 conveys the model risk factor frequencies in these samples. Although the number of isolated CABG procedures appears to be declining over time, the rates of risk factor frequency changed very little across the three years. The percentage of patients with a renal failure (CC 131) increased from 11.8% in 2008 to 14.1% in 2010. The percentage of patients diagnosed with other endocrine/metabolic/nutritional disorders (CC 24) increased from 83.9% in 2008 to 85.7% in 2010. The percentage of patients diagnosed with specified heart arrhythmias (CC 92-93) increased from 25.7% in 2008 to 27.2% in 2010. There were no other notable changes.

Table 9 shows the adjusted odds ratios for the logistic regression (patient-level) model variables and readmission in the 2008, 2009 and 2010 data samples. There are no notable differences in the odds ratios across the samples. The consistency in the rates of the risk-adjustment variables and in their relationship to the outcome across the three years of data demonstrates the reliability of the measure data elements used in risk adjustment.

3.2.2 Reliability of Model and Measure Results

To test the reliability of the model, we assessed model performance (Table 10) and the effect of the risk-adjustment variables on the outcome across the years of data (Table 9). Model performance is similar across years with strong model discrimination and fit. Predictive ability is also similar in all three samples. The C-statistic (area under the receiver operator curve) is nearly identical for development and validation samples; 0.62 when applied to the development sample and 0.63 when applied to the validation samples (Table 10). No notable differences were observed in risk factor ORs across the years of data.

In terms of measure results reliability, there were 175,891 admissions in the combined three-year sample, with 87,872 admissions in one of randomly selected sample and 88,019 admissions in the other randomly selected sample. The intra class correlation (ICC) between the two RSRRs for each hospital was 0.331, which according to the conventional interpretation is “Fair.”[55] The intra-class correlation coefficient is based on a split sample of 3 years of data, resulting in a volume of patients in each sample equivalent to only 1.5 years of data, whereas, if publicly reported, the measure is likely to be reported with a full three years of data. Based on our experiences with similar measures using split samples from 4 years of data (and resulting sample volumes equivalent to 2 years), the intra-class correlation coefficient would be higher and likely in the “Moderate” range.

3.2.3 Validity

CMS has validated the six NQF-endorsed measures currently used in public reporting (mortality and readmission measures for AMI, heart failure, and pneumonia). They validated the claims-based measures by building comparable models using medical record data for risk adjustment for heart failure patients (National Heart Failure data), AMI patients (Cooperative Cardiovascular Project data), and pneumonia patients (National Pneumonia Project dataset). When the medical record-based models were applied to the corresponding patient populations for these medical conditions, the hospital risk-standardized rates estimated using the claims-based risk adjustment models had a high level of agreement with the results based on the medical record model, thus supporting the use of the claims-based models for public reporting.[42-44,57,58]

In regard to measure face validity, 14 TEP members provided the following responses: Moderately Disagreed (2), Somewhat Disagreed (2), Somewhat Agreed (4), Moderately Agreed (5), and Strongly Agreed (1). Hence, 71% of TEP members agreed (43% moderately or strongly agreed) that the measure will provide an accurate reflection of quality.

Results of the readmission measure validation study using the national STS Adult Cardiac Surgery database demonstrated the following:

3.2.3.1 Validation of the administrative isolated CABG cohort

There were no changes to the CABG readmission measure cohort detailed in this report based upon the results of cohort validation using the companion CABG readmission measure and the national STS Adult Cardiac Surgery database.

The cohort validation demonstrated an overall agreement rate of 96.5% (200,475 of 207,656 matched patients were designated as isolated or non-isolated CABG patients by both measure cohort definitions). Among the 4,720 patients identified as isolated CABG by the claims measure but not by the registry measure, 37% were due to expected causes (i.e., the fact that the registry measure excludes all MAZE procedures while the claims measure excluded only open MAZE procedures).The remaining 2,976 patients identified as isolated CABG by the claims measure but not by the registry measure and the 2,461 patients identified as isolated CABG patients by the registry measure but not by the claims measure were due to inconsistencies that could not clearly be attributed to inaccuracies in the claims-based definition of the isolated CABG cohort. For example, among a proportion of patients, the patient had a code for an aortic valve replacement but the registry data did not show that this procedure was performed. Alternatively, the registry data indicated an aortic valve procedure was performed but there was no corresponding claims code for this procedure. Such

inconsistencies could be due to coding errors in the claims data, abstraction errors in the registry data, or may be due to inconsistencies in the probabilistic matching process used to create a matched set of patients for the validation. An additional reason that patients might be identified as isolated CABG patients by the registry measure but not by the claims measure is that the CABG procedure occurred on a separate day within the index admission than the valve or other procedure that excluded the patient from the claims-based isolated CABG cohort. Only two of 286 such discrepant aortic valve procedures could be attributed to procedures occurring on different days during the index admission. Among the discrepant patients, the non-CABG-related ICD-9 procedure codes represented only non-specific ancillary procedures to CABG surgery, such as code 39.61 "Extracorporeal circulation auxiliary to open heart surgery" and could not be used to further increase the precision of the administrative claims-based isolated CABG cohort definition. The level of agreement for this measure was higher than prior studies comparing administrative definitions of isolated CABG to registry data.[59] Further details of the cohort validation are provided in Appendix E.

3.2.3.2 Validation of the administrative risk adjustment model

The comparison of the risk adjustment performance of the administrative and clinical models in a matched set of patients produced an overall agreement of 97% (807 of 829 hospitals had concurrent performance categorization) and the correlation was between 0.92 and 0.96, depending upon the statistic used. Both measures displayed similar distributions in hospital RSRRs following CABG and the median hospital RSRR differed by only 0.1% point (16.7% and 16.8% for registry-based and claims-based measures, respectively). No hospitals were rated as performing Worse than expected by the claims-based measure and Better than expected by the registry-based measure (or vice versa). Among 14 hospitals rated Better than expected by the registry-based measure, 8 (57%) were rated As expected by the claims-based measure and among 9 hospitals rated Better than expected by the claims-based measure, 3 (33%) were rated As expected by the registry-based measure. Among 14 hospitals rated Worse by the registry model, 6 (42.9%) were rated As expected by the claims model and among 13 programs rated Worse by the claims model, 5 (38.5%) were rated As expected by the registry model. Overall 63 of 829 hospitals (7.6%) had greater than a 1% absolute difference in RSRR calculated by the claims-based versus registry-based measures. However, of these 63, only 8 hospitals actually changed performance category. Further details of the risk adjustment validation are provided in Appendix E.

3.2.3.3 "Real world" comparison of the administrative claims-based and clinical registry-based readmission measures

The comparison of the results of the administrative CABG readmission measure in the administrative isolated CABG measure cohort and the STS clinical data-based CABG readmission measure in the STS isolated CABG cohort produced a correlation between 0.89 and 0.90, depending upon the statistic used. There was broad, nearly identical overlap in the distribution of hospital RSRRs between the measures with identical median RSRRs (16.8% for both measures). Overall agreement between measures was 95.1% (797 out of 838 hospitals received identical performance categorization by both measures). No hospitals were rated as performing Worse than expected by the Claims-based measure and Better than expected by the Registry-based measure (or vice versa). Of the 838 hospitals in the "real world" comparison measure cohorts from STS-participating hospitals with at least a 90% match rate, 188 (22.4%) had >1% absolute difference in RSRR by the two measures, and only 22 (2.6%) had >2% absolute difference in RSRR. Of 59 total outliers identified by one or both models, 41 were discordant. Among 25 hospitals rated Better than Expected by the registry-based measure, 15 (60%) were rated As Expected by the claims-based measure. Among 11 hospitals rated Better than Expected by the claims-based measure, 1 (9%) was rated As Expected by the registry-based measure. Among 27 hospitals rated Worse than Expected by the registry-based measure, 19 (70.4%) were rated As expected by the claims-based measure. Among 14 programs rated Worse than Expected by the claims-based measure, 6 (42.9%) were rated As Expected by the registry-based measure.

There is no accepted "gold standard" for this comparison. Differences in performance categorization between the two measures in this analysis may be due to differences in cohort definition at the hospital and/or patient level, outcome differences, and/or differences in the risk adjustment models. The registry measure excluded 351 hospitals with approximately 26,000 isolated CABG patients that either do not participate in the STS registry or had insufficient data linkage between claims and registry data. The registry-based measure does not exclude planned readmissions and, although they are rare following CABG surgery, this is another reason for discordance. In the validation of the administrative risk adjustment model, differences in risk-adjustment alone led to differences in performance categorization.

3.2.4 Testing of Measure in All-Payer Data

Using all-payer data, the C statistic for the CABG readmission model in FFS patients aged 65 years or over was 0.65 and in 18-64 year old all-payer patients was 0.67. When the model was applied to all patients aged 18 years and older the overall discrimination was good (C statistic=0.66). Moreover, the distribution of Pearson residuals was comparable across the patient subgroups. When comparing the model with and without interaction terms: (a) the reclassification

analysis using models with and without age-risk factor interaction terms demonstrated 85%-95% overall agreement in patient risk categorization across age (18-64 versus 65 or over) and insurance (all-payer versus FFS) subgroups; (b) the C statistic was identical (0.66 in both models); and (c) hospital-level risk-standardized rates were highly correlated (ICC=0.998). Thus, the inclusion of interactions did not substantively affect either patient-level model performance or hospital-level results. Based on the results of the all-payer testing (detailed in Appendix F), we conclude that the CABG readmission measure performs well when applied to all-payer data (all patients aged 18 years or over). Although there was one statistically significant age-by-risk-factor interaction terms (Older and Pneumonia), the inclusion of the interactions did not substantively affect either patient-level model performance or hospital-level results. Therefore, the measure can be applied to all-payer data for patients 18 years and older. For simplicity and pending further study, the only change currently recommended to the measure specifications to allow application to an all-payer, 18 years or over population is transformation of the Age variable from “Age – 65” to a fully continuous age variable.

4. MAIN FINDINGS / SUMMARY

This proposed 30-day all-cause readmission measure for CABG recipients will inform healthcare providers about opportunities to improve care, and strengthen incentives for quality improvement, particularly for care at the time of transitions (e.g., discharge to home or a skilled nursing facility) among Medicare FFS patients 65 years and over as well as among adults 18 years and over in all-payer data. Improvements in inpatient care and care transitions for this common, costly condition are likely to reduce costly readmissions. We found significant differences in risk-standardized readmission rates across hospitals following isolated CABG surgery, suggesting that there are differences in quality of care. The proposed risk-standardized model is consistent with the consensus standards for publicly reported outcomes measures, and can be implemented using available data. This measure was developed with input from experts with clinical and methodological expertise relevant to cardiothoracic surgery quality measurement. The cohort for inclusion in the measure is appropriately defined, consisting of patients undergoing isolated CABG procedures and excluding those procedures that may be asymmetrically performed across hospitals and constitute greatly increased risk of readmission. We excluded covariates that are not appropriate for inclusion in a quality measure, such as race, socioeconomic status, and hospital-level factors (e.g., hospital bed size and case volume). The hierarchical modeling accounts for hospital case-mix, the clustering of patients within hospitals, and differences in sample size across hospitals. We tested the applicability of the model to an all-payer dataset and/or patients less than 65 years of age. The model is reliable and valid. The validation of the claims-based risk adjustment with registry data-based risk-adjustment in a matched cohort of patients showed that registry and claims-based measures produce similar results, although performance category classification differed for some hospitals. There is a range of views in our TEP and working group about the relative importance of these differences. The advantages and disadvantages of implementing this claims-based model and/or the companion registry-based model merit full consideration, informed by this collaborative work.

Table 6. Adjusted OR* for Model Risk Factors and Readmission in Development Samples (Logistic Regression Model)**

	2009 Development Sample (n=58,676 admissions at 1,160 hospitals)				
Variable	**Frequency (%)**	**Estimate**	**SE**	**OR**	**95% CI**
Demographics					
Age-65 (Continuous)		0.03	0.00	1.03	(1.02-1.03)
Male	68.3	-0.25	0.02	0.78	(0.75-0.82)
Comorbidities					
History of Prior CABG or Valve Surgery	5.5	0.08	0.05	1.09	(0.99-1.19)
Cardiogenic Shock (ICD-9 Code 785.51)	3.5	0.25	0.06	1.28	(1.15-1.42)
COPD (CC108)	23.5	0.24	0.03	1.28	(1.21-1.34)
Renal Failure (CC131)	13.2	0.26	0.03	1.30	(1.22-1.39)
Diabetes and DM Complications(CC 15-20, 119, 120)	45.6	0.14	0.02	1.15	(1.10-1.20)
Obesity/Disorders of Thyroid, Cholesterol, Lipids (CC 24)	84.5	-0.19	0.03	0.83	(0.78-0.88)
Congestive Heart Failure (CC 80)	19.5	0.16	0.03	1.18	(1.11-1.24)
Arrhythmias (CC 92-93)	26.9	0.14	0.03	1.15	(1.10-1.21)
Other Lung Disorders (CC 115)	33.7	0.11	0.02	1.12	(1.07-1.17)
Major Psychiatric Disorders (CC 54-56)	3.2	0.26	0.06	1.30	(1.16-1.46)
Vascular or Circulatory Disease (CC 104-106)	32.9	0.11	0.02	1.12	(1.07-1.17)
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	14.9	0.16	0.03	1.18	(1.11-1.25)
Pneumonia (CC 111-113)	12.1	0.14	0.03	1.15	(1.08-1.23)
Cerebrovascular Disease (CC 97-99, 103)	27.0	-0.09	0.03	0.92	(0.87-0.96)
Polyneuropathy (CC 71)	6.6	0.17	0.04	1.19	(1.09-1.29)
Protein-Calorie Malnutrition (CC 21)	3.0	0.19	0.06	1.22	(1.09-1.36)
Severe Hematological Disorders (CC 44)	1.1	0.37	0.09	1.45	(1.21-1.73)
Fibrosis Of Lung And Other Chronic Lung Disorders (CC 109)	4.6	0.15	0.05	1.17	(1.06-1.28)
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	3.1	0.23	0.06	1.25	(1.12-1.40)
End-Stage Renal Disease Or Dialysis (CC 130)	1.2	0.26	0.09	1.30	(1.09-1.54)
Hemiplegia, Paraplegia, Paralysis, Functional Disability (CC 67-69, 100-102)	2.7	0.18	0.06	1.20	(1.06-1.36)
Stroke (CC 95-96)	4.7	0.14	0.05	1.15	(1.04-1.27)
Dementia or Senility (CC 49-50)	4.9	0.13	0.05	1.13	(1.03-1.25)
Cancer (CC 7-12)	19.4	-0.00	0.03	1.00	(0.94-1.05)

SE = Standard Error; OR = Odds Ratio; CI = Confidence Interval

* Each variable in the model is adjusted for the effects of the others.
** The results are similar when using the January 1, 2009-September 30, 2011 sample.

Table 7. Adjusted OR* for Model Risk Factors and Readmission in Development Sample (Hierarchical Logistic Regression Model)**

	2009 Development Sample (n=58,676 admissions at 1,160 hospitals)				
Variable	**Frequency (%)**	**Estimate**	**SE**	**OR**	**95% CI**
Demographics					
Age-65 (Continuous)		0.03	0.00	1.03	(1.02-1.03)
Male	68.3	-0.25	0.02	0.78	(0.75-0.82)
Comorbidities					
History of Prior CABG or Valve Surgery	5.5	0.08	0.05	1.09	(0.99-1.19)
Cardiogenic Shock (ICD-9 Code 785.51)	3.5	0.25	0.06	1.29	(1.15-1.43)
COPD (CC108)	23.5	0.24	0.03	1.27	(1.21-1.34)
Renal Failure (CC131)	13.2	0.26	0.03	1.30	(1.22-1.39)
Diabetes and DM Complications(CC 15-20, 119, 120)	45.6	0.14	0.02	1.15	(1.09-1.20)
Obesity/Disorders of Thyroid, Cholesterol, Lipids (CC 24)	84.5	-0.19	0.03	0.83	(0.78-0.88)
Congestive Heart Failure (CC 80)	19.5	0.16	0.03	1.17	(1.11-1.24)
Arrhythmias (CC 92-93)	26.9	0.14	0.03	1.15	(1.09-1.21)
Other Lung Disorders (CC 115)	33.7	0.11	0.02	1.12	(1.07-1.18)
Major Psychiatric Disorders (CC 54-56)	3.2	0.26	0.06	1.30	(1.16-1.45)
Vascular or Circulatory Disease (CC 104-106)	32.9	0.11	0.02	1.12	(1.06-1.17)
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	14.9	0.16	0.03	1.18	(1.11-1.25)
Pneumonia (CC 111-113)	12.1	0.14	0.03	1.15	(1.08-1.23)
Cerebrovascular Disease (CC 97-99, 103)	27.0	-0.09	0.03	0.92	(0.87-0.96)
Polyneuropathy (CC 71)	6.6	0.17	0.04	1.19	(1.10-1.29)
Protein-Calorie Malnutrition (CC 21)	3.0	0.20	0.06	1.22	(1.09-1.36)
Severe Hematological Disorders (CC 44)	1.1	0.37	0.09	1.44	(1.21-1.73)
Fibrosis Of Lung And Other Chronic Lung Disorders (CC 109)	4.6	0.15	0.05	1.16	(1.06-1.28)
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	3.1	0.22	0.06	1.25	(1.11-1.39)
End-Stage Renal Disease Or Dialysis (CC 130)	1.2	0.26	0.09	1.30	(1.09-1.54)
Hemiplegia, Paraplegia, Paralysis, Functional Disability (CC 67-69, 100-102)	2.7	0.18	0.06	1.20	(1.06-1.35)
Stroke (CC 95-96)	4.7	0.14	0.05	1.15	(1.04-1.27)
Dementia or Senility (CC 49-50)	4.9	0.12	0.05	1.13	(1.03-1.24)
Cancer (CC 7-12)	19.4	0.00	0.03	1.00	(0.94-1.05)

* Each variable in the model is adjusted for the effects of the others.
** The results are similar when using the January 1, 2009-September 30, 2011 sample.

Table 8. Risk Factor Frequency (%) in Data Years*

Description	2008 n= 62,811	2009 n= 58,676	2010 n=54,404
Demographics			
Age-65 (Continuous)	-	-	-
Male	68.0	68.3	69.5
Comorbidities			
History of Prior CABG or Valve Surgery	5.5	5.5	5.3
Cardiogenic Shock (ICD-9 Code 785.51)	3.2	3.5	4.2
COPD (CC108)	23.8	23.5	23.6
Renal Failure (CC131)	11.8	13.2	14.1
Diabetes and DM Complications(CC 15-20, 119, 120)	44.9	45.6	46.1
Obesity/Disorders of Thyroid, Cholesterol, Lipids (CC 24)	83.9	84.5	85.7
Congestive Heart Failure (CC 80)	19.0	19.5	19.2
Arrhythmias (CC 92-93)	25.7	26.9	27.2
Other Lung Disorders (CC 115)	33.5	33.7	33.1
Major Psychiatric Disorders (CC 54-56)	3.0	3.2	3.3
Vascular or Circulatory Disease (CC 104-106)	32.6	32.9	33.2
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	14.4	14.9	15.6
Pneumonia (CC 111-113)	12.1	12.1	11.8
Cerebrovascular Disease (CC 97-99, 103)	26.4	27.0	27.6
Polyneuropathy (CC 71)	6.6	6.6	6.9
Protein-Calorie Malnutrition (CC 21)	2.5	3.0	3.2
Severe Hematological Disorders (CC 44)	0.9	1.1	1.0
Fibrosis Of Lung And Other Chronic Lung Disorders (CC 109)	4.9	4.6	4.6
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	3.0	3.1	3.2
End-Stage Renal Disease Or Dialysis (CC 130)	1.2	1.2	1.4
Hemiplegia, Paraplegia, Paralysis, Functional Disability (CC 67-69, 100-102)	2.9	2.7	2.8
Stroke (CC 95-96)	4.9	4.7	4.7
Dementia or Senility (CC 49-50)	4.8	4.9	4.9
Cancer (CC 7-12)	20.0	19.4	19.2

* The results are similar when using the January 1, 2009-September 30, 2011 sample.

Table 9. Temporal Trends in Adjusted OR* for Model Risk Factors and Readmission in Development and Validation Samples (Logistic Regression Model)**

Description	2008 n= 62,811		2009 n= 58,676		2010 n=54,404	
	OR	95% CI	OR	95% CI	OR	95% CI
Demographics						
Age-65 (Continuous)	1.03	(1.02-1.03)	1.03	(1.02-1.03)	1.03	(1.02-1.03)
Male	0.75	(0.72-0.78)	0.78	(0.75-0.82)	0.80	(0.76-0.84)
Comorbidities						
History of Prior CABG or Valve Surgery	0.97	(0.89-1.07)	1.09	(0.99-1.19)	1.02	(0.92-1.13)
Cardiogenic Shock (ICD-9 Code 785.51)	1.42	(1.27-1.58)	1.28	(1.15-1.42)	1.33	(1.20-1.48)
COPD (CC108)	1.20	(1.14-1.26)	1.28	(1.21-1.34)	1.27	(1.20-1.34)
Renal Failure (CC131)	1.35	(1.26-1.44)	1.30	(1.22-1.39)	1.31	(1.23-1.40)
Diabetes and DM Complications(CC 15-20, 119, 120)	1.14	(1.09-1.19)	1.15	(1.10-1.20)	1.18	(1.13-1.24)
Obesity/Disorders of Thyroid, Cholesterol, Lipids (CC 24)	0.87	(0.83-0.93)	0.83	(0.78-0.88)	0.86	(0.80-0.92)
Congestive Heart Failure (CC 80)	1.24	(1.17-1.31)	1.18	(1.11-1.24)	1.23	(1.16-1.31)
Arrhythmias (CC 92-93)	1.14	(1.08-1.19)	1.15	(1.10-1.21)	1.10	(1.05-1.16)
Other Lung Disorders (CC 115)	1.11	(1.06-1.16)	1.12	(1.07-1.17)	1.03	(0.98-1.08)
Major Psychiatric Disorders (CC 54-56)	1.18	(1.05-1.32)	1.30	(1.16-1.46)	1.22	(1.09-1.38)
Vascular or Circulatory Disease (CC 104-106)	1.08	(1.03-1.13)	1.12	(1.07-1.17)	1.11	(1.06-1.17)
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	1.17	(1.10-1.24)	1.18	(1.11-1.25)	1.25	(1.17-1.33)
Pneumonia (CC 111-113)	1.23	(1.15-1.31)	1.15	(1.08-1.23)	1.22	(1.14-1.31)
Cerebrovascular Disease (CC 97-99, 103)	0.94	(0.90-0.99)	0.92	(0.87-0.96)	0.97	(0.92-1.03)
Polyneuropathy (CC 71)	1.20	(1.11-1.30)	1.19	(1.09-1.29)	1.17	(1.07-1.27)
Protein-Calorie Malnutrition (CC 21)	1.19	(1.05-1.34)	1.22	(1.09-1.36)	1.30	(1.16-1.45)
Severe Hematological Disorders (CC 44)	1.37	(1.13-1.66)	1.45	(1.21-1.73)	1.20	(0.98-1.47)
Fibrosis Of Lung And Other Chronic Lung Disorders (CC 109)	0.95	(0.86-1.04)	1.17	(1.06-1.28)	1.13	(1.02-1.25)
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	1.33	(1.20-1.49)	1.25	(1.12-1.40)	1.35	(1.20-1.51)
End-Stage Renal Disease Or Dialysis (CC 130)	1.48	(1.25-1.74)	1.30	(1.09-1.54)	1.30	(1.10-1.54)
Hemiplegia, Paraplegia, Paralysis, Functional Disability (CC 67-69, 100-102)	1.07	(0.94-1.20)	1.20	(1.06-1.36)	1.10	(0.96-1.25)
Stroke (CC 95-96)	1.14	(1.03-1.25)	1.15	(1.04-1.27)	1.00	(0.90-1.12)
Dementia or Senility (CC 49-50)	1.19	(1.09-1.30)	1.13	(1.03-1.25)	1.17	(1.06-1.29)
Cancer (CC 7-12)	1.03	(0.98-1.09)	1.00	(0.94-1.05)	0.99	(0.93-1.05)

* Each variable in the model is adjusted for the effects of the others.

** The results are similar when using the January 1, 2009-September 30, 2011 sample.

Table 10. Model Performance for Development and Validation Samples (Logistic Regression Model)*

Indices	Development Sample	Validation Sample	
Year	**2009**	**2008**	**2010**
Number of Admissions	58,676	62,811	54,404
Number of Hospitals	1,160	1,163	1,164
Mean Risk-Standardized Readmission Rate % (SD)	17.0 (1.4)	17.0 (1.2)	16.6 (1.4)
Calibration ($\gamma 0$, $\gamma 1$)[§]	(0, 1)	(0.02,1.01)	(-0.03,1.00)
Discrimination -Predictive Ability (lowest decile %, highest decile %)	(8.7-29.8)	(8.8-30.5)	(8.4-30.3)
Discrimination – Area Under Receiver Operator Curve (C statistic) [**]	0.62	0.63	0.63
Residuals Lack of Fit (Pearson Residual Fall %)			
<-2	0.0	0.0	0.0
[-2, 0)	82.95	82.92	83.39
[0, 2)	6.23	6.19	5.64
[2+	10.83	10.89	10.96
Model Wald χ^2 [Number of Covariates] (p-value)	1557 [26] (<0.0001)	1734 [26] (<0.0001)	1525 [26] (<0.0001)
Between-Hospital Variance (τ) (Standard Error)	0.04 (0.01)	0.03 (0.01)	0.04 (0.01)

***** The results are similar when using the January 1, 2009-September 30, 2011 sample.

[§] Over-Fitting Indices (γ_0, γ_1) provide evidence of over-fitting and require several steps to calculate. Let *b* denote the *estimated vector* of regression coefficients. *Predicted Probabilities* ($\hat{p}$) = 1/(1+exp{-Xb}), and *Z* = *Xb* (e.g., the linear predictor that is a scalar value for everyone). A new logistic regression model that includes only an intercept and a slope by regressing the logits on Z is fitted in the validation sample; e.g., Logit (P(Y=1|Z)) = $\gamma_0 + \gamma_1 Z$. Estimated values of γ_0 far from 0 and estimated values of γ_1 far from 1 provide evidence of over-fitting.

[**] Calculated using logistic regression model

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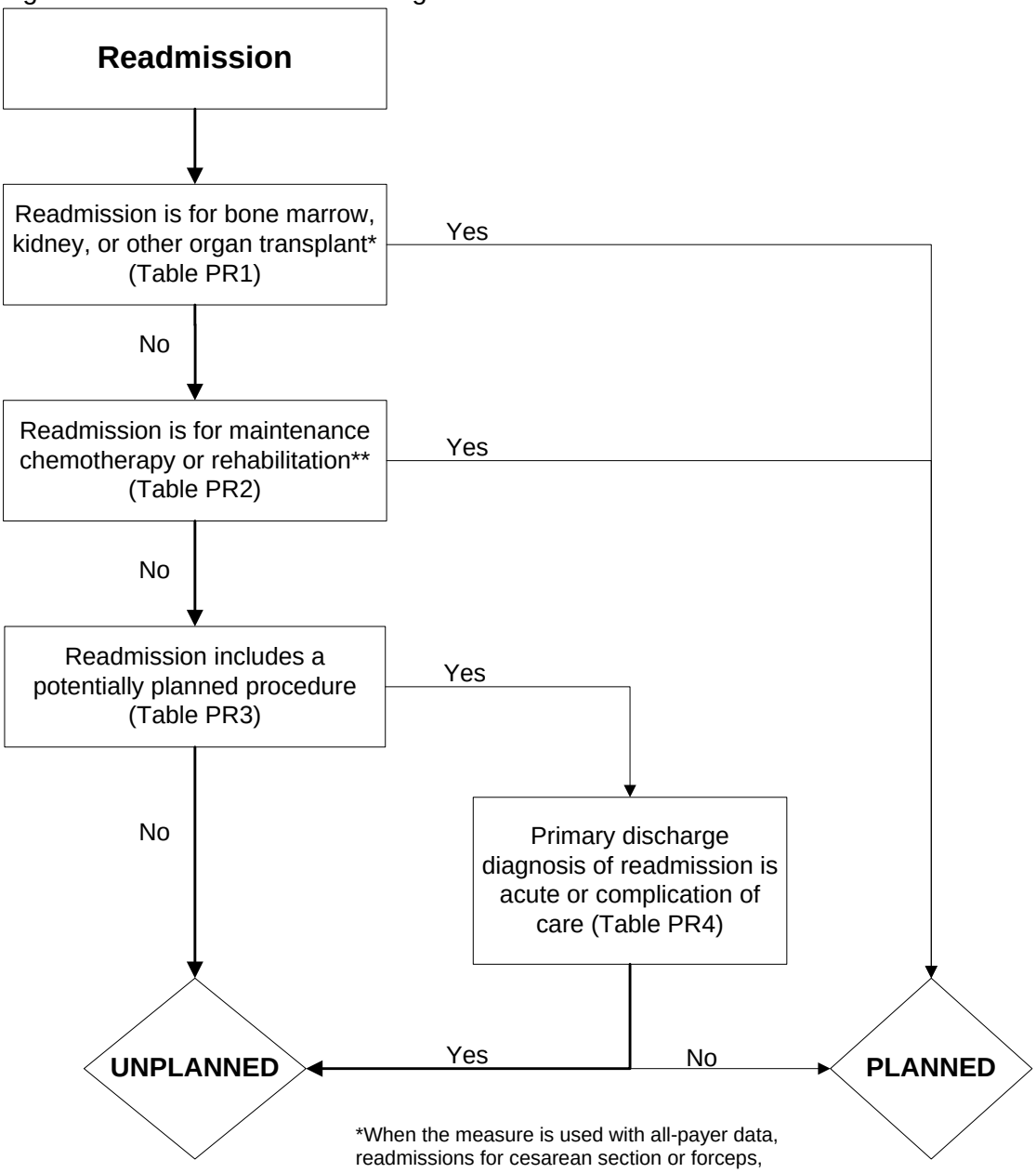
6. APPENDIX

Appendix A: CABG Planned Readmission Algorithm (Version 3.0)

Figure 4. Planned Readmission Algorithm Version 3.0 Flow Chart



*When the measure is used with all-payer data, readmissions for cesarean section or forceps, vacuum, or breech delivery are considered planned

**When the measure is used with all-payer data, readmissions for forceps or normal delivery are considered planned

Table PR1: Procedure Categories that are Always Planned Regardless of Diagnosis (Version 3.0)

Procedure CCS	Description
64	Bone marrow transplant
105	Kidney transplant
134	Cesarean section*
135	Forceps; vacuum; and breech delivery*
176	Other organ transplantation

*CCS to be included only in all-payer settings, not intended for inclusion in CMS' claims-based readmission measures for Medicare fee-for-service beneficiaries aged 65+ years

Table PR2: Diagnoses that are Always Planned Regardless of Procedure (Version 3.0)

Diagnosis CCS	Description
45	Maintenance chemotherapy
194	Forceps delivery*
196	Normal pregnancy and/or delivery*
254	Rehabilitation

*CCS to be included only in all-payer settings, not intended for inclusion in CMS' claims-based readmission measures for Medicare fee-for-service beneficiaries aged 65+ years

Table PR3: Complete List of Potentially Planned Procedures (Version 3.0)

Procedure CCS	Description
3	Laminectomy; excision intervertebral disc
5	Insertion of catheter or spinal stimulator and injection into spinal
9	Other OR therapeutic nervous system procedures
10	Thyroidectomy; partial or complete
12	Other therapeutic endocrine procedures
33	Other OR therapeutic procedures on nose; mouth and pharynx
36	Lobectomy or pneumonectomy
38	Other diagnostic procedures on lung and bronchus
40	Other diagnostic procedures of respiratory tract and mediastinum
51	Endarterectomy; vessel of head and neck
52	Aortic resection; replacement or anastomosis
53	Varicose vein stripping; lower limb
59	Other OR procedures on vessels of head and neck
62	Other diagnostic cardiovascular procedures
66	Procedures on spleen
67	Other therapeutic procedures; hemic and lymphatic system
74	Gastrectomy; partial and total
78	Colorectal resection
85	Inguinal and femoral hernia repair
86	Other hernia repair

99	Other OR gastrointestinal therapeutic procedures
104	Nephrectomy; partial or complete
106	Genitourinary incontinence procedures
107	Extracorporeal lithotripsy; urinary
109	Procedures on the urethra
112	Other OR therapeutic procedures of urinary tract
113	Transurethral resection of prostate (TURP)
114	Open prostatectomy
119	Oophorectomy; unilateral and bilateral
120	Other operations on ovary
124	Hysterectomy; abdominal and vaginal
129	Repair of cystocele and rectocele; obliteration of vaginal vault
132	Other OR therapeutic procedures; female organs
152	Arthroplasty knee
153	Hip replacement; total and partial
154	Arthroplasty other than hip or knee
158	Spinal fusion
166	Lumpectomy; quadrantectomy of breast
167	Mastectomy
170	Excision of skin lesion
172	Skin graft
ICD-9 Codes	**Description**
30.1, 30.29, 30.3, 30.4, 31.74, 34.6	Laryngectomy, revision of tracheostomy, scarification of pleura (from Proc CCS 42- Other OR Rx procedures on respiratory system and mediastinum)
55.03, 55.04	Percutaneous nephrostomy with and without fragmentation (from Proc CCS 103- Nephrotomy and nephrostomy)
94.26, 94.27	Electroshock therapy (from Proc CCS 218- Psychological and psychiatric evaluation and therapy)

Table PR4: Acute Diagnosis Groups that Disqualify a Readmission from Being Considered Planned (Version 3.0)

Diagnosis CCS	Description
1	Tuberculosis
2	Septicemia (except in labor)
3	Bacterial infection; unspecified site
4	Mycoses
5	HIV infection
7	Viral infection
8	Other infections; including parasitic
9	Sexually transmitted infections (not HIV or hepatitis)
54	Gout and other crystal arthropathies
55	Fluid and electrolyte disorders
60	Acute posthemorrhagic anemia

61	Sickle cell anemia
63	Diseases of white blood cells
76	Meningitis (except that caused by tuberculosis or sexually transmitted disease)
77	Encephalitis (except that caused by tuberculosis or sexually transmitted disease)
78	Other CNS infection and poliomyelitis
82	Paralysis
83	Epilepsy; convulsions
84	Headache; including migraine
85	Coma; stupor; and brain damage
87	Retinal detachments; defects; vascular occlusion; and retinopathy
89	Blindness and vision defects
90	Inflammation; infection of eye (except that caused by tuberculosis or sexually transmitted disease)
91	Other eye disorders
92	Otitis media and related conditions
93	Conditions associated with dizziness or vertigo
99	Hypertension with complications
100	Acute myocardial infarction (with the exception of ICD-9 codes 410.x2)
102	Nonspecific chest pain
104	Other and ill-defined heart disease
107	Cardiac arrest and ventricular fibrillation
109	Acute cerebrovascular disease
112	Transient cerebral ischemia
116	Aortic and peripheral arterial embolism or thrombosis
118	Phlebitis; thrombophlebitis and thromboembolism
120	Hemorrhoids
122	Pneumonia (except that caused by TB or sexually transmitted disease)
123	Influenza
124	Acute and chronic tonsillitis
125	Acute bronchitis
126	Other upper respiratory infections
127	Chronic obstructive pulmonary disease and bronchiectasis
128	Asthma
129	Aspiration pneumonitis; food/vomitus
130	Pleurisy; pneumothorax; pulmonary collapse
131	Respiratory failure; insufficiency; arrest (adult)
135	Intestinal infection
137	Diseases of mouth; excluding dental
139	Gastroduodenal ulcer (except hemorrhage)
140	Gastritis and duodenitis
142	Appendicitis and other appendiceal conditions
145	Intestinal obstruction without hernia
146	Diverticulosis and diverticulitis
148	Peritonitis and intestinal abscess

153	Gastrointestinal hemorrhage
154	Noninfectious gastroenteritis
157	Acute and unspecified renal failure
159	Urinary tract infections
165	Inflammatory conditions of male genital organs
168	Inflammatory diseases of female pelvic organs
172	Ovarian cyst
197	Skin and subcutaneous tissue infections
198	Other inflammatory condition of skin
225	Joint disorders and dislocations; trauma-related
226	Fracture of neck of femur (hip)
227	Spinal cord injury
228	Skull and face fractures
229	Fracture of upper limb
230	Fracture of lower limb
232	Sprains and strains
233	Intracranial injury
234	Crushing injury or internal injury
235	Open wounds of head; neck; and trunk
237	Complication of device; implant or graft
238	Complications of surgical procedures or medical care
239	Superficial injury; contusion
240	Burns
241	Poisoning by psychotropic agents
242	Poisoning by other medications and drugs
243	Poisoning by nonmedicinal substances
244	Other injuries and conditions due to external causes
245	Syncope
246	Fever of unknown origin
247	Lymphadenitis
249	Shock
250	Nausea and vomiting
251	Abdominal pain
252	Malaise and fatigue
253	Allergic reactions
259	Residual codes; unclassified
650	Adjustment disorders
651	Anxiety disorders
652	Attention-deficit, conduct, and disruptive behavior disorders
653	Delirium, dementia, and amnestic and other cognitive disorders
656	Impulse control disorders, NEC
658	Personality disorders
660	Alcohol-related disorders
661	Substance-related disorders
662	Suicide and intentional self-inflicted injury
663	Screening and history of mental health and substance abuse codes

670	Miscellaneous disorders
ICD-9 codes	**Description**
Acute ICD-9 codes within Dx CCS 97: Peri-; endo-; and myocarditis; cardiomyopathy	
3282	Diphtheritic myocarditis
3640	Meningococcal carditis nos
3641	Meningococcal pericarditis
3642	Meningococcal endocarditis
3643	Meningococcal myocarditis
7420	Coxsackie carditis nos
7421	Coxsackie pericarditis
7422	Coxsackie endocarditis
7423	Coxsackie myocarditis
11281	Candidal endocarditis
11503	Histoplasma capsulatum pericarditis
11504	Histoplasma capsulatum endocarditis
11513	Histoplasma duboisii pericarditis
11514	Histoplasma duboisii endocarditis
11593	Histoplasmosis pericarditis
11594	Histoplasmosis endocarditis
1303	Toxoplasma myocarditis
3910	Acute rheumatic pericarditis
3911	Acute rheumatic endocarditis
3912	Acute rheumatic myocarditis
3918	Acute rheumatic heart disease nec
3919	Acute rheumatic heart disease nos
3920	Rheumatic chorea w heart involvement
3980	Rheumatic myocarditis
39890	Rheumatic heart disease nos
39899	Rheumatic heart disease nec
4200	Acute pericarditis in other disease
42090	Acute pericarditis nos
42091	Acute idiopath pericarditis
42099	Acute pericarditis nec
4210	Acute/subacute bacterial endocarditis
4211	Acute endocarditis in other diseases
4219	Acute/subacute endocarditis nos
4220	Acute myocarditis in other diseases
42290	Acute myocarditis nos
42291	Idiopathic myocarditis
42292	Septic myocarditis
42293	Toxic myocarditis
42299	Acute myocarditis nec
4230	Hemopericardium
4231	Adhesive pericarditis
4232	Constrictive pericarditis
4233	Cardiac tamponade

4290	Myocarditis nos
Acute ICD-9 codes within Dx CCS 105: Conduction disorders	
4260	Atrioventricular
42610	Atrioventricular block nos
42611	Atrioventricular block-1st degree
42612	Atrioventricular block-mobitz ii
42613	Atrioventricular block-2nd degree nec
4262	Left bundle branch hemiblock
4263	Left bundle branch block nec
4264	Right bundle branch block
42650	Bundle branch block nos
42651	Right bundle branch block/left posterior fascicular block
42652	Right bundle branch block/left ant fascicular block
42653	Bilateral bundle branch block nec
42654	Trifascicular block
4266	Other heart block
4267	Anomalous atrioventricular excitation
42681	Lown-ganong-levine syndrome
42682	Long qt syndrome
4269	Conduction disorder nos
Acute ICD-9 codes within Dx CCS 106: Dysrhythmia	
4272	Paroxysmal tachycardia nos
7850	Tachycardia nos
42789	Cardiac dysrhythmias nec
4279	Cardiac dysrhythmia nos
42769	Premature beats nec
Acute ICD-9 codes within Dx CCS 108: Congestive heart failure; nonhypertensive	
39891	Rheumatic heart failure
4280	Congestive heart failure
4281	Left heart failure
42820	Unspecified systolic heart failure
42821	Acute systolic heart failure
42823	Acute on chronic systolic heart failure
42830	Unspecified diastolic heart failure
42831	Acute diastolic heart failure
42833	Acute on chronic diastolic heart failure
42840	Unspec combined syst & dias heart failure
42841	Acute combined systolic & diastolic heart failure
42843	Acute on chronic combined systolic & diastolic heart failure
4289	Heart failure nos
Acute ICD-9 codes within Dx CCS 149: Biliary tract disease	
5740	Calculus of gallbladder with acute cholecystitis
57400	Calculus of gallbladder with acute cholecystitis without mention of obstruction
57401	Calculus of gallbladder with acute cholecystitis with obstruction
5743	Calculus of bile duct with acute cholecystitis

57430	Calculus of bile duct with acute cholecystitis without mention of obstruction
57431	Calculus of bile duct with acute cholecystitis with obstruction
5746	Calculus of gallbladder and bile duct with acute cholecystitis
57460	Calculus of gallbladder and bile duct with acute cholecystitis without mention of obstruction
57461	Calculus of gallbladder and bile duct with acute cholecystitis with obstruction
5748	Calculus of gallbladder and bile duct with acute and chronic cholecystitis
57480	Calculus of gallbladder and bile duct with acute and chronic cholecystitis without mention of obstruction
57481	Calculus of gallbladder and bile duct with acute and chronic cholecystitis with obstruction
5750	Acute cholecystitis
57512	Acute and chronic cholecystitis
5761	Cholangitis
Acute ICD-9 codes within Dx CCS 152: Pancreatic disorders	
5770	Acute pancreatitis
Acute ICD-9 within Dx CCS 254: Rehabilitation care; fitting of prostheses; and adjustment of devices	
V520	Fitting and adjusting of artificial arm (complete) (partial) (Fitting artificial arm)
V521	Fitting and adjusting of artificial leg (complete) (partial) (Fitting artificial leg)
V528	Fitting and adjusting of other specified prosthetic device (Fitting prosthesis NEC)
V229	Fitting and adjustment of unspecified prosthetic device (Fitting prosthesis NOS)
V5882	Fitting and adjustment of nonvascular catheter, NEC (Fit/adj non-vsc cath NEC)

Appendix B: Definition of Isolated CABG Procedures in Administrative Claims Data

CABG Cohort Definition:

- All 36.1x codes that do not occur concomitantly with the exclusion codes in Table 11.
- Excluded cohort codes should be for index hospitalization or, for transfer scenarios, the first hospital performing CABG.

Table 11. Codes used to Identify Non-Isolated CABG Procedures Not Included in Final Cohort

EXCLUDE from CABG cohort if 36.1x occurs with any of the following:	Description	N	Category
0.61	Percutaneous angioplasty or atherectomy of precerebral (extracranial) vessel(s)	105	Head, neck, intracranial vascular procedure
0.62	Percutaneous angioplasty or atherectomy of intracranial vessel(s)	11	Head, neck, intracranial vascular procedure
0.63	Percutaneous insertion of carotid artery stent(s)	102	Head, neck, intracranial vascular procedure
0.64	Percutaneous insertion of other precerebral (extracranial) artery stent(s)	6	Head, neck, intracranial vascular procedure
0.65	Percutaneous insertion of intracranial vascular stent(s)	2	Head, neck, intracranial vascular procedure
32.4x	Lobectomy with segmental resection of adjacent lobes of lung, excludes that with radical dissection [excision] of thoracic structures	23	Lobectomy
33.5x	Lung transplant	20	Lung Transplant
33.6	Combined heart-lung transplantation	0	Lung Transplant
35.00	Closed heart valvotomy, unspecified valve	0	Valve procedures
35.01	Closed heart valvotomy, aortic valve	1	Valve procedures
35.02	Closed heart valvotomy, mitral valve	3	Valve procedures
35.03	Closed heart valvotomy, pulmonary valve	0	Valve procedures
35.04	Closed heart valvotomy, tricuspid valve	0	Valve procedures
35.10	Open heart valvuloplasty without replacement, unspecified valve	2	Valve procedures
35.11	Open heart valvuloplasty of aortic valve without replacement	232	Valve procedures
35.12	Open heart valvuloplasty of mitral valve without replacement	3,636	Valve procedures
35.13	Open heart valvuloplasty of pulmonary valve without replacement	9	Valve procedures
35.14	Open heart valvuloplasty of tricuspid valve without replacement	621	Valve procedures
35.20	Replacement of unspecified heart valve	2	Valve procedures
35.21	Replacement of aortic valve with tissue graft	15,503	Valve procedures
35.22	Other replacement of aortic valve	6,554	Valve procedures
35.23	Replacement of mitral valve with tissue graft	2,614	Valve procedures
35.24	Other replacement of mitral valve	1,680	Valve procedures

EXCLUDE from CABG cohort if 36.1x occurs with any of the following:	Description	N	Category
35.25	Replacement of pulmonary valve with tissue graft	9	Valve procedures
35.26	Other replacement of pulmonary valve	4	Valve procedures
35.27	Replacement of tricuspid valve with tissue graft	47	Valve procedures
35.28	Other replacement of tricuspid valve	53	Valve procedures
35.31	Operations on papillary muscle	10	Valve procedures
35.32	Operations on chordae tendineae	75	Valve procedures
35.33	Annuloplasty	3,189	Valve procedures
35.34	Infundibulectomy	0	Valve procedures
35.35	Operations on trabeculae carneae cordis	1	Valve procedures
35.39	Operations on other structures adjacent to valves of heart	53	Valve procedures
35.41	Enlargement of existing atrial septal defect	2	Atrial Septal Defect
35.42	Creation of septal defect in heart	1	Atrial Septal Defect
35.50	Repair of unspecified septal defect of heart with prosthesis	0	Atrial Septal Defect
35.51	Repair of atrial septal defect with prosthesis, open technique	36	Atrial Septal Defect
35.52	Repair of atrial septal defect with prosthesis, closed technique	32	Atrial Septal Defect
35.53	Repair of ventricular septal defect with prosthesis, open technique	33	Ventricular Septal Defect
35.54	Repair of endocardial cushion defect with prosthesis	2	Ventricular Septal Defect
35.55	Repair of ventricular septal defect with prosthesis, closed technique	0	Ventricular Septal Defect
35.60	Repair of unspecified septal defect of heart with tissue graft	1	Ventricular Septal Defect
35.61	Repair of atrial septal defect with tissue graft	62	Atrial Septal Defect
35.62	Repair of ventricular septal defect with tissue graft	41	Ventricular Septal Defect
35.63	Repair of endocardial cushion defect with tissue graft	5	Ventricular Septal Defect
35.70	Other and unspecified repair of unspecified septal defect of heart	41	Ventricular Septal Defect
35.71	Other and unspecified repair of atrial septal defect	1,101	Atrial Septal Defect
35.72	Other and unspecified repair of ventricular septal defect	60	Ventricular Septal Defect
35.73	Other and unspecified repair of endocardial cushion defect	6	Ventricular Septal Defect
35.81	Total repair of tetralogy of Fallot	1	Correction of congenital anomalies
35.82	Total repair of total anomalous pulmonary venous connection	4	Correction of congenital anomalies
35.83	Total repair of truncus arteriosus	0	Correction of congenital anomalies
35.84	Total correction of transposition of great vessels, not elsewhere classified	1	Correction of congenital anomalies

EXCLUDE from CABG cohort if 36.1x occurs with any of the following:	Description	N	Category
35.91	Interatrial transposition of venous return	3	Correction of congenital anomalies
35.92	Creation of conduit between right ventricle and pulmonary artery	0	Correction of congenital anomalies
35.93	Creation of conduit between left ventricle and aorta	7	Correction of congenital anomalies
35.94	Creation of conduit between atrium and pulmonary artery	0	Correction of congenital anomalies
35.95	Revision of corrective procedure on heart	14	Correction of congenital anomalies
35.96	Percutaneous valvuloplasty	7	Valve procedures
35.98	Other operations on septa of heart	2	Ventricular Septal Defect
35.99	Other operations on valves of heart	23	Other valve procedures
37.31	Pericardiectomy	255	Repair/restoration of pericardium
37.32	Excision of aneurysm of heart	430	Other open cardiac procedures
37.33	Excision or destruction of other lesion or tissue of heart,open approach	4,784	Other open cardiac procedures
37.35	Partial ventriculectomy	6	Other open cardiac procedures
37.51	Heart transplantation	1	Heart transplant
37.52	Implantation of total internal biventricular heart replacement system	0	Heart replacement procedures
37.53	Replacement or repair of thoracic unit of (total) replacement heart system	0	Heart replacement procedures
37.54	Replacement or repair of other implantable component of (total) replacement heart system	0	Heart replacement procedures
37.55	Removal of internal biventricular heart replacement system	1	Heart replacement procedures
37.63	Repair of heart assist system	12	Circulatory assist devices (includes VAD)
37.67	Implantation of cardiomyostimulation system	0	Circulatory assist devices (includes VAD)
38.11	Head and Neck Endarterectomy	3	Head, neck, intracranial vascular procedure
38.12	Endarterectomy, other vessels of head and neck	2,033	Head, neck, intracranial vascular procedure
38.14	Endarterectomy of Aorta	372	Aorta or other non-cardiac arterial bypass procedures
38.15	Thoracic Endarterectomy	12	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, Umbi	12	Aorta or other non-cardiac arterial bypass procedures
38.17	Endarterectomy - abdominal veins: Iliac, Portal, Renal, Splenic, Vena cava.	0	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)	0	Aorta or other non-cardiac arterial bypass procedures

EXCLUDE from CABG cohort if 36.1x occurs with any of the following:	Description	N	Category
38.42	Resection of vessel with replacement: Angiectomy, excision of aneurysm with replacement (2= other vessels of head and neck; carotid, jugular)	4	Head, neck, intracranial vascular procedure
38.44	Resection of vessel with replacement, aorta, abdominal	203	Aorta or other non-cardiac arterial bypass procedures
38.45	Resection of vessel with replacement, thoracic vessels	1,612	Aorta or other non-cardiac arterial bypass procedures
39.21	Caval-pulmonary artery anastomosis	2	Aorta or other non-cardiac arterial bypass procedures
39.22	Aorta-subclavian-carotid bypass	75	Aorta or other non-cardiac arterial bypass procedures
39.23	Other intrathoracic vascular shunt or bypass	4	Aorta or other non-cardiac arterial bypass procedures
39.24	Aorta-renal bypass	2	Aorta or other non-cardiac arterial bypass procedures
39.25	Aorta-iliac-femoral bypass	13	Aorta or other non-cardiac arterial bypass procedures
39.26	Other intra-abdominal vascular shunt or bypass	5	Aorta or other non-cardiac arterial bypass procedures
39.28	Extracranial-intracranial (EC-IC) vascular bypass	0	Head, neck, intracranial vascular procedure
39.29	Other (peripheral) vascular shunt or bypass	151	Aorta or other non-cardiac arterial bypass procedures
39.71	Endovascular implantation of graft in abdominal aorta	69	Aorta or other non-cardiac arterial bypass procedures
39.72	Endovascular embolization or occlusion of head and neck vessels	4	Head, neck, intracranial vascular procedure
39.73	Endovascular implantation of graft in thoracic aorta	82	Aorta or other non-cardiac arterial bypass procedures
39.74	Endovascular removal of obstruction from head and neck vessel(s)	22	Head, neck, intracranial vascular procedure
39.75	Endovascular embolization or occlusion of vessel(s) of head or neck using bare coils	0	Head, neck, intracranial vascular procedure
39.76	Endovascular embolization or occlusion of vessel(s) of head or neck using bioactive coils	0	Head, neck, intracranial vascular procedure
39.79	Other endovascular procedures on other vessels	62	Aorta or other non-cardiac arterial bypass procedures
85.22	Resection of quadrant of breast	0	Mastectomy
85.23	Subtotal Mastectomy, which excludes quadrant resection (85.22)	0	Mastectomy
85.4x	Mastectomy - includes simple/extended simple, unilateral/bilateral, radical/extended radical	1	Mastectomy

Table 12. ICD-9 Procedure Codes Explicitly Considered for Exclusion but Ultimately Included in CABG Cohort

Category	ICD-9 code	Description	N
Computer Assisted Surgery	0.31	Computer assisted surgery with CT/CTA	1
Computer Assisted Surgery	0.32	Computer assisted surgery with MR/MRA	0
Computer Assisted Surgery	0.33	Computer assisted surgery with fluoroscopy	4
Computer Assisted Surgery	0.34	Imageless computer assisted surgery	2
Computer Assisted Surgery	0.34	Imageless computer assisted surgery	2
Computer Assisted Surgery	0.35	Computer assisted surgery with multiple datasets	0
-	0.36	(No longer exists)	1
Computer Assisted Surgery	0.39	Other computer assisted surgery	3
Computer Assisted Surgery	17.41	Open robotic assisted procedure	295
Computer Assisted Surgery	17.42	Laparoscopic robotic assisted procedure	12
Computer Assisted Surgery	17.43	Percutaneous robotic assisted procedure	6
Computer Assisted Surgery	17.44	Endoscopic robotic assisted procedure	85
Computer Assisted Surgery	17.45	Thoracoscopic robotic assisted procedure	145
Computer Assisted Surgery	17.49	Other and unspecified robotic assisted procedure	55
Circulatory assist devices (includes VAD)	37.60	Implantation or insertion of biventricular external heart assist system	17
Circulatory assist devices (includes VAD)	37.61	Implant of pulsation balloon	13,039
Circulatory assist devices (includes VAD)	37.62	Insertion of temporary non-implantable extracorporeal circulatory assist device	42
Circulatory assist devices (includes VAD)	37.64	Removal of external heart assist system(s) or device(s)	270
Circulatory assist devices (includes VAD)	37.65	Implant of single ventricular (extracorporeal) external heart assist system	47
Circulatory assist devices (includes VAD)	37.66	Insertion of implantable heart assist system	41
Circulatory assist devices (includes VAD)	37.68	Insertion of percutaneous external heart assist device	72
Lead removal/revision/replacement	37.75	Revision of lead [electrode]	116
Lead removal/revision/replacement	37.76	Replacement of transvenous atrial and/or ventricular lead(s) [electrode]	85
Lead removal/revision/replacement	37.77	Removal of lead(s) [electrode] without replacement	50
Pacemaker implantation	37.72	Initial insertion of transvenous leads [electrodes] into atrium and ventricle	1,827
Pacemaker implantation	37.73	Initial insertion of transvenous lead [electrode] into atrium	10
Pacemaker implantation	37.74	Insertion or replacement of epicardial lead [electrode] into epicardium	514
Pacemaker implantation	37.78	Insertion of temporary transvenous pacemaker system	456
Pacemaker implantation	37.79	Revision or relocation of cardiac device pocket	34
Pacemaker implantation	37.80	Insertion of permanent pacemaker, initial or replacement, type of device not specified	18
Pacemaker implantation	37.81	Initial insertion of single-chamber device, not specified as rate responsive	45
Pacemaker implantation	37.82	Initial insertion of single-chamber device, rate responsive	36
Pacemaker implantation	37.83	Initial insertion of dual-chamber device	1,618
Pacemaker implantation	37.85	Replacement of any type pacemaker device with single-chamber device, not specified as rate responsive	8
Pacemaker implantation	37.86	Replacement of any type of pacemaker device with single-chamber device, rate responsive	6

Category	ICD-9 code	Description	N
Pacemaker implantation	37.87	Replacement of any type pacemaker device with dual-chamber device	101
Pacemaker implantation	37.89	Revision or removal of pacemaker device	33
Pacemaker implantation	37.90	Insertion of left atrial appendage device	11
ICD implantation	37.94	Implantation or replacement of automatic cardioverter/defibrillator, total system [AICD]	827
ICD implantation	37.95	Implantation of automatic cardioverter/defibrillator lead(s) only	12
ICD implantation	37.96	Implantation of automatic cardioverter/defibrillator pulse generator only	1
ICD implantation	37.97	Replacement of automatic cardioverter/defibrillator lead(s) only	6
ICD implantation	37.98	Replacement of automatic cardioverter/defibrillator pulse generator only	12
Transmyocardial revascularization	36.31	Open chest transmyocardial revascularization	938
Transmyocardial revascularization	36.32	Other transmyocardial revascularization	68
Transmyocardial revascularization	36.33	Endoscopic transmyocardial revascularization	5
Transmyocardial revascularization	36.34	Percutaneous transmyocardial revascularization	1
Miscellaneous	36.39	Other heart revascularization	8
Miscellaneous	36.91	Repair of aneurysm of coronary vessel	97
Miscellaneous	36.99	Other operations on vessels of heart (Exploration, Incision, Ligation of coronary artery, Repair of arteriovenous fistula)	544
Miscellaneous	37.34	Excision or destruction of other lesion or tissue of heart,other approach	574
Atrial appendage	37.36	Excision or destruction of left atrial appendage	3,626
Miscellaneous	37.37	Excision or destruction of other lesion or tissue of heart, thoracoscopic approach	0
Miscellaneous	37.91	Open chest cardiac massage	421
Miscellaneous	37.92	Injection of therapeutic substance into heart	6
Miscellaneous	37.93	Injection of therapeutic substance into pericardium	2
Miscellaneous	37.99	Other (Atrioplasty NEC; Ligation , atrium, heart; Ligation , auricle, heart; Operation , cardiac NEC; Operation , heart NEC; Operation , pericardium NEC; Repair , cardioverter/ defibrillator (automatic) pocket, (skin) (subcutaneous))	564
Miscellaneous	39.27	Arteriovenostomy for renal dialysis	78

Appendix C: Conditions That May Represent Adverse Outcomes of Care Received During Index Admission

CC	Description
2	Septicemia/Shock
6	Other Infectious Diseases
17	Diabetes with Acute Complications
23	Disorders of Fluid/Electrolyte/Acid-Base
28	Acute Liver Failure/Disease
31	Intestinal Obstruction/Perforation
34	Peptic Ulcer, Hemorrhage, Other Specified Gastrointestinal Disorders
46	Coagulation Defects and Other Specified Hematological Disorders
47	Iron Deficiency and Other/ Unspecified Anemias and Blood Disease
48	Delirium and Encephalopathy
51	Drug/Alcohol Psychosis
75	Coma, Brain Compression/Anoxic Damage
77	Respirator Dependence/Tracheostomy Status
78	Respiratory Arrest
79	Cardio-respiratory failure and shock
80	Congestive heart failure
85	Heart Infection/Inflammation, Except Rheumatic
86	Valvular and Rheumatic Heart Disease
92	Specified Heart Arrhythmias
93	Other Heart Rhythm and Conduction Disorders
95	Cerebral Hemorrhage
96	Ischemic or Unspecified Stroke
97	Precerebral Arterial Occlusion and Transient Cerebral Ischemia
100	Hemiplegia/Hemiparesis
101	Cerebral Palsy and Other Paralytic Syndromes
102	Speech, Language, Cognitive, Perceptual
104	Vascular Disease with Complications
105	Vascular Disease
106	Other Circulatory Disease
111	Aspiration and Specified Bacterial Pneumonias
112	Pneumococcal Pneumonia, Emphysema, Lung Abscess
114	Pleural Effusion/Pneumothorax
130	Dialysis Status
131	Renal failure
133	Urinary Obstruction and Retention
135	Urinary Tract Infection
148	Decubitus Ulcer of Skin
152	Cellulitis, Local Skin Infection
154	Severe Head Injury
155	Major Head Injury
156	Concussion or Unspecified Head Injury
158	Hip Fracture/Dislocation
159	Major Fracture, Except of Skull, Vertebrae, or Hip
160	Internal Injuries
163	Poisonings and Allergic Reactions
164	Major Complications of Medical Care and Trauma
165	Other Complications of Medical Care
166	Major Symptoms, Abnormalities
177	Amputation Status, Lower Limb/Amputation
178	Amputation Status, Upper Limb

Appendix D: CCs Not Considered for Risk Adjustment

CC	Description	Rationale
66	Attention Deficit Disorder	Pediatric ; Low frequency
123	Cataracts	Marker of clinical practice, not clinically relevant
129	End Stage Renal Disease	Not included in CMS-HCC Model
137	Female Infertility	Irrelevant to Medicare FFS Population
141	Ectopic Pregnancy	Irrelevant to Medicare FFS Population
142	Miscarriage/Abortion	Irrelevant to Medicare FFS Population
143	Completed Pregnancy with Major Complications	Irrelevant to Medicare FFS Population
144	Completed Pregnancy with Complications	Irrelevant to Medicare FFS Population
145	Completed Pregnancy without Complication	Irrelevant to Medicare FFS Population
146	Uncompleted Pregnancy with Complications	Irrelevant to Medicare FFS Population
147	Uncompleted Pregnancy with No or Minor Complications	Irrelevant to Medicare FFS Population
168	Extremely Low Birthweight Neonates	Fetal Effects; Irrelevant to Medicare FFS Population
169	Very Low Birthweight Neonates	Fetal Effects; Irrelevant to Medicare FFS Population
170	Serious Perinatal Problems Affecting Newborn	Fetal Effects; Irrelevant to Medicare FFS Population
171	Other Perinatal Problems Affecting Newborn	Fetal Effects; Irrelevant to Medicare FFS Population
172	Normal, Single Birth	Fetal Effects; Irrelevant to Medicare FFS Population
173	Major Organ Transplant	Not included in CMS-HCC Model
176	Artificial Openings for Feeding or Elimination	CC too heterogeneous; Mix of disparate codes
179	Post-Surgical States/Aftercare/Elective	CC too heterogeneous; Mix of disparate codes
180	Radiation Therapy	CC too heterogeneous; Mix of disparate codes
181	Chemotherapy	CC too heterogeneous; Mix of disparate codes
182	Rehabilitation	CC too heterogeneous; Mix of disparate codes
183	Screening/Observation/Special Exams	CC too heterogeneous; Mix of disparate codes
184	History of Disease	CC too heterogeneous; Mix of disparate codes
185	Oxygen	Not included in CMS-HCC Model; Durable Medical Equipment (DME)
186	CPAP/IPPB/Nebulizers	Not included in CMS-HCC Model; DME
187	Patient Lifts, Power Operated Vehicles, Beds	Not included in CMS-HCC Model; DME
188	Wheelchairs, Commodes	Not included in CMS-HCC Model; DME
189	Walkers	Not included in CMS-HCC Model; DME

Appendix E: Clinical Registry Data Validation of CABG Readmission Measure

Validation of

Administrative Claims-Based 30-Day All-Cause CABG Readmission Measure

using

Registry-Based 30-Day All-Cause CABG Readmission Measure

and Comparison of Final Measure Results

The measure developers of the Administrative Claims-Based 30-Day All-Cause CABG Readmission Measure (Yale New Haven Health Services Corporation/Center for Outcomes Research and Evaluation or CORE) and the Registry-Based 30-Day All-Cause CABG Readmission Measure (the Society of Thoracic Surgeons or STS) worked collaboratively to validate the administrative cohort definition and risk adjustment using clinical data from the national STS Adult Cardiac Surgery Database. We also assessed hospital performance using the two measures and compared the results. STS and CORE jointly designed the analyses. Because STS's contracts with hospitals participating in the registry restrict any release of data that could be used to identify either hospitals or patients, STS and their subcontractor, the Duke Clinical Research Institute, performed the analyses presented below and shared the results as non-identifiable, summary data with CORE.

We performed three separate validation studies:

1. administrative cohort validation,
2. administrative risk-adjustment validation, and
3. "real world" comparison of both measures' results (administrative cohort and risk model compared with STS clinical cohort and model)

This report presents the methods and findings for each of the above listed studies.

1. Validation of the Administrative Claims-Based Readmission Measure Isolated CABG Cohort definition using the Registry-Based CABG Readmission Measure Isolated CABG Cohort

To validate the claims codes used to identify an isolated CABG cohort, we compared patients identified as having isolated CABG by the claims-based readmission measure to those identified as isolated CABG by the registry-based readmission measure.

Overview and Methods:

Study Population: From all inpatient claims for Medicare fee-for-service (FFS) patients who had an ICD-9-CM procedural code for CABG (36.1x) in any position during 2008-2010, we excluded patients who were less than 65 years at admission (n = 45,236), those who died in hospital (n = 12,976), those who were not FFS eligible for at least 12 months before, during the month of, and 1 month after their index CABG admission (n = 112,282), and those who left against medical advice (n = 78). Because STS data elements were required for application of the registry-based cohort definition, we also excluded CMS records that failed to link to the STS database based on the linkage algorithm described below (n = 32,521). The final study population consisted of 207,656 index CABG admissions from 1,014 hospitals. Of these, 147,668 (71%) were classified as isolated CABG by the registry-based cohort selection algorithm and 149,927 (72%) were classified as isolated CABG by the claims-based cohort selection algorithm, as described below.

Linkage of STS and CMS Records: In order to apply the registry-based cohort definition, CABG admissions in the CMS database were linked to CABG records in the STS database. Because we did not have unique identifiers, the linkage was performed using combinations of indirect identifiers (hospital, sex, age, admission date, and discharge date). Prior to linkage, the STS cohort was restricted to patients age 65 years or older at discharge and the CMS cohort was restricted to admissions meeting the study inclusion criteria described above. Eligible STS and CMS records were considered to link if they agreed exactly on all 5 matching variables or if they agreed exactly on 4 matching variables and the 5th variable was one of the following: (1) age differed by 1 year; (2) date of admission differed by one day; (3) date of discharge differed by one day. The frequency of partial matching in this cohort was rare: 96% of patients matched exactly on all 5 variables, 1% matched on 4 variables but had an age that differed by 1 year in the registry versus claims data, and 3% matched on 4 variables but had an admission or discharge date that differed by 1 day in registry versus claims data.

Registry-Based Isolated CABG Algorithm: Records in the study population were classified as “isolated CABG” according to the registry definition if the STS field #1280 “coronary artery bypass grafting” was “yes” and all of the following fields were “no” or “missing”: valve surgery (STS field #1290), aortic valve operation (STS field #1630), mitral valve operation (STS field #1640), tricuspid valve operation (STS field #1650), pulmonic valve operation (STS field #1660), other non-cardiac procedure (STS field #1320), left ventricular aneurysm repair (STS field #2360) , ventricular septal defect repair (STS field #2370), atrial septal defect repair (STS field #2380), batista (STS field #2390), surgical ventricular restoration (STS field #2400), congenital defect repair (STS field #2410), cardiac trauma (STS field #2430), cardiac transplant (STS field #2440), atrial fibrillation correction surgery (STS field # 2470), aortic aneurysm operation (STS field #2510), and field “other” (STS field #2560) from section “other cardiac procedures.” Records not meeting the above criteria were classified as “not isolated CABG” according to the registry definition.

Claims-Based Isolated CABG Algorithm: Records in the study population were classified as “isolated CABG” according to the claims-based definition of isolated CABG, which is detailed in Sections 2.4 and 2.5 of the CABG Readmission Measure Methodology Report.

Analysis: We quantified the agreement between the registry-based and claims-based isolated CABG definitions using the registry-based definition as the reference standard. Results were summarized by calculating various measures of agreement including relative sensitivity, specificity, positive predictive value, and negative predictive value. Where possible, we attempted to discern the reason(s) for discordant records. Records that were classified as non-isolated CABG were labeled as:

- **Claims Only** (i.e., the claims-based algorithm defined them as isolated CABG patients while the registry-based algorithm did not);
- **Registry Only** (i.e., the registry-based algorithm defined them as isolated CABG patients while the claims-based algorithm did not); or
- **Neither** (i.e., neither algorithm considered them isolated CABG patients).

Results:

Table 1.1 classifies matched patients as having been identified by one or both algorithms as isolated CABG patients.

Table 1.1: Agreement Between Registry-Based and Claims-Based Isolated CABG Definitions
(2008-2010, cohort of 207,656 Medicare FFS patients in STS registry)

		Registry Isolated CABG		
		Yes	**No**	**Total**
Claims Isolated CABG	**Yes**	145,207 (Both)	**4,720 (Claims Only)**	149,927
	No	**2,461 (Registry Only)**	55,268 (Neither)	57,729
	Total	147,668	59,988	207,656

- **Claims Only** (i.e., claims data identified patient as isolated CABG patient, but registry data did not) occurred in **7.9% or 4,720 of 59,988 non-isolated CABG patients in registry data**
- **Registry Only** (i.e., registry data identified patient as isolated CABG patient, but claims data did not) occurred in **1.7% or 2,461 of 147,668 isolated CABG patients in registry data**

Table 1.2: Patient characteristics, readmission rates and distribution of matching and non-matching isolated CABG patients across hospitals

(2008-2010 cohort of 207,656 Medicare FFS patients in STS registry)

		Group			
Characteristics		**Both**	**Registry Only**	**Claims Only**	**Neither**
Number of Patients		145,207	2,461	4,720	55,268
Number of Hospitals		1014	705	840	998
Age at admission, years	Mean (25^{th}-75^{th} percentile)	73.9 (69.0-78.0)	74.2 (70.0-78.0)	74.3 (70.0-78.0)	76.1 (71.0-81.0)
Sex, % male		68.8	70.8	70.7	64.9
30-d readmission, %		16.9	21.9	21.8	23.1
Proportion of hospital's admissions in each group, % [1]	Mean (25^{th}-75^{th} percentile)	72.4 (66.2-79.3)	1.3 (0.0-1.6)	2.5 (0.8-3.1)	23.8 (16.0-29.9)

[1] These are calculated with all hospitals contributing patients to each column as noted in row labeled "Number of Hospitals."

In terms of diagnostic test accuracy (assuming that the registry definition is the gold standard for identifying isolated CABG procedures), the administrative claims definition of isolated CABG had the following performance characteristics:

- Among 149,927 isolated CABG procedures identified by the Claims algorithm, 145,207 (96.8%) were confirmed as isolated CABG by the Registry algorithm (positive predictive value)
- Among 57,729 procedures identified as not being isolated CABG by the Claims algorithm, 55,268 (95.7%) were also not isolated CABG by the Registry algorithm (negative predictive value)
- Among 147,668 isolated CABG procedures identified by the Registry algorithm, 145,207 (98.3%) were also isolated CABG by the Claims algorithm (sensitivity)
- Among 59,988 non-isolated CABG cases identified by the Registry algorithm, 55,268 (92.1%) were also non-isolated CABG by the Claims algorithm (specificity)

As noted below, these findings include 1,744 patients with concomitant MAZE procedures that we intentionally included in the claims cohort, but are excluded from the registry cohort. Thus, this analysis represents a conservative estimate of the accuracy of the claims-based isolated CABG definition; excluding expected reasons for cohort differences from the above comparison would produce even higher performance characteristics. Nevertheless, based on these findings, the accuracy of the claims algorithm is higher than that of prior administrative claims definitions of isolated CABG.[1]

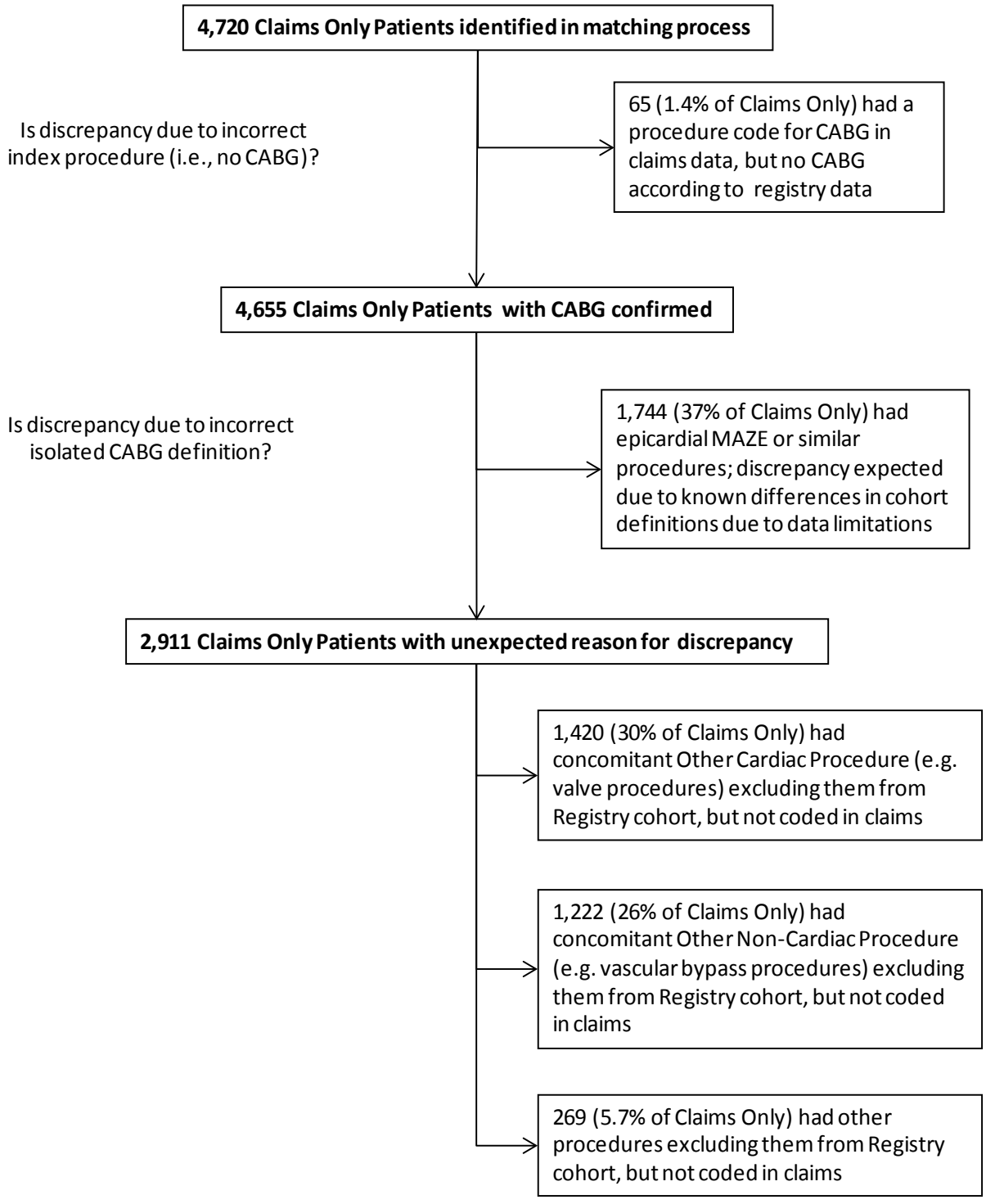
Details Regarding Claims-Only Isolated CABG Patients

- 1,744 patients were excluded from the registry definition of isolated CABG due to concomitant MAZE procedures for atrial fibrillation. This is an expected discrepancy between the two cohorts due to their respective cohort definitions -- the claims-based measure excludes only open MAZE procedures, as these reflect greater risk to the patient, while the registry-based measure excludes all (open and epicardial) MAZE procedures as the registry data does not currently differentiate between open and epicardial procedures (Figure 1.1)
- Other reasons for discrepancies included:
    - 65 patients had no CABG procedure, but rather had a valve procedure, documented in registry data;
    - 1,420 had a concomitant Other Cardiac Procedure (e.g. valve procedures) excluding them from the registry cohort that was not coded in claims. For example, approximately 400 Claims-Only patients had an aortic or mitral valve procedure indicated in registry data, but there was no corresponding claims code for such a procedure;
    - 1,222 had a concomitant Other Non-Cardiac Procedure (e.g. vascular bypass procedures) excluding them from the registry cohort that was not coded in claims
- The most common non-CABG procedure code (i.e., non-36.1x code) found among Claims-Only patients was 39.61 "Extracorporeal circulation auxiliary to open heart surgery," which was also the most common non-CABG procedure code found among matched patients and false negatives (Table 1.3)
- Among the 4,720 Claims-Only patients, we did not identify any procedure codes that could further improve the specificity of the Administrative Isolated CABG cohort definition

Details Regarding Registry-Only Isolated CABG Patients

- All 2,461 Registry-Only patients had a 36.1x (CABG) procedure code, but were excluded from the Claims-Only cohort due to other concomitant procedure codes, such as carotid endarterectomy codes, open MAZE procedure codes, peripheral bypass surgery codes or valvular procedures codes
- For example, 286 patients had a code for an aortic or mitral valve procedure but the registry data did not show that such a procedure was performed. One cause for such discrepancies may be that the procedures occurred on different days within the index admission (e.g., isolated CABG on day 1 and valve replacement on day 5). At least 2 cases (of the 286) were identified in the registry data where the valve procedure occurred after the index CABG procedure and therefore were appropriately excluded from the isolated CABG registry-cohort.

Figure 1.1: Sources of discrepancies among Claims-Only Isolated CABG patients
(4,720 Isolated CABG Medicare FFS patients in STS registry)



Note: All percentages are calculated as percentages of all Claims Only patients (i.e., of 4,720)

Table 1.3: Frequency of Most Common Other (non-CABG or non-36.1x) ICD-9 Codes
(2008-2010 cohort of 207,656 Medicare FFS patients in STS registry)

ICD-9 Code	ICD-9 Procedure Code Description	Both	Neither	Claims Only	Registry Only	All
3961	Extracorporeal circulation auxiliary to open heart surgery	99,611	43,018	3,162	1,449	147,240
3722	Left heart cardiac catheterization	71,804	9,370	2,123	1,057	84,354
8856	Coronary arteriography using two catheters	61,223	10,509	1,531	657	73,920
8853	Angiocardiography of left heart structures	49,098	4,863	1,076	397	55,434
9904	Transfusion of packed cells	27,645	10,291	732	325	38,993
8872	Diagnostic ultrasound of heart	21,057	13,127	595	258	35,037
3521	Replacement of aortic valve with tissue graft	0	25,565	0	137	25,702
3761	Implant of pulsation balloon	12,028	3,717	457	201	16,403
3723	Combined right and left heart cardiac catheterization	4,076	8,358	223	127	12,784
3893	Venous catheterization, not elsewhere classified	8,249	2,626	255	113	11,243
3963	Cardioplegia	6,646	2,794	241	76	9,757
3522	Other replacement of aortic valve	0	9,653	0	61	9,714
3733	Excision or destruction of other lesion or tissue of heart, open approach	0	8,522	0	605	9,127
9905	Transfusion of platelets	5,973	2,818	184	70	9,045
9907	Transfusion of other serum	5,063	2,741	181	47	8,032
8964	Pulmonary artery wedge monitoring	5,968	1,646	141	63	7,818
9900	Perioperative autologous transfusion of whole blood or blood components	4,995	1,452	235	58	6,740
3891	Arterial catheterization	4,719	1,337	140	71	6,267
3964	Intraoperative cardiac pacemaker	4,281	1,671	137	37	6,126
9671	Continuous invasive mechanical ventilation for less than 96 consecutive hours	4,213	1,613	144	52	6,022
3512	Open heart valvuloplasty of mitral valve without replacement	0	5,623	0	43	5,666
0066	Percutaneous transluminal coronary angioplasty [PTCA] or coronary atherectomy	4,648	482	168	60	5,358
3736	Excision or destruction of left atrial appendage (LAA)	1,233	2,805	1,029	63	5,130

ICD-9 Code	ICD-9 Procedure Code Description	Both	Neither	Claims Only	Registry Only	All
3491	Thoracentesis	3,165	1,781	121	44	5,111
3533	Annuloplasty	0	4,735	0	28	4,763
3403	Reopening of recent thoracotomy site	2,471	1,778	102	52	4,403
8842	Aortography	3,394	744	94	51	4,283
9604	Insertion of endotracheal tube	2,932	1,116	111	32	4,191
8968	Monitoring of cardiac output by other technique	2,950	1,108	86	27	4,171
3523	Replacement of mitral valve with tissue graft	0	3,767	0	17	3,784
9672	Continuous invasive mechanical ventilation for 96 consecutive hours or more	2,066	1,515	127	38	3,746
311	Temporary tracheostomy	1,565	1,602	123	55	3,345
3772	Initial insertion of transvenous leads [electrodes] into atrium and ventricle	1,450	1,786	68	37	3,341
0040	Procedure on single vessel	1,182	1,450	59	564	3,255
3812	Endarterectomy, other vessels of head and neck	0	2,143	0	958	3,101
3783	Initial insertion of dual-chamber device	1,308	1,559	61	28	2,956
3404	Insertion of intercostal catheter for drainage	2,059	768	66	17	2,910
3995	Hemodialysis	1,724	588	62	20	2,394
0017	Infusion of vasopressor agent	1,705	616	37	27	2,385
3845	Resection of vessel with replacement, thoracic vessels	0	2,298	0	40	2,338
3962	Hypothermia (systemic) incidental to open heart surgery	1,503	599	48	19	2,169
9962	Other electric countershock of heart	1,361	709	55	22	2,147

Summary Results for Validation of Administrative Isolated CABG Cohort Definition:

- Excluding expected causes of discrepant results (i.e., 1,744 MAZE procedures), 5,437 patients of 207,656 (2.6%) patients in a matched cohort were discordantly identified by the two measures:
    - 2,976 (1.4%) were identified as Isolated CABG patients by the claims-based cohort definition and not by the registry-based cohort definition (Claims Only).
- 2,461 (1.2%) were identified as Isolated CABG patients by the registry-based cohort definition and not by the claims-based cohort definition (Registry Only).
- This level of agreement is greater than previously documented.[1]
- Such inconsistencies could be due to coding errors in the claims data, abstraction errors in the registry data, procedures occurring on different days within the index admission, or may be due to inconsistencies in the probabilistic matching process used to create a matched set of patients for the validation.
- In diagnostic test terms, the claims algorithm had the following performance characteristics: PPV: 96.8% (145,207 of 149,927); NPV: 95.7% (55,268 of 57,729); Sensitivity: 98.3% (145,207 of 147,668); and Specificity: 92.1% (55,268 of 59,988) [Note: These numbers include the expected discrepant MAZE procedures among the "false positives"; removal of these patients would further improve the performance of the claims-based cohort definition in comparison to the registry-based cohort].
- There were no individual ICD-9-CM codes that could be identified from the validation to further increase the precision of the administrative claims-based isolated CABG cohort definition.
- These findings do not indicate large, systematic concerns with the cohort definitions requiring revisions to either measure's cohort definition. They do, however, suggest that, given the careful input of surgical experts in the development of both measures, complete concordance between claims and registry cohorts is unlikely to ever be achieved and hampered by data inconsistencies in both data sources.

2. Validation of the Administrative Claims-Based Readmission Measure Risk Adjustment using the Registry-Based CABG Readmission Measure

Overview:

To validate the administrative risk-adjustment model, we calculated hospital-level risk-standardized readmission rates (RSRRs) using both measures in a common cohort of isolated CABG patients (2008-2010) and compared the results using the registry measure as the gold standard. We first measured the correlation between the two measure results at the hospital-level. Next, we performed a reclassification analysis to determine how many hospitals might be reclassified to a different performance category if assessed by the administrative as compared to the registry measure. In order to isolate differences due to the method of risk-adjustment, both measures were calculated in the same cohort of patients and used the same endpoint definition and same type of risk-adjustment model.

Methods:

Creation of Matched Cohort: Inclusion criteria for each measure are described in their respective measure methodology reports. To allow each measure to be calculated in a common set of patients, we identified CABG admissions in the Medicare database during 2008-2010 that met eligibility requirements for both measures (matched cohort, n = 145,157; see Section 1 for derivation of common cohort). The common cohort of matched patients for this comparison included all of the 145,207 matched patients in 1,014 hospitals identified in Section 1 with the exception of 50 patients from 3 hospitals due to multiple minor exclusions[††], which left the final matched sample of 145,157 patients at 1,011 hospitals. Patients who were eligible for only one of the two measures were excluded from calculations for both measures. The final matched cohort for this analysis was 83% of the overall administrative cohort (n = 175,891) and 89% of the overall clinical cohort (n = 162,575).

Definition of 30-Day Readmission: The claims-based and registry-based measures differ in their handling of planned readmissions. Likely planned readmissions are excluded (i.e., do not count as readmission outcomes) in the claims-based measure but are included (i.e., count as readmission outcomes) in the registry-based measure, as STS believes that virtually all 30-day readmissions after CABG are unplanned and that it would be extremely difficult to determine those few that were truly planned. To focus the validation on differences in risk adjustment by eliminating other potential sources of discrepant results, we used the registry-based definition of readmission for both measures and did not identify any readmissions as planned. Using this endpoint definition, the frequency of 30-day all-cause readmission in this sample was 24,525 / 145,157 = 16.9%.

Calculation of RSRRs and Performance Categories: For each of the two measures, RSRRs were estimated in a hierarchical logistic regression model with hospital-specific random intercept parameters. Methods of estimation were identical to the currently publicly reported CMS mortality and readmission measures for acute myocardial infarction, heart failure and pneumonia. A bootstrapping algorithm was used to construct a 95% interval estimate for each RSRR. To complete this analysis, we categorized hospitals into three performance groups -- "Better," "No different" and "Worse" than expected -- according to the methodology used for the currently publicly reported CMS mortality and readmission measures. We classified a hospital as performing "Better than expected" if the 95%

[††]Additional cohort exclusions not applied to the matched cohort derived in Section 1 were patients at hospitals with fewer than 10 CABG cases within the measurement period, and subsequent CABG surgeries for the same patient within the measurement period.

interval estimate for that hospital was entirely below the overall aggregate readmission rate for all hospitals of 16.9%, "Worse" if the estimate for that hospital was entirely above the overall aggregate readmission rate, and "No different" if the estimate included the overall aggregate readmission rate.

Analysis: For each measure, RSRRs and 95% interval estimates were calculated in the common cohort comprising 145,157 index CABG admissions and 1,011 hospitals. Subsequently, before summarizing and comparing hospital-level results, we excluded 107 hospitals with fewer than 30 eligible cases (as very small volume hospitals may not yield stable estimates for public reporting) and an additional 75 hospitals in which fewer than 90% of eligible CMS records were linked to STS registry records (as a threshold assessment for complete registry participation). This left 829 hospitals for the risk-adjustment validation analysis. Agreement between claims-based and registry-based RSRRs was assessed by various correlation coefficients (Pearson Correlation (ρ), Intraclass Correlation (ρ^2) and Spearman Rank Correlation) and depicted graphically as a scatterplot. For each individual hospital, the difference between the administrative-based and registry-based RSRR was quantified by the absolute difference (= |claims-based RSRR - registry-based RSRR|) and the relative absolute difference (= 100 x |claims-based RSRR - registry-based RSRR| / registry-based RSRR). Agreement between claims-based and registry-based performance categories was assessed in a 3 x 3 table using the clinical-based results as the reference standard.

Results:

Table 2.1 and Figure 2.1 present the distribution of claims-based and registry-based hospital-level RSRRs in the subset of hospitals with at least 30 eligible cases between 2008 and 2010 and at least 90% of CMS records linked to STS. Figure 2.2 presents a scatterplot of the hospital-level RSRRs produced by both measures in a matched cohort of patients, where each dot represents a single hospital. The correlation between RSRR measurement by both models was high, ranging from 0.92-0.96 depending upon the statistic used (Table 2.2).

The claims-based and registry-based RSRRs differed by more than 1 percentage point for 57 hospitals (7%) and by more than 3 percentage points for 1 hospital (Table 2.3). Only 8 of the 57 hospitals with >1% absolute difference between measures were categorized differently by the two measures, using the method employed by the currently publicly reported measures to characterize hospital performance. That is, a hospital's 95% interval estimate of their RSRR, a measure of uncertainty surrounding the point estimate of that hospital's RSRR, must be completely below the national rate to be categorized as "Better than expected"; completely above the national rate to be categorized as "Worse than expected"; and the remaining hospitals are statistically "No different than expected." On a relative scale, 90 hospitals (11%) had relative differences in their RSRR >5% and 8 hospitals (1%) had relative differences >10% (Table 2.4). Of the 90 hospitals with >5% relative difference, only 11 changed performance categories.

Table 2.1: Distribution of Claims-Based Model RSRRs and Registry-Based Model RSRRs, %
(2008-2010 Matched cohort subset of 829 hospitals with at least 30 eligible cases and at least 90% of CMS records linked to STS)

Model	Minimum	25th Percentile	Median	75th Percentile	Maximum
Claims-based	12.8	15.7	16.8	18.0	21.7
Registry-based	12.6	15.6	16.7	18.2	23.0

Figure 2.1: Distribution of Hospital-level Claim-Based and Registry-Based Model RSRRs
(2008-2010 Matched cohort subset of 829 hospitals with at least 30 eligible cases and at least 90% of CMS records linked to STS)

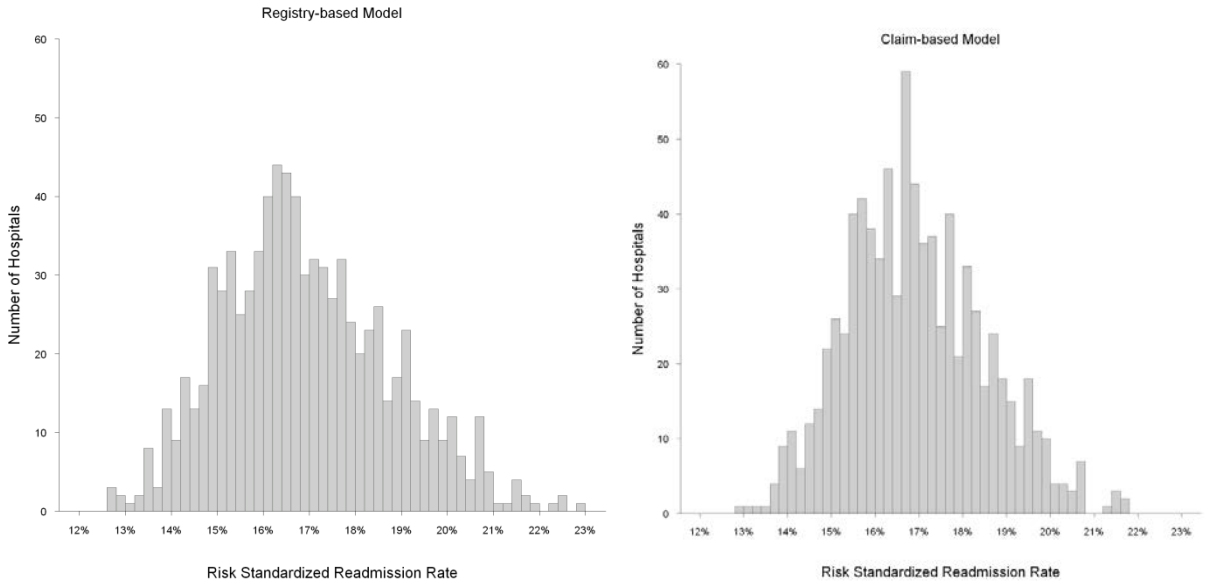


Figure 2.2: Comparison of Registry-Based and Claims-Based Model RSRRs (2008-2010 Matched cohort subset of 829 hospitals with at least 30 eligible cases and at least 90% of CMS records linked to STS)

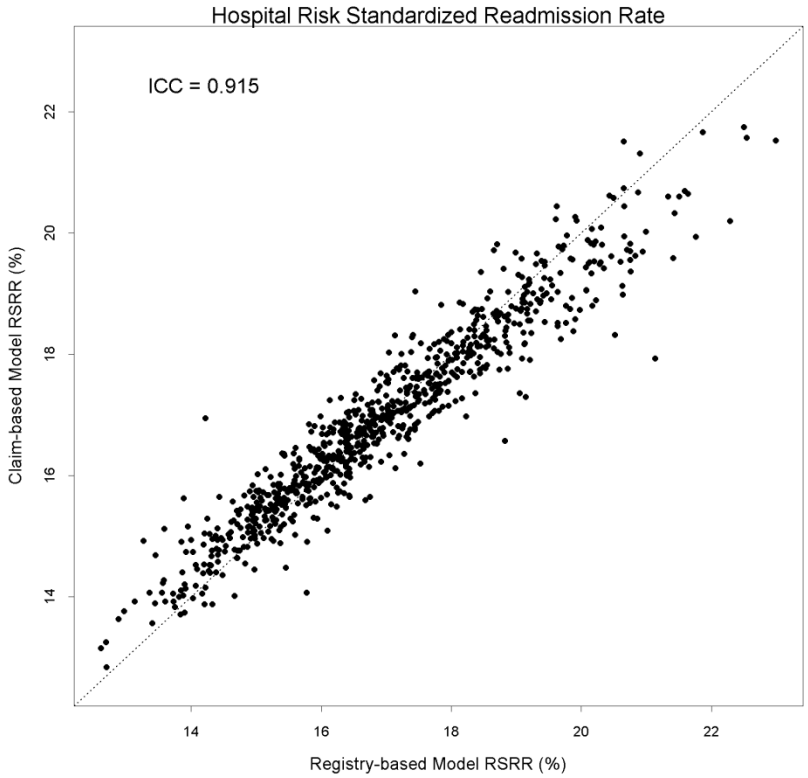


Table 2.2: Correlation of Hospital-Level RSRRs Calculated Using Registry-Based and Claims-Based Models (2008-2010 Matched cohort subset of 829 hospitals with at least 30 eligible cases and at least 90% of CMS records linked to STS)

Pearson Correlation (ρ)	Intraclass Correlation (ρ^2)*	Spearman Rank Correlation
0.956	**0.915**	**0.960**

* The population parameter of interest is the proportion of variation in the measured RSRR that is due to true signal variation in the RSRR as opposed to measurement error or, equivalently, it is the square of the correlation between the measured and true RSRRs. For analyzing the matched sample, RSRRs based on the registry-based model were regarded as the gold standard and were therefore interpreted as "true" RSRRs. Hence the ICC of interest was estimated directly as [cor(x,y)]^2 where x=registry-based RSRR and y=claim-based RSRR.

Table 2.3: Number of Hospitals With *Absolute* Difference in RSRRs Exceeding 1%, 2%, 3%, or 4%
(2008-2010 Matched cohort subset of 829 hospitals with at least 30 eligible cases and at least 90% of CMS records linked to STS)

Absolute Difference in RSRRs	>1%	>2%	>3%	>4%
Number of Hospitals	57	5	1	0
Percent of Hospitals	7.0%	0.6%	0.1%	0%
Number of Hospitals that Changed Performance Category (e.g., Better by claims and Same by registry, or vice versa)	8	2	1	0

Table 2.4: Number of Hospitals With *Relative* Difference in RSRRs Exceeding 5%, 10%, 15%, or 20% (2008-2010 Matched cohort of 829 hospitals with at least 30 eligible cases and at least 90% of CMS records linked to STS)

Relative Difference in RSRRs	>5%	>10%	>15%	>20%
Number of Hospitals	90	8	2	0
Percent of Hospitals	11.0%	1.0%	0.2%	0%
Number of Hospitals that Changed Performance Category (e.g., Better by claims and Same by registry, or vice versa)	11	4	1	0

Table 2.5, Table 2.6 and Table 2.7 and Figure 2.3 and Figure 2.4 provide information about how the different measures categorize hospitals using the method employed by the currently publicly reported measures to assess hospital performance. Table 2.5 compares the performance categories produced by each measure, defined with 95% interval estimates around each hospital's RSRR. If the lower bound of the 95% CI is higher than the readmission rate in the matched sample, the hospital is considered Worse than expected. If the upper bound is lower than the readmission rate in the matched sample, the hospital is considered Better than expected. Other hospitals are considered No different than expected.

Table 2.6 and Table 2.7 further examine the ability of the claims-based measure to identify Better- and Worse-performing hospitals, respectively. Sensitivity in Tables 2.6 and 2.7 is calculated as the number of Better (or Worse) outlier hospitals where both measures agreed on the performance categorization, divided by the total number of Better (or Worse) outlier hospitals as defined by the registry measure; specificity in Tables 2.6 and 2.7 is calculated as the number of hospitals in either the No different OR Worse categories (or No different OR Better categories for Table 2.7) where both measures agreed on the performance categorization, divided by the total number of No different OR Worse (or No different OR Better) hospitals as defined by the registry measure.

Table 2.5: Reclassification Analysis of Administrative and Registry Measure Hospital-Level Results (2008-2010 Matched cohort subset of 829 hospitals with at least 30 eligible cases and at least 90% of CMS records linked to STS)

		Registry-Based CABG Readmission Measure			
		Better than expected	**No different than expected**	**Worse than expected**	**Total**
Claims-Based CABG Readmission Measure	**Better than expected**	6	3	0	**9**
	No different than expected	8	793	6	**807**
	Worse than expected	0	5	8	**13**
	Total	**14**	**801**	**14**	**829**

Table 2.6: Accuracy of Claims-based Measure in Identifying "Better" Performing Hospitals (2008-2010 Matched cohort subset of 829 hospitals with at least 30 eligible cases and at least 90% of CMS records linked to STS)

		Registry-Based CABG Readmission Measure				
		Better than expected	**No different or Worse than expected**	**Total**	**Sensitivity**	**Specificity**
Claims-Based CABG Readmission Measure	**Better than expected**	6	3	**9**	**42.9%**	**99.6%**
	No Different or Worse than expected	8	812	**820**		
	Total	**14**	**815**	**829**		

Table 2.7: Accuracy of Claims-based Measure in Identifying "Worse" Performing Hospitals (2008-2010 Matched cohort subset of 829 hospitals with at least 30 eligible cases and at least 90% of CMS records linked to STS)

		Registry-Based CABG Readmission Measure				
		Worse than expected	**No different or Better than expected**	**Total**	**Sensitivity**	**Specificity**
Claims-Based CABG Readmission Measure	**Worse than expected**	8	5	**13**	**57.1%**	**99.4%**
	No different or Better than expected	6	810	**816**		
	Total	**14**	**815**	**829**		

Detailed Comparison of Outlier Hospitals According to Registry and Claims Measures

- 36 hospitals were identified by one or both models as outliers (i.e., either Better than or Worse than expected)
- Of these 36 hospitals, 22 were discordant between the registry and claims models
    - Among 14 hospitals rated Better than expected by the Registry-based measure, 8 (57%) were rated No different than expected by the Claims-based measure
    - Among 9 hospitals rated Better than expected by the Claims-based measure, 3 (33%) were No different than expected by the Registry-based measure
    - Among 14 hospitals rated Worse by the Registry model, 6 (42.9%) were rated No different than expected by the Claims model
    - Among 13 programs rated Worse by the Claims model, 5 (38.5%) were rated No different than expected by the Registry model
- Of 22 outlier hospitals with discordant performance categorization, 8 had >1% absolute percentage point difference in RSRR by Registry versus Claims model; 2 hospitals had >2% absolute percentage point difference in RSRR by Registry versus Claims model
- Figures 2.3 and 2.4 show the national readmission rate (grey bar), RSRRs (black diamonds) and 95% interval estimates produced by each model for the 17 "Better" and 19 "Worse" outlier hospitals (listed as 1 through 36, 22 of whom had discordant performance categorization; registry results listed first for each registry-claims pair). Table 2.6 provides the numbers presented in Figures 2.3 and 2.4 plus the hospital-level crude (unadjusted) readmission rate for these discordant outlier hospitals as well
- For all hospitals, the RSRRs produced by the registry measure were within the interval estimate produced by the claims-based measure, and vice versa
- Table 2.7 provides the distribution of patient volumes across the 22 discordant outlier hospitals

Figure 2.3: Comparison of Registry and Claims Measure Results (RSRR with 95% CIs) among Concordant and Discordant Better (e.g., "Better than expected" by registry model and "No different than expected (or Average)" by claims model) Outlier Hospitals

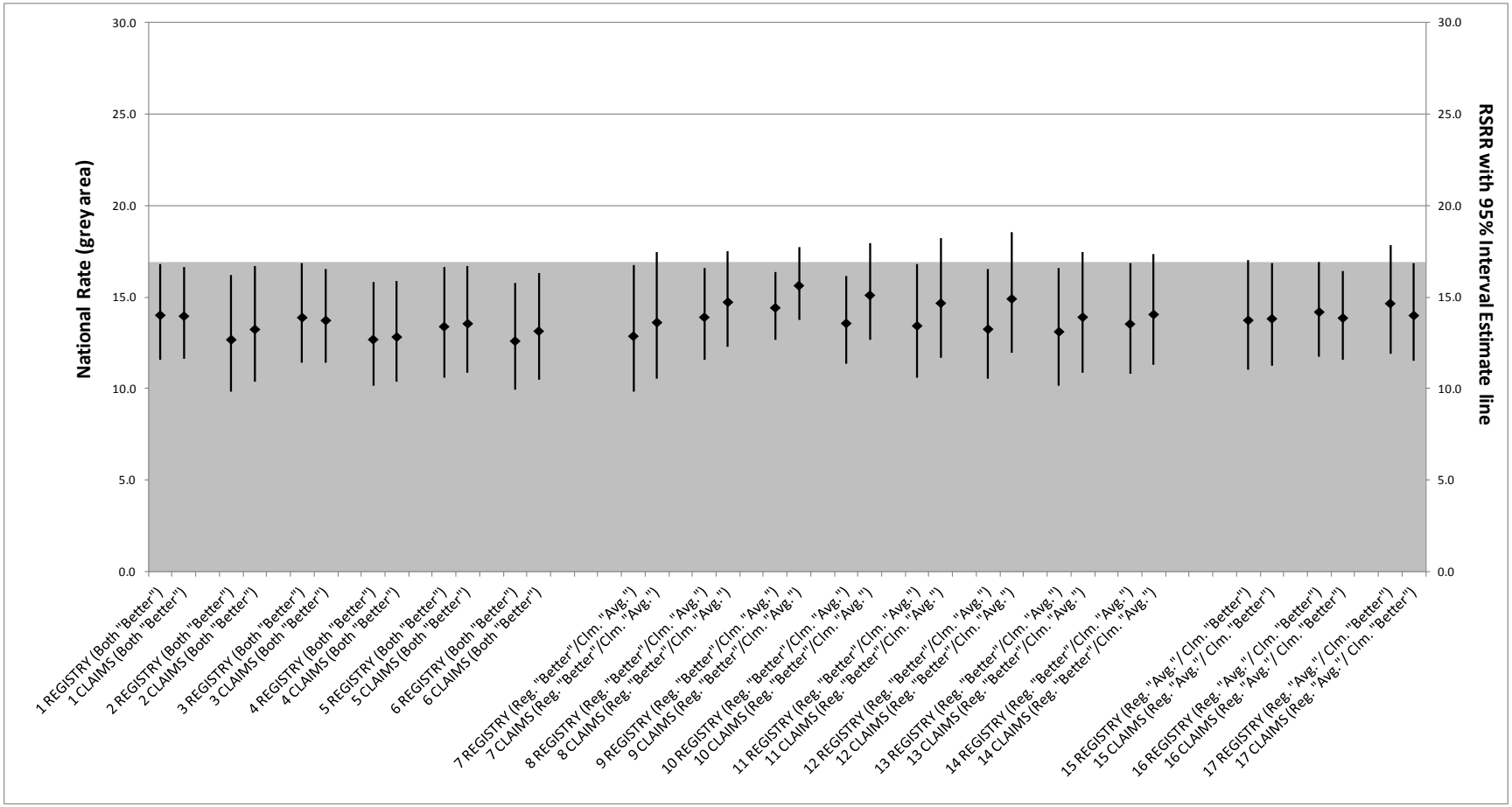


Figure 2.4: Comparison of Registry and Claims Measure Results (RSRR with 95% CIs) among Concordant and Discordant Worse (e.g., "Worse than expected" by registry model and "No different than expected (or Average)" by claims model) Outlier Hospitals

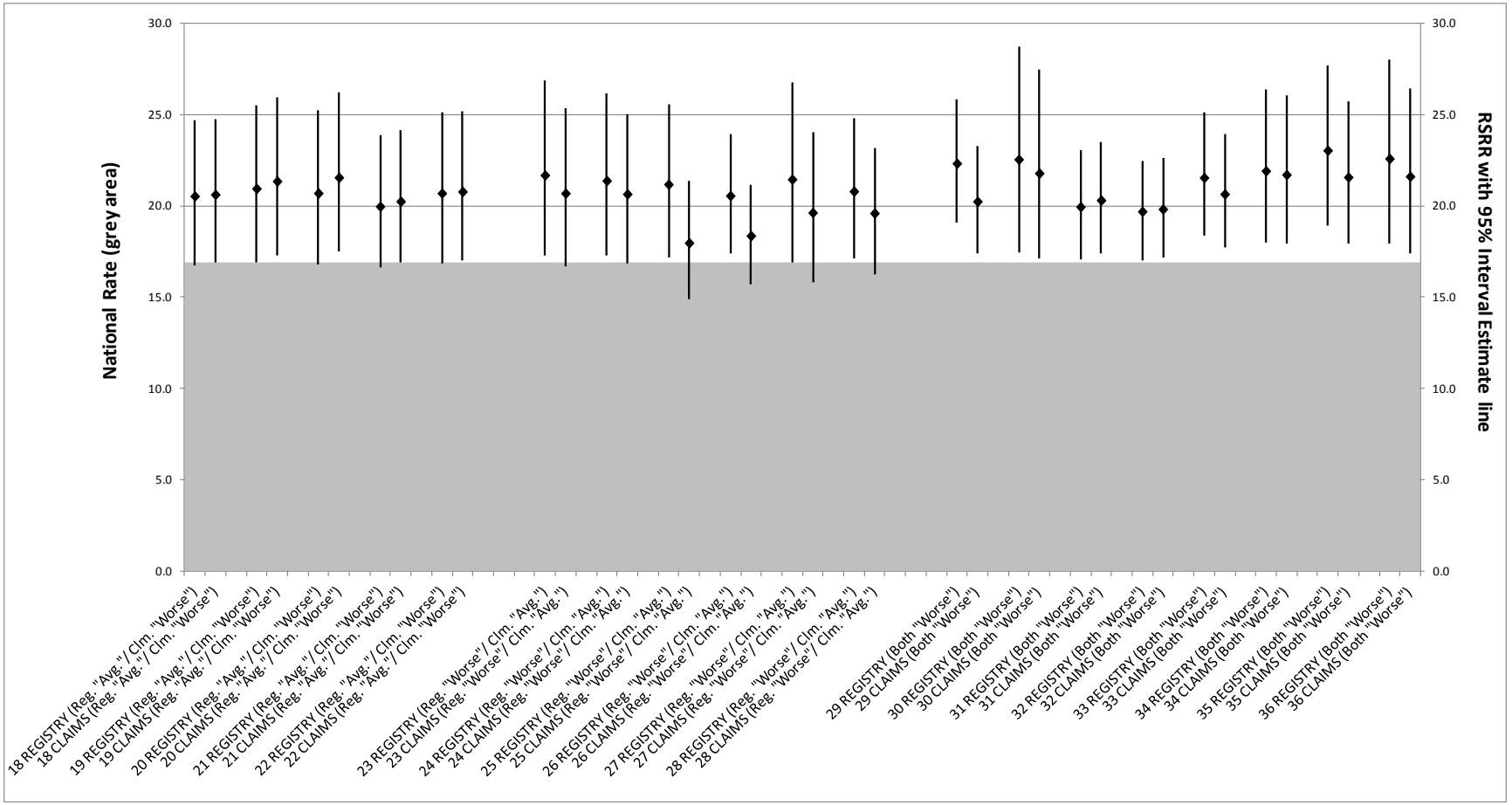


Table 2.6: Raw (observed) rates, RSRRs and 95% interval estimates produced by each model for hospitals with discordant performance categorization

		REGISTRY			CLAIMS		
			95% Interval Estimate			95% Interval Estimate	
Hospital	Raw Rate	RSRR	Lower bound	Upper bound	RSRR	Lower bound	Upper bound
Better Performing Concordant Outliers (i.e., both measures agree hospital "Better than expected")							
1	13%	14.0	11.6	16.8	14.0	11.6	16.6
2	9%	12.7	9.8	16.2	13.3	10.4	16.7
3	11%	13.9	11.4	16.9	13.7	11.4	16.5
4	10%	12.7	10.1	15.8	12.8	10.4	15.9
5	11%	13.4	10.6	16.6	13.6	10.9	16.7
6	9%	12.6	10.0	15.8	13.2	10.5	16.3
Better Performing Discordant Outliers							
Registry rates as "Better than expected" and Claims "As expected"							
7	8%	12.9	9.9	16.7	13.6	10.5	17.4
8	13%	13.9	11.6	16.6	14.7	12.3	17.5
9	17%	14.4	12.7	16.4	15.6	13.8	17.7
10	13%	13.6	11.4	16.2	15.1	12.7	17.9
11	12%	13.4	10.6	16.8	14.7	11.7	18.2
12	12%	13.3	10.6	16.5	14.9	11.9	18.5
13	10%	13.1	10.1	16.6	13.9	10.8	17.5
14	10%	13.5	10.8	16.9	14.1	11.3	17.3
Registry rates as "As expected" and Claims "Better than expected"							
15	12%	13.8	11.1	17.0	13.8	11.3	16.9
16	12%	14.2	11.7	16.9	13.9	11.6	16.4
17	13%	14.7	11.9	17.8	14.0	11.5	16.9
Worse Performing Discordant Outliers							
Registry rates as "As expected" and Claims "Worse than expected"							
18	23%	20.5	16.7	24.7	20.6	16.9	24.7
19	26%	20.9	16.9	25.5	21.3	17.3	26.0
20	26%	20.7	16.8	25.2	21.5	17.5	26.2
21	22%	19.9	16.6	23.9	20.2	16.9	24.1
22	25%	20.6	16.9	25.1	20.7	17.0	25.2
Registry rates as "Worse than expected" and Claims "As expected"							
23	28%	21.6	17.3	26.9	20.6	16.7	25.3
24	26%	21.3	17.3	26.1	20.6	16.8	25.0
25	20%	21.1	17.2	25.6	17.9	14.9	21.3
26	22%	20.5	17.4	23.9	18.3	15.7	21.2
27	25%	21.4	16.9	26.7	19.6	15.8	24.0
28	22%	20.8	17.1	24.8	19.6	16.3	23.2
Worse Performing Concordant Outliers (i.e., both measures agree hospital "Worse than expected")							
29	23%	22.3	19.1	25.8	20.2	17.4	23.3
30	30%	22.5	17.5	28.7	21.7	17.1	27.5
31	22%	19.1	17.1	23.1	20.3	17.4	23.5
32	22%	19.7	17.0	22.4	19.8	17.1	22.6
33	26%	21.5	18.4	25.1	20.6	17.7	23.9

34	25%	21.9	18.0	26.4	21.7	17.9	26.0
35	27%	23.0	18.9	27.7	215	17.9	25.7
36	40%	22.5	17.9	28.0	21.6	17.4	26.4

Table 2.7: Distribution of patient volumes for 22 outlier hospitals with discordant performance categorization

Mean	Min	10th	25th	50th	75th	90th	Max
310	75	140	193	276	445	515	929

Additional Notes Regarding 22 Discordant Outlier Hospitals

- Risk factor frequencies were examined among the matched cohort and specifically among the outlier hospitals with discrepancies between RSRRs produced by registry versus claims models. These analyses demonstrated that the claims-based model typically captures a higher number of comorbidities than the registry model. The significance of this observation is uncertain. On the one hand, it could represent enhanced sensitivity of claims data to detect real comorbidities. Conversely, it could reflect the greater specificity of registry model definitions, which would tend to reduce coding of risk factors for which there is insufficient justification.

- For example, 33,748 patients in the matched cohort were coded as having CC108 Chronic Obstructive Pulmonary Disease in the last 12 months of claims data. In registry data, there are four categories (none, mild, moderate, and severe) of Chronic Lung Disease. Among the 33,748 patients identified as COPD by claims data in the matched cohort, only 18,869 (55.9%) of these met criteria for Chronic Lung Disease according to registry data definitions and only 4,250 (12.6%) had severe Chronic Lung Disease. Similar findings were observed for other important predictors such as renal failure.

- Despite these differences, the two models produce similar c statistics in their respective measure cohorts: c-statistic for registry-based model = 0.631 and for claims-based model = 0.624.

Summary Results for Validation of Administrative Isolated CABG Risk Adjustment:

- Both measures display similar distributions in hospital RSRRs following CABG; RSRRs ranging from 12.8% to 21.7% for the claims-based measure and 12.6% to 23.0% for the registry-based measure
- Overall agreement was 97% (807 of 829 hospitals had concordant performance categorization) and the correlation was between 0.92 and 0.96, depending upon the statistic used
- 22 hospitals had discordant performance categorization by the claims versus registry model
- No hospital was rated as performing Worse than expected by the claims-based measure and Better than expected by the registry-based measure (or vice versa)
- Among 14 hospitals rated Better than expected by the registry-based measure, 8 (57%) were rated No different as expected by the claims-based measure
- Among 9 hospitals rated Better than expected by the claims-based measure, 3 (33%) were rated No different as expected by the registry-based measure
- Among 14 hospitals rated Worse by the registry model, 6 (42.9%) were rated No different by the claims model
- Among 13 programs rated Worse by the claims model, 5 (38.5%) were rated No different by the registry model
- Among 801 hospitals rated No different by the registry model, 3 (0.4%) were rated Better and 5 (0.6%) were rated Worse by the claims model
- Among 807 hospitals rated No different by the claims model, 8 (1%) were rated Better and 6 (0.7%) were rated Worse by the registry model
- 57 of 829 hospitals (7.0%) had greater than a 1% absolute difference in RSRR calculated by the claims-based versus registry-based measures and 8 of these 57 had discordant performance categories
- 90 of 829 hospitals (11%) had relative differences of >5% between methods, and 8 (1%) hospitals had relative differences of >10% and 11 of these 90 had discordant performance categories
- Reason for differences in performance category assigned by the two different measures are likely differences in the risk adjustment (registry-based measure uses clinical data at the time of the index admission and claims-based measure uses 12 months of administrative claims data plus claims from the index admission)
- Risk-adjustment variables in the claims and registry readmission models capture different frequencies of comorbidities but produce nearly identical c-statistics

3. "Real world" Comparison of the Administrative Claims-Based Readmission Measure and the Registry-Based CABG Readmission Measure (claims measure cohort and risk model compared to registry measure cohort and risk model)

Overview and Methods:

The previous validation analyses used a common patient cohort, thereby isolating the validation analysis to differences in the risk algorithms. However, there are likely additional differences in hospital performance classification that would be observed if the claims and registry cohorts were used rather than the common cohort—these are the differences that would actually be observed if the overall claims-based measure or registry measure were implemented as they would be in an actual practice (i.e., there would be differences in performance assessments resulting from both the different cohorts and different risk models).

To perform this "real-life" comparison, we evaluated hospital-level performance results in two different ways: (1) application of the administrative claims-based CABG readmission measure to the administrative isolated CABG measure cohort; (2) application of the registry-based CABG readmission measure in the STS registry isolated CABG cohort. While there is no "gold standard" for this analysis, these results will provide CMS and the public with information about how hospital performance assessments might differ depending upon which readmission measure is implemented. We have termed this comparison "real world," although it is limited to only those hospitals participating in the STS registry and with sufficient volume for stable estimates for this analysis.

Creation of Registry-Based Measure Cohort: The registry-based cohort included CMS inpatient records with an ICD-9 procedural code for CABG during 2008-2010 that were linked to the STS database and met the criteria in Table 3.1 (final cohort: 162,572 admissions from 1,012 hospitals). This cohort was used for estimating the registry-based hierarchical risk-adjustment model. Although all 162,572 admissions and 1,012 hospitals were included and contributed to parameter estimation, hospital-specific results were only reported and analyzed for the following smaller subsets of hospitals:

(1) 846 hospitals having at least 30 cases in the registry-based cohort and at least 90% of eligible CMS records linked to the STS registry;

(2) 838 hospitals having at least 30 cases in each of the two cohorts and at least 90% of eligible CMS records linked to the STS registry.

The thresholds of ≥30 cases and linkage rate ≥90% were adopted for exploratory analyses for the purpose of developing and pilot testing the registry-based measure. Different thresholds may be selected for implementation if the measure is adopted.

Creation of Claims-Based Measure Cohort: Inclusion criteria for the claims-based cohort are detailed in Sections 2.4 and 2.5 of the claims-based readmission Measure Methodology Report. As shown in Table 3.2, a total of 175,891 index CABG admissions at 1,197 hospitals were included in the cohort for 2008-2010. Hospital-specific results were reported and analyzed for all 1,197 hospitals and for the subset of 838 hospitals that had at least 30 cases in each of the two cohorts and a linkage rate of at least 90% in the registry-based cohort. This cohort excluded 8 hospitals with at least 30 cases in the registry-based cohort but not the claims-based cohort.

Analysis: The distribution of hospital-specific RSRRs for each measure were summarized by percentiles and plotted as histograms. For the registry-based measure, only results from hospitals (n = 846) with at least 30 cases in the registry-based cohort and with at least 90% linkage to STS were included in the summary. Agreement between claims-based versus registry-based RSRRs and performance categories was assessed using plots and summary measures similar to the "matched cohort" analysis reported in Section 2 above. For this "real-world" comparison, neither measure is assumed to be the gold standard. For analyses assessing agreement between two sets of measures at the hospital-level, only hospitals (n = 838) with at least 30 eligible cases in each of the 2 cohorts and at least a 90% STS-CMS linkage in the registry-based cohort were included.

Results:

Table 3.1 and Table 3.2 present the derivation of the "real world" comparison sample. The numbers of exclusions for specific exclusion criteria listed below differ between measures due to the order in which they were excluded; for simplicity, the exclusions are listed in descending order of magnitude for both measures. Table 3.3 and Figure 3.1 present the distribution of RSRRs produced by the two models in their respective hospital subsets. There is nearly complete overlap between the measure result distributions. The median hospital-level RSRR was 16.8% for the registry-based measure versus 16.9% for the claims-based measure. Figure 3.2 represents a scatterplot of the hospital-level RSRRs produced by both measures in the subset of 838 hospitals with at least 90% of CABG admissions linked to STS and at least 30 cases per hospital in both measures, where each dot represents a single hospital. The correlation between the RSRRs produced by the two measures was 0.885. Table 3.3 summarizes the estimated Pearson's correlation and intraclass correlation coefficients (ICC) between the two measures at different volume cut-offs.

Table 3.1: Derivation of registry-based measure cohort (from 410,741 CABG admissions in 1,210 hospitals between 2008 and 2010)

Cohort Exclusions	Admissions Excluded	Hospitals Excluded
Age 65+ at discharge and eligible for Medicare FFS for at least 1 month or until month of death	131,695	0
Patients with non-isolated CABG procedures	64,388	0
Patients at hospitals insufficiently linked to STS Registry	38,474	160
Patients who died during index CABG admission	12,776	0
Patients with incomplete transfer chain discharge or readmission information or an index admission > 1 year in duration	627	0
Patients at hospitals with fewer than 10 CABG cases between 2008-2010	107	38
Patients who left against medical advice	101	0
Admissions for patients undergoing a subsequent qualifying isolated CABG procedures during the measurement period (only the first qualifying procedure is included in the measure cohort; subsequent procedures cannot be additional index admissions)	1	0
Final *Registry* Cohort for "Real World" Comparison	**Final No. of Admissions**	**Final No. of Hospitals**
	162,572	**1,012**

Table 3.2: Derivation of claims-based measure cohort (from 410,741 CABG admissions in 1,210 hospitals between 2008 and 2010)

Cohort Exclusions	Admissions Excluded	Hospitals Excluded
Patients <65 without continuous Medicare FFS enrollment for 12 months prior to index CABG admission and at least 30 days post-discharge AND Patients with non-isolated CABG procedures†	405,866	13
Patients who died during index CABG admission	4,811	0
Patients who left against medical advice	55	0
Admissions for patients undergoing a subsequent qualifying isolated CABG procedures during the measurement period (only the first qualifying procedure is included in the measure cohort; subsequent procedures cannot be additional index admissions)	9	0
Final *Claims* Cohort for "Real World" Comparison	**Final No. of Admissions**	**Final No. of Hospitals**
	175,891	**1,197**

† In 2009 development sample, 28% of patients ≥65 years with adequate Medicare FFS enrollment and a CABG procedure code (36.1x) were excluded due to concomitant non-isolated CABG (other major cardiac, thoracic or vascular) procedures

Table 3.3: Distribution of RSRRs (2008-2010 "real world" respective measure cohorts)

Model	N	Minimum	25th Percentile	Median	75th Percentile	Maximum	Performance Category	
							Better than national rate, N (%)	Worse than national rate, N (%)
Claims-Based	1,197	12.5	15.9	16.9	18.0	22.4	14 (1.2)	18 (1.5)
Registry-Based	846	12.6	15.6	16.8	18.1	23.6	25 (3.0)	27 (3.2)

Figure 3.1: Distribution of Hospital-Level Registry- and Claims-Based Model RSRRs
(2008-2010 "real world" measure cohorts: for registry-based model, results are summarized for the subset of 846 hospitals with at least 30 cases in the registry cohort and at least a 90% match rate of CMS records)

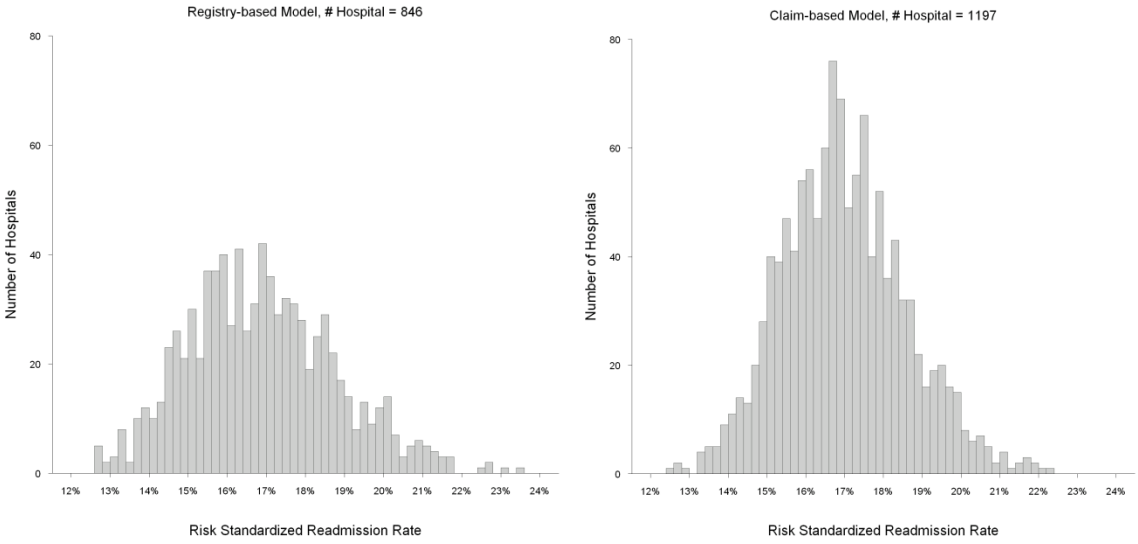


Figure 3.2: Comparison of Risk-Standardized Readmission Rates Based on Registry- and Claims-Based Models (2008-2010 "real world" measure cohorts in subset of 838 hospitals with at least 30 eligible cases in each cohort and at least a 90% match rate to STS registry)

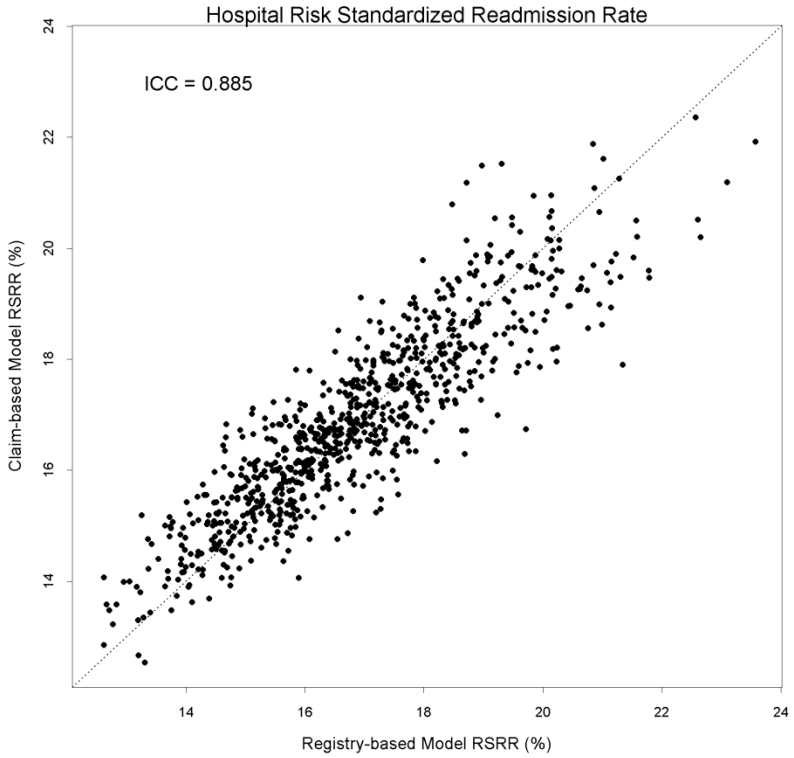


Table 3.4: Unweighted Correlation of Hospital Rankings of RSRR's from Registry- and Claims-Based Models According to Different Volume Cut-Offs (2008-2010 "real world" measure cohorts in subset of 838 hospitals with at least 30 eligible cases in each cohort and at least a 90% match rate to STS registry)

	Pearson Correlation	Intraclass Correlation‡	Spearman Rank Correlation
Overall	0.892	0.885	0.897
< 100 patients per hospital	0.907	0.894	0.901
100 to < 185 patients per hospital	0. 883	0.880	0.892
≥ 185 patients per hospital	0.891	0.880	0.892

‡ Formula (2,1) from Shrout, Patrick E. and Fleiss, Joseph L. Intraclass correlations: uses in assessing rater reliability. *Psychological Bulletin*, 1979, 86, 420-3428

Table 3.5, Table 3.6 and Table 3.7 summarize the results of the reclassification analysis. Although we are not assuming either measure is the gold standard for this analysis, for ease of comparison we use a 3-by-3 table similar to the reclassification table in Step 2, Table 2.3. The table compares the performance categories produced by each measure, defined with 95% interval estimates around each hospital's RSRR. If the lower bound of the 95% CI is higher than the population average readmission rate of 16.8% (in all 1,012 hospitals, for registry-based measure) or 16.9% (in all 1,197 hospitals, for claim-based measure), the hospital is considered Worse than expected. If the upper bound is lower than the population rate, the hospital is considered Better than expected. Other hospitals are considered No different than expected.

Overall agreement between measures was 95.1% (797 out of 838 hospitals received identical performance categorization by both measures). No hospitals were rated as performing Worse than expected by the claims-based measure and Better than expected by the registry-based measure (or vice versa).

Of 59 total outliers identified by one or both models, 41 were discordant:

- Among 25 hospitals rated Better than expected by the registry-based measure, 15 (60%) were rated No different than expected by the claims-based measure
- Among 11 hospitals rated Better than expected by the claims-based measure, 1 (9%) was rated No different than expected by the registry-based measure
- Among 27 hospitals rated Worse by the Registry model, 19 (70.4%) were rated No different than expected by the Claims model
- Among 14 programs rated Worse by the claims model, 6 (42.9%) were rated No different than expected by the registry model.

Of the 838 hospitals in the "real world" comparison sample, 188 (22.4%) had >1% absolute difference in RSRR by the two measures, but only 27 of these had discordant performance categorization; 22 (2.6%) had >2% absolute difference in RSRR, of whom 12 had discordant performance categorization (Table 3.5). On a relative scale, 239 hospitals (28.5%) had relative differences in their RSRR >5% and 49 hospitals (5.9%) had relative differences >10% (Table 3.6). Of 239 hospitals with >5% relative difference, only 32 changed performance categories.

Table 3.5: Comparison of Hospital Performance Categories Based on Registry and Claims-Based Models (2008-2010 "real world" measure cohorts in subset of 838 hospitals with at least 30 eligible cases in each cohort and at least a 90% match rate to STS registry) **– No gold standard assumed**

		Registry-Based CABG Readmission Measure			
		Better than expected	**No different than expected**	**Worse than expected**	**Total**
Claims-Based CABG Readmission Measure	**Better than expected**	10	1	0	**11**
	No different than expected	15	779	19	**813**
	Worse than expected	0	6	8	**14**
	Total	**25**	**786**	**27**	**838**

Table 3.6: Number of Hospitals with *Absolute* Difference in RSRR's Exceeding 1%, 2%, 3%, or 4%
(2008-2010 "real world" measure cohorts in subset of hospitals with at least 30 eligible cases in each cohort and at least a 90% match rate to STS registry)

Absolute Difference in RSRRs	>1%	>2%	>3%	>4%
Number of Hospitals	188	22	1	0
Percent of Hospitals	22.4%	2.6%	0.1%	0%
Number of Hospitals that Changed Performance Category (e.g., Better by claims and No different by registry)	27	12	1	0

Table 3.7: Number of Hospitals with *Relative* Difference in RSRR's Exceeding 5%, 10%, 15%, or 20%
(2008-2010 "real world" measure cohorts in subset of hospitals with at least 30 eligible cases in each cohort and at least a 90% match rate to STS registry)

Absolute Difference in RSRRs	>5%	>10%	>15%	>20%
Number of Hospitals	239	49	2	0
Percent of Hospitals	28.5%	5.9%	0.2%	0%
Number of Hospitals that Changed Performance Category (e.g., Better by claims and No different by registry)	32	14	1	0

Discussion of difference in results

There are several reasons why the two readmission measures may produce different results. These reasons can be categorized as cohort differences, outcome differences and risk-adjustment differences:

Cohort Differences at the Hospital Level: The registry measure as specified for this comparison excluded 38 hospitals with fewer than 10 CABG admissions in the CMS database during the measurement period and an additional 160 hospitals that did not participate in the STS database during the measurement period. The claims-based measure retained these hospitals. Since the measures assess each hospital's performance relative to other hospitals caring for similar patients, a difference in the hospitals included in the measure will lead to differences in results.

Cohort Differences at the Patient Level: The registry measure excludes all MAZE procedures and the claims measure excludes only open MAZE procedures. There remains limited consensus among clinicians and methodologists as to how best to identify and handle these diverse procedures for quality measurement. For the claims-based measure, CORE chose to exclude only those procedures that are likely to represent greater technical complexity and carry greater inherent risk; for the registry-based measure, STS chose to exclude all such procedures until it can better differentiate between those that represent greater clinical risk and those that do not. Both measure developers will continue to examine these procedures in the future as needed. As demonstrated above, this discordance produced only a small difference in the measure cohorts.

Further, the cohort validation demonstrated other inconsistencies that may indicate either registry data abstraction or claims coding errors (such as patients with a valve procedure documented in registry data, but only an isolated CABG procedure documented within claims). In a few cases, the two measures differed in their handling of inconsistent and illogical data.

Outcome Differences: The claims-based measure designates certain rare readmissions as planned and excludes them from the outcome; the registry measure does not.

Risk-Adjustment Differences: The risk-adjustment validation demonstrated that differences in model risk adjustment alone lead to differences in results.

Summary Results for "Real World" Comparison of Registry- and Claims-Based CABG Readmission Measures:

- There is no gold standard for this analysis since differences in performance categorization between the two measures in this analysis may be due to differences in cohort definition at the hospital and/or patient level, outcome differences and/or differences in the risk-adjustment models
- Both measures display similar distributions in hospital RSRRs following CABG
- Overall agreement was 95% (797 of 829 hospitals had concurrent performance categorization) and the correlation of RSRRs was 0.89
- No hospitals were rated as performing Worse than expected by the claims-based measure and Better than expected by the registry-based measure (or vice versa)
- Among 25 hospitals rated Better than expected by the registry-based measure, 15 (60%) were rated No different than expected by the claims-based measure
- Among 11 hospitals rated Better than expected by the claims-based measure, 1 (9%) was rated No different than expected by the registry-based measure
- Among 27 hospitals rated Worse by the Registry model, 19 (70.4%) were rated No different by the Claims model
- Among 14 programs rated Worse by the claims model, 6 (42.9%) were rated No different by the registry model
- Among 786 hospitals rated No different by the registry model, 1 (0.1%) was rated Better and 6 (0.8%) were rated Worse by the claims model
- Among 813 hospitals rated No different by the claims model, 15 (1.9%) were rated Better and 19 (2.3%) were rated Worse by the registry model
- 188 of 838 hospitals (22.4%) had greater than a 1% absolute difference in RSRR calculated by the claims-based versus registry-based measures and, of these, 27 changed performance categorization
- 239 of 838 hospitals (28.5%) had relative differences of the absolute differences of >5% between methods and, of these, 32 changed performance categorization
- There is no "gold standard" for this comparison

Consensus Summary of Comparison of Claims-Based and Registry-Based CABG Readmission Measures

Through close collaboration and harmonization, and with input from a national technical expert panel, the measure developers of the claims-based and registry-based CABG readmission measures have created two outcome measures for assessing hospital performance following hospitalization for isolated CABG procedures. When compared in a match set of patients where the registry measures constituted the gold standard, the two measures categorize some hospitals differently (see Reclassification Table 2.5), despite the similar discriminatory ability of the models. The measures showed greater differences when compared in a real-world comparison where each model was applied to its respective patient cohort but where there is no accepted gold standard.

The measures have relative strengths and weaknesses for potential use in public reporting. The strengths of the claims-based measure include its feasibility and inclusion of all hospitals. The strengths of the registry measure include its face validity and depth of clinical information. These and other attributes of the measures merit further consideration in planning for their use.

ADDITIONAL DISCUSSION FROM THE STS PERSPECTIVE

1. Through extensive clinician input, the claims-based procedure specification algorithm used in this study produced a cohort of isolated CABG patients that was more similar to the clinical cohort than in previously published analyses.[1,2]

2. Both the claims and clinical-based readmission models have inferior discrimination compared with models for other outcomes such as mortality. This has been a consistent finding among several previously reported readmission risk models used for profiling. Readmission risk is impacted not only by traditional patient clinical risk factors but also by factors not included (by convention) in profiling models, such as race and ethnicity, socioeconomic status, past frequency of hospital admissions, and community resources. Furthermore, the adequacy of a regression model should be assessed in relation to a particular purpose. In the current instance, our purpose was to compare readmission rates across hospitals while minimizing confounding bias from variation in case mix. In this context, it is possible for a regression model to exhibit low discrimination but still achieve the specific goal of reducing bias, as can be readily demonstrated using Monte Carlo simulations.

3. For the primary validation analyses in this study, it was agreed that we would use a matched cohort of patients. For the reasons outlined in Section 6 of this summary, it was agreed that the results of the STS model applied to that cohort would be considered the “gold standard.”

4. When the claims and clinical measures were applied to the same cohort of patients, there was overall strong correlation between the two sets of hospital performance estimates (RSRRs). However, STS believes that overall correlation is an inadequate validation metric. For example, despite a strong global association, there were differences at the level of individual hospitals. For example, 63 of 829 hospitals (7.6%) had greater than a 1% **absolute** difference in RSRRs calculated by the claims-based versus registry-based measures; 90 of 829 hospitals (11%) had **relative** differences of >5% between methods, and 8 (1%) hospitals had **relative** differences of >10%, although this does not take into account the known uncertainty of the RSRR point estimates.

4. In addition to estimating RSRRs, the current CMS methodology also assigns each hospital to one of three performance categories (“Better than U.S. National Rate”, “No Different Than U.S. National Rate”,

"Worse Than U.S. National Rate"). Such classifications have substantial implications for consumer choice, payer tiering and/or center of excellence designation, and reimbursement. Thus, one of our objectives was to assess agreement between hospital performance category assignments derived from the clinical-based measure (reference standard) to those derived from the claims-based measure. This type of analysis is supported by an AHA Scientific Statement which states: *"In addition, models developed from administrative data should be validated against a model with a more comprehensive description of the patients' clinical conditions, such as medical record data. This validation should include a comparison of how much agreement in classification exists between the administrative and 'gold standard' models."*[3]

As shown in Table 2.5, using the claims-based model led to differences in hospital performance categories compared with results derived from the clinical-based measure. Among hospitals that were outliers by one or the other model, 33-57% changed from outlier to "No different" or vice versa when using the other classification system. Sensitivity of the claims models to correctly classify "Better" or "Worse" than expected performance ranged from 43 to 57%. These findings are highly relevant, as the current *Hospital Compare* default reporting format displays performance categories, and does not emphasize the underlying RSRR or its associated 95% interval estimator. The observed differences were even greater in the "real world" comparison.

5. CMS will ultimately decide how to interpret these findings and implement these measures. No guidelines exist, to our knowledge, as to how much agreement or disagreement between models and classification results should be considered acceptable. However, differences of the magnitude observed in this validation study may be disconcerting for STS Database participants, who constitute the vast majority of US cardiac surgical programs.

6. STS clinical-based measure strengths and limitations

Strengths

- Broad acceptance by hospitals, surgeons, payers and the public
- 22-year track record of collecting detailed clinical data to improve outcomes
- National leader in voluntarily reporting detailed surgical outcomes (collaboration with *Consumer Reports*)
- Over 90% national penetration
- Highly granular, clinical data collected according to standardized, detailed data specifications, updated every 3 years to reflect evolving clinical science and national standards
- Data collection and entry by trained abstractors; extensive support available when needed
- Independent data warehouse/analysis center at Duke Clinical Research Institute
- Routine internal data quality checks
- External site audits by Telligen; currently 5% of programs annually, increasing to 8% in 2013; results consistently demonstrate high accuracy and completeness
- Broad experience developing risk models and NQF-endorsed performance measures (fully transparent and published in peer-reviewed publications)

Limitations

- Remaining <10% non-participants nationally
- Voluntary participation
- Cost of participation and data collection for sites not already participating (<10%)

ADDITIONAL DISCUSSION FROM THE CORE PERSPECTIVE

The close collaboration with STS and extensive clinical input produced two very highly correlated and scientifically valid hospital-level measures of readmission following isolated CABG surgery.

The claims-based measure successfully defines the cohort of isolated CABG patients.

The claims-based cohort definition of isolated CABG was nearly identical to that assigned by registry data. The level of agreement greatly exceeded that of previous efforts for CABG.[1] The discrepant patients were either due to expected differences due to the respective measure cohort definitions (e.g., MAZE procedures, which are handled differently in the two measures) or to reasons that cannot be clearly ascribed to errors or inadequacies in the claims-based definition.

The risk-adjustment validation provides evidence of the claims-based measure's scientific soundness.

The risk-adjustment validation produced a substantial correlation of RSRRs between the two measures in a matched cohort of patients, with an intraclass correlation coefficient of 0.92. When hospitals were categorized as "Better", "Worse" or "No different" than average as noted above, over 97% (807 of 829) of hospitals in the matched cohort were categorized identically by the two measures (the vast majority were considered "No different than average" by either measure). Twenty-two hospitals were assigned to an outlier category ("Better" or "Worse") by one measure but not by the other; however, no hospital was rated as "Better" by one measure and "Worse" by the other (or vice versa). The individual RSRRs estimated by the claims-based measure for the 22 hospitals with discordant performance categorization all fell within the 95% interval estimates for the RSRR estimated by the registry-based measure.

As illustrated in Figure 2.3 and Figure 2.4, the visual inspection of hospital performance by the two measures confirms that, even where there is disagreement in the performance category, the measures profile hospitals similarly -- all better performing hospitals (those with either their claims- or registry-based interval estimates below the national rate) have RSRRs for both measures well below the national readmission rate); conversely, the worse performing hospitals (those with either their claims- or registry-based interval estimates above the national rate) have RSRRs for both measures well above the national rate. The differences in the results could have implications for a small number of individual hospitals if these classifications are used for assigning payments or penalties. The implications of the differences will depend on the specifics of the public reporting and/or payment programs using the results and merit careful consideration.

Finally it is important to note that the validation of the claims-based measure risk adjustment is only generalizable to STS hospitals. Because the STS registry does not capture all patients in all hospitals, and because non-STS hospitals do not represent a random sample of hospitals (see Appendix), the validation results reported in this document only provide information as to the performance of the claims-based measure in STS hospitals. The risk model used in the claims-based measure uses information from both STS and non-STS hospitals in selecting and estimating the impact of risk variables, but, as the STS model is only developed in STS hospitals, this validation work cannot assess the performance of the claims-based measure in other hospitals. However, the STS registry represents the largest and most comprehensive dataset available for this type of validation.

The "real world" validation has no gold standard.

We concur that it is important to consider the different results achieved with each model in their respective cohorts. However, the "real world" validation has no accepted gold standard and, as such, any measurement discordance cannot be intrinsically interpreted as either right or wrong, or acceptable or unacceptable – these assessments require an interpretation of the data and may vary among different individuals and organizations.

The measures have trade-offs – while the registry-based measure carries greater risk-adjustment face validity and acceptance among clinicians than the claims-based measure, it does not capture all patients undergoing isolated CABG, imposes a greater data collection burden on hospitals and offers additional opportunities for data errors. We still lack an ideal situation in which highly accurate clinical data, consistently collected in a standardized fashion across all hospitals performing these procedures are provided in a form that is amenable to their use in risk models.

Claims-Based CABG Readmission Measure Strengths

- Provides assessment for all hospitals treating Medicare FFS patients
- Uses precise unique identifier to link to outcome (versus probabilistic match)
- Risk adjustment contains comprehensive variables including risk factors occurring prior to the index admission
- Less subject to gaming
- Systematically audited
- Data for measure generated as part of routine business, at no additional cost to hospitals

Claims-Based CABG Readmission Measure Weaknesses

- Cohort may be less specific than that defined by clinical data, although cohort validation showed a high level of agreement and discrepant cases could not be definitively assigned to errors in the claims-based cohort definition
- Risk variables have limited specificity and less face validity among clinicians
- Present On Admission (POA) codes are evolving and currently not used consistently across hospitals

VALIDATION REPORT APPENDIX: COMPARISON OF STS REGISTRY AND NON-STS REGISTRY HOSPITALS

In order to examine differences between hospitals included in the validation analyses (i.e., those participating in the STS registry) and nonparticipants, we examined the frequency and impact of risk variables in the full claims-based readmission measure cohort ("full sample") and compared it to the subgroups of registry participants ("STS hospitals") and nonparticipants ("non-STS hospitals"). We also examined the distribution of raw and risk-standardized readmission and mortality rates (Table III and Table IV) and hospital volume (Table V) across these subgroups. In addition, we examined the geographic distribution of non-STS hospitals, as well as other characteristics (Table VI).

The model performance is identical (c statistic = 0.624) in all three groups. Non-STS hospitals have higher readmission and mortality rates (Table I and Table II) and tend to be smaller volume hospitals (Table III). While all risk variables in the readmission and mortality models have similar frequencies (Table IV and Table V), the estimates for the variables differ somewhat when you look at STS versus non-STS hospitals. However, no variable in the readmission model carries opposite risk in the two subgroups; only the Decubitus Ulcer or Chronic Skin Ulcer risk variable in the mortality model had an opposing effect in the non-STS hospitals (OR 0.90, 95% CI 0.59-1.39) as compared to the STS hospitals (OR 1.27, 95% CI 1.12-1.44), but the confidence interval was not statistically significant. Non-STS hospitals are found in all regions of the U.S., but are concentrated in the South and only four are located in rural areas (Table VI). Forty percent of non-STS hospitals are teaching hospitals and 33% are safety net hospitals.

Table I: Distribution of readmission rates in hospitals participating in 2008-2010 STS registry ("STS hospitals") and those not participating in registry ("non-STS hospitals")

	Mean		Minimum		10th percentile		25th percentile		Median		75th percentile		90th percentile		Maximum	
	Raw	RSRR	Raw	RSRR	Raw	RSRR	Raw	RSRR	Raw	RSRR	Raw	RSRR	Raw	RSRR	Raw	RSRR
Full sample (n=175,891 admissions at 1,197 hospitals)	17.8	17.0	0.0	12.5	10.4	15.0	13.6	15.9	16.8	16.9	20.8	18.0	25.3	19.1	100.0	22.4
STS hospitals (n=163,501 admissions at 1,012 hospitals)	17.3	16.9	0.0	12.6	10.9	14.9	13.6	15.7	16.7	16.7	20.4	17.9	24.3	19.0	66.7	22.1
non-STS hospitals (n=12,840 admissions at 185 hospitals)	20.2	18.4	0.0	13.0	0.0	15.9	13.4	17.3	18.1	18.2	24.4	19.4	33.3	20.7	100.0	25.5

Table II: Distribution of mortality rates in hospitals participating in 2008-2010 STS registry ("STS hospitals") and those not participating in registry ("non-STS hospitals")

	Mean		Minimum		10th percentile		25th percentile		Median		75th percentile		90th percentile		Maximum	
	Raw	RSMR	Raw	RSMR	Raw	RSMR	Raw	RSMR	Raw	RSMR	Raw	RSMR	Raw	RSMR	Raw	RSMR
Full Sample (n=182,191 admissions at 1,197 hospitals)	3.8	3.3	0.0	1.5	0.0	2.4	1.8	2.7	3.0	3.1	4.7	3.7	6.9	4.4	100.0	8.2
STS hospitals (n=167,958 admissions at 1,012 hospitals)	3.4	3.2	0.0	1.5	0.7	2.3	1.8	2.7	2.9	3.1	4.5	3.7	6.5	4.3	25.0	8.2
non-STS hospitals (n=13,333 admissions at 185 hospitals)	5.5	4.0	0.0	2.1	0.0	3.1	0.0	3.6	3.6	3.9	6.6	4.5	9.8	5.1	100.0	7.3

Table III: Distribution of hospital volume in hospitals participating in 2008-2010 STS registry ("STS hospitals") and those not participating in registry ("non-STS hospitals")

	Mean	Minimum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Maximum
	N	N	N	N	N	N	N	N
Full Sample (n=175,891 admissions at 1,197 hospitals)	146.9	1	28	57	112	193	305	969
STS hospitals (n=163,501 admissions at 1,012 hospitals)	161.8	2	39	69	128	212	333	969
non-STS hospitals (n=12,840 admissions at 185 hospitals)	67.9	1	3	16	46	89	164	571

Table IV: Frequency and estimates of claims-based CABG readmission model estimates in hospitals participating in STS registry ("STS hospitals") and those not participating in registry ("non-STS hospitals")

Readmission Risk Factors in STS and non-STS hospitals	2008-2010 Full Sample (n=175,891 admissions at 1,197 hospitals)					2008-2010 STS hospitals (n=163,051 admissions at 1,012 hospitals)					2008-2010 non-STS hospitals (n=12,840 admissions at 185 hospitals)				
Variable	**Freq. (%)**	**Est.**	**SE**	**OR**	**95% CI**	**Freq. (%)**	**Est.**	**SE**	**OR**	**95% CI**	**Freq. (%)**	**Est.**	**SE**	**OR**	**95% CI**
Demographics															
Age-65 (Continuous)		0.03	0.00	1.03	(1.02-1.03)		0.03	0.00	1.03	(1.02-1.03)		0.02	0.00	1.02	(1.01-1.03)
Male	120,576 (68.6)	-0.26	0.01	0.77	(0.75-0.79)	111,909 (68.6)	-0.26	0.01	0.77	(0.75-0.79)	8,667 (67.5)	-0.18	0.05	0.83	(0.76-0.92)
Comorbidities															
History of Prior CABG or Valve Surgery	9,575 (5.4)	0.03	0.03	1.03	(0.97-1.08)	8,887 (5.5)	0.03	0.03	1.03	(0.97-1.09)	688 (5.4)	0.01	0.10	1.01	(0.83-1.23)
Cardiogenic Shock (ICD-9 Code 785.51)	6,283 (3.6)	0.29	0.03	1.34	(1.26-1.42)	5,841 (3.6)	0.30	0.03	1.35	(1.27-1.44)	442 (3.4)	0.18	0.12	1.20	(0.95-1.51)
COPD (CC108)	41,586 (23.6)	0.22	0.02	1.25	(1.21-1.28)	38,295 (23.5)	0.21	0.02	1.24	(1.20-1.28)	3,291 (25.6)	0.29	0.05	1.34	(1.20-1.48)
Renal Failure (CC131)	22,826 (13.0)	0.28	0.02	1.32	(1.27-1.37)	21,152 (13.0)	0.27	0.02	1.31	(1.26-1.37)	1,674 (13.0)	0.32	0.07	1.38	(1.21-1.58)
Diabetes and DM Complications(CC 15-20, 119, 120)	79,981 (45.5)	0.14	0.01	1.15	(1.13-1.19)	73,854 (45.3)	0.14	0.01	1.15	(1.12-1.18)	6,127 (47.7)	0.18	0.05	1.19	(1.08-1.31)
Obesity/Disorders of Thyroid, Cholesterol, Lipids (CC 24)	148,907 (84.7)	-0.16	0.02	0.85	(0.83-0.88)	138,266 (84.8)	-0.16	0.02	0.85	(0.82-0.89)	10,641 (82.9)	-0.14	0.06	0.87	(0.77-0.98)
Congestive Heart Failure (CC 80)	33,815 (19.2)	0.19	0.02	1.22	(1.18-1.26)	31,126 (19.1)	0.20	0.02	1.22	(1.18-1.27)	2,689 (20.9)	0.11	0.06	1.12	(1.00-1.26)
Arrhythmias (CC 92-93)	46,705 (26.6)	0.12	0.01	1.13	(1.10-1.16)	43,205 (26.5)	0.13	0.02	1.14	(1.10-1.17)	3,500 (27.3)	0.06	0.05	1.06	(0.95-1.17)
Other Lung Disorders (CC 115)	58,782 (33.4)	0.08	0.01	1.09	(1.06-1.12)	54,560 (33.5)	0.09	0.01	1.09	(1.06-1.12)	4,222 (32.9)	0.05	0.05	1.05	(0.95-1.16)
Major Psychiatric Disorders (CC 54-56)	5,533 (3.2)	0.21	0.03	1.23	(1.15-1.32)	5,073 (3.1)	0.22	0.04	1.25	(1.16-1.34)	460 (3.6)	0.08	0.12	1.09	(0.86-1.37)

Readmission Risk Factors in STS and non-STS hospitals	2008-2010 Full Sample (n=175,891 admissions at 1,197 hospitals)					2008-2010 STS hospitals (n=163,051 admissions at 1,012 hospitals)					2008-2010 non-STS hospitals (n=12,840 admissions at 185 hospitals)				
Variable	**Freq. (%)**	**Est.**	**SE**	**OR**	**95% CI**	**Freq. (%)**	**Est.**	**SE**	**OR**	**95% CI**	**Freq. (%)**	**Est.**	**SE**	**OR**	**95% CI**
Vascular or Circulatory Disease (CC 104-106)	57,776 (32.9)	0.10	0.01	1.10	(1.07-1.13)	53,268 (32.7)	0.10	0.02	1.10	(1.07-1.13)	4,508 (35.1)	0.11	0.05	1.12	(1.01-1.24)
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	26,212 (14.9)	0.18	0.02	1.20	(1.15-1.24)	24,314 (14.9)	0.18	0.02	1.20	(1.16-1.24)	1,898 (14.8)	0.16	0.07	1.17	(1.03-1.34)
Pneumonia (CC 111-113)	21,102 (12.0)	0.18	0.02	1.20	(1.16-1.25)	19,363 (11.9)	0.18	0.02	1.19	(1.15-1.24)	1,739 (13.5)	0.25	0.07	1.29	(1.13-1.46)
Cerebrovascular Disease (CC 97-99, 103)	47,455 (27.0)	-0.06	0.02	0.94	(0.91-0.97)	44,219 (27.1)	-0.06	0.02	0.94	(0.91-0.97)	3,236 (25.2)	-0.07	0.06	0.94	(0.84-1.05)
Polyneuropathy (CC 71)	11,760 (6.7)	0.17	0.02	1.19	(1.13-1.25)	10,910 (6.7)	0.18	0.03	1.19	(1.14-1.25)	850 (6.6)	0.12	0.09	1.13	(0.95-1.34)
Protein-Calorie Malnutrition (CC 21)	5,108 (2.9)	0.21	0.03	1.23	(1.15-1.32)	4,729 (2.9)	0.20	0.04	1.22	(1.14-1.31)	379 (3.0)	0.29	0.12	1.34	(1.06-1.70)
Severe Hematological Disorders (CC 44)	1,759 (1.0)	0.29	0.06	1.34	(1.20-1.50)	1,629 (1.0)	0.30	0.06	1.35	(1.20-1.51)	130 (1.0)	0.26	0.21	1.30	(0.86-1.95)
Fibrosis Of Lung And Other Chronic Lung Disorders (CC 109)	8,250 (4.7)	0.07	0.03	1.07	(1.01-1.13)	7,655 (4.7)	0.07	0.03	1.07	(1.01-1.13)	595 (4.6)	0.09	0.10	1.09	(0.89-1.34)
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	5,446 (3.1)	0.27	0.03	1.31	(1.23-1.39)	4,987 (3.1)	0.27	0.03	1.31	(1.23-1.41)	459 (3.6)	0.22	0.11	1.25	(1.00-1.56)
End-Stage Renal Disease Or Dialysis (CC 130)	2,180 (1.2)	0.31	0.05	1.36	(1.23-1.50)	1,991 (1.2)	0.31	0.05	1.36	(1.23-1.51)	189 (1.5)	0.27	0.17	1.31	(0.94-1.83)
Hemiplegia, Paraplegia, Paralysis, Functional Disability (CC 67-69, 100-102)	4,954 (2.8)	0.11	0.04	1.12	(1.04-1.20)	4,572 (2.8)	0.08	0.04	1.08	(1.00-1.17)	382 (3.0)	0.46	0.12	1.59	(1.25-2.02)
Stroke (CC 95-96)	8,368 (4.8)	0.09	0.03	1.10	(1.04-1.17)	7,725 (4.7)	0.09	0.03	1.10	(1.03-1.17)	643 (5.0)	0.10	0.10	1.10	(0.90-1.35)

Readmission Risk Factors in STS and non-STS hospitals	2008-2010 Full Sample (n=175,891 admissions at 1,197 hospitals)					2008-2010 STS hospitals (n=163,051 admissions at 1,012 hospitals)					2008-2010 non-STS hospitals (n=12,840 admissions at 185 hospitals)				
Variable	**Freq. (%)**	**Est.**	**SE**	**OR**	**95% CI**	**Freq. (%)**	**Est.**	**SE**	**OR**	**95% CI**	**Freq. (%)**	**Est.**	**SE**	**OR**	**95% CI**
Dementia or Senility (CC 49-50)	8,537 (4.9)	0.15	0.03	1.17	(1.10-1.23)	7,878 (4.8)	0.15	0.03	1.17	(1.10-1.23)	659 (5.1)	0.15	0.10	1.17	(0.96-1.41)
Cancer (CC 7-12)	34,375 (19.5)	0.01	0.02	1.01	(0.97-1.04)	31,928 (19.6)	0.01	0.02	1.01	(0.98-1.04)	2,447 (19.1)	-0.04	0.06	0.97	(0.86-1.09)

Table V: Frequency and estimates of claims-based CABG mortality model estimates in hospitals participating in STS registry ("STS hospitals") and those not participating in registry ("non-STS hospitals")

Mortality Risk Factors in STS and non-STS hospitals	2008-2010 Full Sample (n=182,191 admissions at 1,197 hospitals)					2008-2010 STS hospitals (n=167,958 admissions at 1,012 hospitals)					2008-2010 non-STS hospitals (n=13,333 admissions at 185 hospitals)				
Variable	**Freq. (%)**	**Est.**	**SE**	**OR**	**95% CI**	**Freq. (%)**	**Est.**	**SE**	**OR**	**95% CI**	**Freq. (%)**	**Est.**	**SE**	**OR**	**95% CI**
Demographics															
Age-65 (Continuous)		0.06	0.00	1.06	(1.06-1.07)		0.06	0.00	1.06	(1.06-1.07)		0.05	0.01	1.05	(1.04-1.07)
Male	123,879 (68.3)	-0.31	0.03	0.73	(0.69-0.78)	114,920 (68.4)	-0.30	0.03	0.74	(0.70-0.78)	8,959 (67.2)	-0.38	0.09	0.68	(0.57-0.82)
Comorbidities															
Cardiogenic Shock (ICD-9 Code 785.51)	7,158 (4.0)	1.26	0.04	3.52	(3.26-3.81)	6,645 (4.0)	1.27	0.04	3.56	(3.28-3.87)	513 (3.9)	1.19	0.14	3.28	(2.49-4.33)
History of Prior CABG or Valve Surgery	10,046 (5.5)	0.54	0.05	1.72	(1.55-1.91)	9,317 (5.6)	0.54	0.06	1.72	(1.54-1.91)	729 (5.5)	0.58	0.18	1.78	(1.26-2.52)
Pneumonia (CC 111-113)	22,982 (12.7)	0.38	0.03	1.46	(1.36-1.56)	21,056 (12.5)	0.36	0.04	1.44	(1.34-1.54)	1,926 (14.5)	0.49	0.11	1.63	(1.31-2.02)
Obesity/Disorders of Thyroid, Cholesterol, Lipids (CC 24)	152,852 (84.3)	-0.46	0.03	0.63	(0.59-0.67)	141,857 (84.5)	-0.46	0.03	0.63	(0.59-0.68)	10,995 (82.5)	-0.47	0.11	0.62	(0.50-0.77)
Protein-Calorie Malnutrition (CC 21)	5,566 (3.1)	0.55	0.05	1.73	(1.56-1.92)	5,151 (3.1)	0.54	0.05	1.71	(1.54-1.91)	415 (3.1)	0.69	0.17	1.99	(1.42-2.78)
Renal Failure (CC131)	24,107	0.32	0.04	1.38	(1.29-1.49)	22,326	0.32	0.04	1.38	(1.28-1.49)	1,781	0.39	0.12	1.47	(1.16-1.87)

Mortality Risk Factors in STS and non-STS hospitals	2008-2010 Full Sample (n=182,191 admissions at 1,197 hospitals)					2008-2010 STS hospitals (n=167,958 admissions at 1,012 hospitals)					2008-2010 non-STS hospitals (n=13,333 admissions at 185 hospitals)				
Variable	**Freq. (%)**	**Est.**	**SE**	**OR**	**95% CI**	**Freq. (%)**	**Est.**	**SE**	**OR**	**95% CI**	**Freq. (%)**	**Est.**	**SE**	**OR**	**95% CI**
	(13.3)					(13.3)					(13.4)				
COPD (CC108)	43,397 (23.9)	0.27	0.03	1.32	(1.24-1.40)	39,950 (23.8)	0.28	0.03	1.32	(1.24-1.41)	3,447 (25.9)	0.21	0.10	1.23	(1.01-1.51)
End-Stage Renal Disease Or Dialysis (CC 130)	2,415 (1.3)	0.67	0.08	1.96	(1.68-2.29)	2,212 (1.3)	0.71	0.08	2.04	(1.74-2.40)	203 (1.5)	0.22	0.28	1.25	(0.72-2.15)
Liver and Biliary Disease (CC 25)	9,396 (5.2)	0.29	0.05	1.33	(1.20-1.48)	8,586 (5.1)	0.27	0.06	1.31	(1.17-1.47)	810 (6.1)	0.36	0.17	1.44	(1.04-1.99)
Congestive Heart Failure (CC 80)	35,959 (19.8)	0.27	0.03	1.31	(1.23-1.40)	33,055 (19.7)	0.26	0.03	1.30	(1.22-1.39)	2,904 (21.8)	0.34	0.11	1.41	(1.14-1.74)
Other Gastrointestinal Disorders (CC 36)	80,482 (44.4)	-0.21	0.03	0.81	(0.77-0.86)	74,712 (44.5)	-0.21	0.03	0.81	(0.77-0.86)	5,770 (43.3)	-0.19	0.10	0.83	(0.68-1.00)
Unstable Angina And Other Acute Ischemic Heart Disease (CC 82)	78,761 (43.4)	-0.22	0.03	0.81	(0.76-0.85)	72,732 (43.3)	-0.21	0.03	0.81	(0.76-0.86)	6,029 (45.2)	-0.26	0.10	0.77	(0.64-0.93)
Coronary Atherosclerosis/Other Chronic Ischemic Heart Disease (CC 84)	147,223 (81.2)	-0.28	0.03	0.76	(0.71-0.81)	136,370 (81.2)	-0.27	0.04	0.77	(0.71-0.82)	10,853 (81.4)	-0.37	0.11	0.69	(0.55-0.86)
Hypertension (CC 91)	154,897 (85.4)	-0.25	0.04	0.78	(0.73-0.84)	143,394 (85.4)	-0.26	0.04	0.77	(0.72-0.83)	11,503 (86.3)	-0.15	0.12	0.86	(0.67-1.09)
Acute Myocardial Infarction (CC 81)	29,932 (16.5)	0.29	0.03	1.33	(1.25-1.42)	27,588 (16.4)	0.29	0.03	1.33	(1.24-1.42)	2,344 (17.6)	0.28	0.11	1.33	(1.07-1.65)
Angina Pectoris/Old Myocardial Infarction (CC 83)	71,463 (39.4)	-0.27	0.03	0.77	(0.72-0.81)	65,938 (39.3)	-0.27	0.03	0.76	(0.71-0.81)	5,525 (41.4)	-0.23	0.10	0.79	(0.65-0.97)
Vascular or Circulatory Disease (CC 104-106)	60,330 (33.3)	0.16	0.03	1.18	(1.11-1.25)	55,594 (33.1)	0.17	0.03	1.18	(1.11-1.26)	4,736 (35.5)	0.13	0.10	1.14	(0.94-1.39)
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	5,729 (3.2)	0.21	0.06	1.23	(1.09-1.39)	5,246 (3.1)	0.24	0.07	1.27	(1.12-1.44)	483 (3.6)	-0.10	0.22	0.90	(0.59-1.39)
Cancer (CC 7-12)	35,382 (19.5)	-0.04	0.04	0.97	(0.90-1.04)	32,846 (19.6)	-0.03	0.04	0.97	(0.90-1.04)	2,536 (19.0)	-0.08	0.12	0.92	(0.72-1.17)
Stroke (CC 95-96)	8,878	0.16	0.06	1.17	(1.04-1.31)	8,190	0.16	0.06	1.18	(1.05-1.33)	688	0.09	0.19	1.09	(0.75-1.59)

Mortality Risk Factors in STS and non-STS hospitals	2008-2010 Full Sample (n=182,191 admissions at 1,197 hospitals)					2008-2010 STS hospitals (n=167,958 admissions at 1,012 hospitals)					2008-2010 non-STS hospitals (n=13,333 admissions at 185 hospitals)				
Variable	**Freq. (%)**	**Est.**	**SE**	**OR**	**95% CI**	**Freq. (%)**	**Est.**	**SE**	**OR**	**95% CI**	**Freq. (%)**	**Est.**	**SE**	**OR**	**95% CI**
	(4.9)					(4.9)					(5.2)				
Hemiplegia, Paraplegia, Paralysis, Functional Disability (CC 67-69, 100-102)	5,188 (2.9)	0.06	0.07	1.06	(0.92-1.22)	4,787 (2.9)	0.06	0.08	1.06	(0.91-1.23)	401 (3.0)	0.09	0.25	1.10	(0.68-1.78)
Dementia or Senility (CC 49-50)	9,008 (5.0)	0.13	0.05	1.14	(1.02-1.26)	8,301 (4.9)	0.11	0.06	1.12	(1.00-1.26)	707 (5.3)	0.24	0.17	1.28	(0.91-1.79)

Table VI: Geographic distribution and characteristics of 189 hospitals[7] not participating in registry ("non-STS hospitals")

Hospital Characteristic	Freq. (%)
Census Region	
Midwest	23 (13%)
Northeast	25 (14%)
South	83 (49%)
West	31 (18%)
Other	9 (5%)
Rural Status	
Rural	4 (2%)
Other	167 (98%)
Safety Net Status	
Safety Net	57 (33%)
Non-Safety Net	114 (67%)
Teaching Status	
Teaching	68 (40%)
Non-teaching	103 (60%)
Ownership	
Not For Profit	88 (52%)
Private	52 (30%)
Public	31 (18%)

[7] Data derived from AHA 2008 Hospital Survey Data; data were not available for all 189 non-STS hospitals.

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Testing Hospital-level Coronary Artery Bypass Graft (CABG) Surgery 30-day Mortality & Readmission Measures in California All-payer Data

Submitted By Yale New Haven Health Services Corporation/Center for Outcomes Research & Evaluation (YNHHSC/CORE)

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Introduction

Yale New Haven Health Services Corporation/Center for Outcomes Research and Evaluation (YNHHSC/CORE) is developing hospital 30-day risk-standardized mortality and readmission measures for patients hospitalized for coronary artery bypass graft surgery (CABG) for the Centers for Medicare & Medicaid Services (CMS). We are developing the measures using Medicare fee-for-service (FFS) claims data for beneficiaries aged 65 years and older, given that Medicare is the only current national claims dataset. However, ideally we would like to specify the measure for use in Medicare and all-payer populations so that it can be applied to the expanding number of available all-payer datasets. Consequently, we tested the measure in an all-payer patient population of adults aged 18 years and older. In this report, we detail our approach to addressing this question and present the findings.

The mortality and readmission measures employ administrative claims data, and are calculated using hierarchical logistic regression models to account for the clustering of observations within hospitals and differences in the number of admissions across hospitals. For risk adjustment, patient comorbidities are identified through claims data from each index hospitalization, and from inpatient and outpatient Medicare claims during the 12 months prior to the index hospitalization. The measure development process in the Medicare FFS population is available in the detailed methodology report for each measure.

The results of our all-payer testing support expanding the CABG mortality and readmission measures' patient populations to include both non-FFS Medicare patients aged 65+ years and all-payer patients aged 18-64 years. Based on the results presented below, we conclude that CMS' risk-standardized mortality and readmission rates (RSMRs and RSRRs) for CABG perform well when applied to all-payer data (all patients aged 18+ years). For each measure, model testing demonstrated both strong patient-level model performance and consistent hospital-level results. Although there were few significant age-risk factor interaction terms (Older and COPD, and Older and Dementia or Senility for mortality; and Older and Pneumonia for readmission), they do not appear to affect the model results. For simplicity and pending further study, the only change currently recommended to either measure's specifications to allow application to an all-payer, 18+ year population is transformation of the Age variable from "Age – 65" to a fully continuous age variable.

Methods

Data Source: For our analyses, we used 2006 all-payer data from California. California is a diverse state, and, with more than 37 million residents, California represents 12% of the U.S. population. We used the California Patient Discharge Data (PDD), a large, linked database of patient hospital admissions. In 2006, there were approximately 3 million adult discharges from more than 450 non-federal acute care hospitals. Records are linked by a unique patient identification number, allowing us to determine patient history from previous hospitalizations and to evaluate rates of both mortality and readmission (via linking with California vital statistics records).

Using all-payer data from California as well as CMS Medicare FFS data for California hospitals, we performed analyses to determine whether the CABG measures can be applied to all adult patients, including FFS Medicare patients aged 65+, non-FFS Medicare patients aged 65+, and patients aged 18-64 years at the time of admission. The CABG models developed in Medicare FFS 65+ patients use inpatient and outpatient data for risk adjustment (consistent with CMS' publicly reported mortality and readmission measures for acute myocardial infarction [AMI], heart failure [HF], and pneumonia[1-6]).

To determine whether the measures can be used in all-payer data, the following questions must be addressed:

Question 1: Given that outpatient claims are not available in the all-payer dataset, how do the current CMS models perform when using only inpatient claims data (i.e., hospital claims for admitted patients)? That is, does the exclusion of outpatient claims data adversely affect measure performance and results at the patient level and the hospital level?

Question 2: When applied to all patients 18+, do the models perform well both at the patient level and at the hospital level? That is, at the patient level, do the models, when derived in the full 18+ population, have good discrimination, predictive ability, and model fit across patient subgroups? In addition, when new patients are added, do potential differences in the effects of risk factors across patient subgroups affect risk prediction at the patient level and risk profiling at the hospital level?

Question 1 analyses: Can risk-adjustment data be limited to inpatient claims?

In testing other administrative claims measures developed in Medicare FFS data – including mortality and readmission measures for AMI, HF, pneumonia, and chronic obstructive pulmonary disease (COPD) – we have validated both the accuracy of the PDD in capturing Medicare claims and the use of only inpatient data for risk adjustment.[7-8] We also found that, although the prevalence of most risk factors is lower when using only inpatient claims data, the magnitude of effect for most risk factors was similar when comparing the models that use all patient history data with those that use only inpatient claims data. Over 95% of patients were in a similar risk category (defined as being in the same or adjacent category) regardless of the risk-adjustment dataset used, and the integrated discrimination improvement values were relatively low (ranging from -0.001 for COPD readmission, to 0.007 for pneumonia mortality). For all measures, the C statistic was also qualitatively similar between the two approaches. (The greatest difference in C statistic between inpatient only versus all patient history data risk-adjustment models was 0.012, for AMI mortality.) Moreover, when comparing the models using full history data with the models using only inpatient claims data, hospital-level risk-standardized rates were highly correlated (intraclass correlation coefficients ranged from 0.95 for AMI readmission to 0.99 for HF mortality). Based on this reassuring data across measures, we did not repeat these analyses for the CABG mortality and readmission measures, but rather assumed that inpatient claims data would provide adequate risk-adjustment information for application of the measures in all-payer data.

Question 2 analyses: Can the models be used in all-payer patient population of adults 18 years and older?

To address the question of how well the models perform when applied to all patients 18+, we used the PDD Data. Specifically, using 2006 data, we created measure cohorts with up to one year of hospital inpatient claims history and 30-day follow-up data. For both measures, we:

A. Created the patient cohort using the respective measure inclusion and exclusion criteria (with the exception of including all patients 18+), and compared the FFS 65+, non-FFS 65+, and 18-64 year-old patient subgroups with respect to the distribution of risk factors and the crude outcome rate.

B. Fit the model in all patients 18+ and: (i) examined overall model performance in terms of the C statistic, (ii) compared performance (C statistic and predictive ability) across the patient subgroups (FFS 65+, non-FFS 65+, all 65+, and all-payer 18-64), and (iii) compared the distribution of Pearson residuals (model fit) across the patient subgroups.

C. Fit the model separately in each patient subgroup and compared odds ratios (ORs) associated with the risk factors to assess differences in magnitude or direction of ORs among the subgroups.

To determine whether the relationship between each risk factor and the outcome differed for those aged 65+ vs. 18-64 in ways that would affect measure results, we:

D. Fit the model in all patients 18+ and tested interaction terms between age (65+ vs. 18-64) and each of the other risk factors.

E. Fit the model in all patients 18+ with interaction terms and compared performance (C statistic and predictive ability) across the patient subgroups.

F. Fit the model in all patients 18+ with and without interaction terms and (i) conducted a reclassification analysis to compare risk prediction at the patient level; (ii) compared the C statistic; and (iii) compared hospital-level risk-standardized rates using a scatterplot and the intra-class correlation coefficient (ICC) to assess whether the model with interactions is statistically different from the current model in profiling hospital rates.

All patient-level models were estimated using a logistic regression model; next, hospital-level RSMR and RSRR analyses were conducted using a hierarchical logistic regression model approach.

Results

Can the models be used in all-payer patient population of adults 18 years and older?

A. The CABG mortality and readmission cohorts are presented in Figure 2 of the mortality and readmission methodology reports. As the results in Table 1a-Table

1b (for the mortality and readmission measures, respectively) demonstrate, there are some differences in the risk factor profiles and crude outcome rate among patient subgroups. In general, the prevalence of risk factors was similar in FFS 65+ and non-FFS 65+ patients. When comparing risk factor prevalence estimates between those 65+ and younger patients aged 18-64, frequencies were generally either lower in the younger cohort or similar between the groups. For some risk factors, including Liver and Biliary Disease (CC 25-30) in the mortality model and Diabetes Mellitus (DM) and DM Complications (CC 15-20, 119, 120) in the readmission model, prevalence estimates were in fact higher in younger than in older patients (Table 1a-Table 1b). As expected, the crude mortality and readmission rates were lower in the younger cohorts (Table 1a and Table 1b).

B. Nevertheless, when the current models were applied to all patients 18+, overall discrimination was good (C statistic=0.84 for CABG mortality and 0.66 for CABG readmission) (Table 2a-Table 2b). There was also good discrimination and predictive ability in all subgroups of patients (Table 3a-Table 3b). Moreover, for both measures, the distribution of Pearson residuals was comparable across the patient subgroups (Table 4a-Table 4b).

C. For both measures, ORs were generally similar for FFS 65+ and non-FFS 65+ patients. For some risk factors, such as COPD in the mortality model, there were differences in magnitude of effect between younger and older patients (Table 5a-Table 5b).

D. For mortality, there were significant age-by-risk-factor interaction terms for two variables (Older and COPD, and Older and Dementia or Senility); COPD was protective in younger age groups. Only one interaction term was significant for readmission (Older and Pneumonia) (Table 6a-Table 6b).

E. Inclusion of the interaction terms, however, did not substantively change the level of discrimination and predictive ability across the patient subgroups (Table 7a-Table 7b).

F. In addition, when comparing patient risk classifications for each measure with and without interaction terms, the reclassification analysis for both measures demonstrated good patient-level risk prediction: for both measures and all patient subgroups, nearly 100% of patients were in a similar risk category (defined as being in the same or adjacent category) regardless of risk-adjustment strategy (Table 8a-Table 8b). Moreover, the C statistic was nearly identical for the models with and without interaction terms (0.85 vs. 0.86, respectively, for CABG mortality, and 0.66 vs. 0.66 for CABG readmission) (Table 9a-Table 9b). Finally, when comparing each measure with and without interaction terms, the hospital-level risk-standardized rates estimated by the two versions of each model were highly correlated (ICC is 0.998 for CABG mortality and 0.998 for CABG readmission) (Figure 1a and Figure 1b).

Conclusions

Based on the results presented above, we conclude that CMS's administrative claims-based CABG mortality and readmission measures perform well when applied to all-payer data (all patients aged 18+ years). Although there were a few significant age-risk factor interaction terms (Older and COPD, and Older and Dementia or Senility for mortality; and Older and Pneumonia for readmission), they do not appear to affect the model results, as the inclusion of the interactions did not substantively affect either patient-level model performance or hospital-level results. For simplicity and pending further study, the only change currently recommended to the measure specifications to allow application to an all-payer, 18+ year population is transformation of the Age variable from "Age-65" to a fully continuous age variable. We have demonstrated that the models can be applied to all patients aged 18+ years and that they perform well when only inpatient admission claims data are used to determine patient history. Thus, based on these results, we will specify the measure to include the 18+ population and to allow for the use of inpatient claims only for risk adjustment when complete claims history (i.e., outpatient data) is unavailable.

The California PDD have some limitations. Data on previous admissions and 30-day readmissions are available only from California hospitals; however, it is unlikely that a high proportion of patients sought hospital inpatient care outside the state given that relatively few California residents live in cities bordering other U.S. states. Likewise, linked data on 30-day mortality outside the hospital are available only for deaths within California. Moreover, although in similar measures we confirmed measure performance without the use of outpatient data for risk adjustment in the FFS Medicare 65+ population, we did not assess this for the CABG measures. However, had the testing been possible, it is unlikely to have altered the conclusions, as all other testing demonstrated comparability between FFS Medicare and non-FFS Medicare patients aged 65+ years.

In summary, CMS's CABG measures – hospital 30-day all-cause RSMR and RSRR for CABG – perform well when used in all-payer data (all patients aged 18+ years). For each measure, model testing demonstrated both strong patient-level model performance and consistent hospital-level results.

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Table 1m. Raw Outcome Rates and Prevalence of Risk Factors in CABG Mortality Model for All Patients Aged 18+ Years, FFS 65+ Patients, Non-FFS 65+ Patients, and All Patients 18-64 Years of Age

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Description	All 18+ (Total)	FFS 65+	Non-FFS 65+	Age 18-64 Years
	N (%)	N (%)	N (%)	N (%)
Raw Mortality Rate, %	1.8	2.6	2.4	1.0
Demographics				
Mean Age (SD)	66.0 (10.6)	74.0 (6.1)	73.2 (5.8)	56.1 (6.2)
Male	11,146 (74.9)	3,294 (70.5)	2,723 (71.9)	5,129 (79.8)
Comorbidities				
Cardiogenic Shock (ICD-9 Code 785.51)	477 (3.2)	161 (3.5)	123 (3.3)	193 (3.0)
History of Prior CABG or Valve Surgery	282 (1.9)	99 (2.1)	79 (2.1)	104 (1.6)
Pneumonia (CC 111-113)	1,264 (8.5)	480(10.3)	357(9.4)	427 (6.6)
Obesity/Disorders of Thyroid, Cholesterol, Lipids (CC 24)	11,897 (79.9)	3,615 (77.4)	3,056 (80.7)	5,226 (81.3)
Protein-Calorie Malnutrition (CC 21)	240 (1.6)	111 (2.4)	66 (1.7)	63 (1.0)
Renal Failure (CC 131)	2,754 (18.5)	1,003 (21.5)	833 (22.0)	918 (14.3)
COPD (CC 108)	2,867 (19.3)	1,051 (22.5)	707 (18.7)	1,109 (17.3)
End-Stage Renal Disease Or Dialysis (CC 130)	341 (2.3)	99 (2.1)	52 (1.4)	190 (3.0)
Liver and Biliary Disease (CC 25-30)	513 (3.5)	146 (3.1)	99 (2.6)	268 (4.2)
Congestive Heart Failure (CC 80)	3,784 (25.4)	1,309 (28.0)	1,064 (28.1)	1,411 (22.0)
Other Gastrointestinal Disorders (CC 36)	3,530 (23.7)	1,230 (26.3)	912 (24.1)	1,388 (21.6)
Unstable Angina And Other Acute Ischemic Heart Disease (CC 82)	5,441 (36.5)	1,703 (36.4)	1,313 (34.7)	2,425 (37.7)
Coronary Atherosclerosis/Other Chronic Ischemic Heart Disease (CC 84)	6,785 (45.6)	2,093 (44.8)	1,689 (44.6)	3,003 (46.7)
Hypertension (CC 91)	10,458 (70.2)	3,266 (69.9)	2,729 (72.1)	4,463 (69.4)
Acute Myocardial Infarction (CC 81)	1,578 (10.6)	428 (9.2)	445 (11.8)	705 (11.0)
Angina Pectoris/Old Myocardial Infarction (CC 83)	4,741 (31.8)	1,464 (31.3)	1,253 (33.1)	2,024 (31.5)
Vascular or Circulatory Disease (CC 104-106)	3,568 (24.0)	1,375 (29.4)	1,004 (26.5)	1,189 (18.5)
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	251 (1.7)	67 (1.4)	68 (1.8)	116 (1.8)
Cancer (CC 7-12)	498 (3.3)	228 (4.9)	154 (4.1)	116 (1.8)
Stroke (CC 95-96)	331 (2.2)	136 (2.9)	85 (2.2)	110 (1.7)
Hemiplegia, Paraplegia, Paralysis, Functional Disability (CC 67-69, 100-102, 177-178)	613 (4.1)	211 (4.5)	133 (3.5)	269 (4.2)
Dementia or Senility (CC 49-50)	226 (1.5)	100 (2.1)	79 (2.1)	47 (0.7)

Note:

1. FFS is defined as payer category=Medicare and payer type of coverage=Traditional.

Table 1n. Raw Outcome Rates and Prevalence of Risk Factors in CABG Readmission Model for All Patients Aged 18+ Years, FFS 65+ Patients, Non-FFS 65+ Patients, and All Patients 18-64 Years of Age

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Description	All 18+ Total	FFS 65+	Non-FFS 65+	Age 18-64 Years
	N (%)	N (%)	N (%)	N (%)
Raw Readmission Rate, %	14.5	15.8	16.0	12.8
Demographics				
Mean Age (SD)	65.9 (10.6)	73.9 (6.1)	73.2 (5.7)	56.0 (6.2)
Male	10,982 (75.0)	3,217 (70.7)	2,673 (72.1)	5,092 (79.9)
Comorbidities				
History of Prior CABG or Valve Surgery	271 (1.9)	98 (2.2)	69 (1.9)	104 (1.6)
Cardiogenic Shock (ICD-9 Code 785.51)	384 (2.6)	120 (2.6)	93 (2.5)	171 (2.7)
COPD (CC 108)	2,782 (19.0)	1,001 (22.0)	680 (18.4)	1,101 (17.3)
Renal Failure (CC 131)	2,581 (17.6)	916 (20.1)	781 (21.1)	884 (13.9)
Diabetes and DM Complications (CC 15-20, 119, 120)	6,399 (43.7)	1,860 (40.9)	1,591 (42.9)	2,948 (46.2)
Obesity/Disorders of Thyroid, Cholesterol, Lipids (CC 24)	11,731 (80.2)	3,538 (77.7)	3,003 (81.0)	5,190 (81.4)
Congestive Heart Failure (CC 80)	3,621 (24.7)	1,229 (27.0)	1,013 (27.3)	1,379 (21.6)
Arrhythmias (CC 92-93)	5,527 (37.8)	2,148 (47.2)	1,667 (45.0)	1,712 (26.9)
Other Lung Disorders (CC 115)	1,977 (13.5)	633 (13.9)	520 (14.0)	824 (12.9)
Major Psychiatric Disorders (CC 54-56)	239 (1.6)	78 (1.7)	46 (1.2)	115 (1.8)
Vascular or Circulatory Disease (CC 104-106)	3,431 (23.4)	1,310 (28.8)	959 (25.9)	1,162 (18.2)
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	2,863 (19.6)	1,074 (23.6)	732 (19.8)	1,057 (16.6)
Pneumonia (CC 111-113)	1,165 (8.0)	429 (9.4)	328 (8.9)	408 (6.4)
Cerebrovascular Disease (CC 97-99, 103)	1,122 (7.7)	471 (10.4)	348 (9.4)	303 (4.8)
Polyneuropathy (CC 71)	727 (5.0)	197 (4.3)	169 (4.6)	361 (5.7)
Protein-Calorie Malnutrition (CC 21)	217 (1.5)	96 (2.1)	60 (1.6)	61 (1.0)
Severe Hematological Disorders (CC 44)	38 (0.3)	16 (0.4)	8 (0.2)	14 (0.2)
Fibrosis Of Lung And Other Chronic Lung Disorders (CC 109)	192 (1.3)	77 (1.7)	57 (1.5)	58 (0.9)
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	235 (1.6)	59 (1.3)	65 (1.8)	111 (1.7)
End-Stage Renal Disease Or Dialysis (CC 130)	317 (2.2)	87 (1.9)	48 (1.3)	182 (2.9)
Hemiplegia, Paraplegia, Paralysis, Functional Disability (CC 67-69, 100-102)	593 (4.1)	203 (4.5)	126 (3.4)	264 (4.1)
Stroke (CC 95-96)	308 (2.1)	126 (2.8)	77 (2.1)	105 (1.7)
Dementia or Senility (CC 49-50)	216 (1.5)	94 (2.1)	77 (2.1)	45 (0.7)
Cancer (CC 7-12)	485 (3.3)	219 (4.8)	152 (4.1)	114 (1.8)

Note:

1. FFS is defined as payer category=Medicare and payer type of coverage=Traditional.

Table 2a. Odds Ratios for Risk Factors in CABG Mortality Measure for All Patients 18+ Years (Logistic Regression Model, N=14,889, C Statistic=0.84)

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Description	OR (95% CI)
Demographics	
Age-65 (Continuous)	1.05 (1.03-1.06)
Male	0.68 (0.52-0.90)
Comorbidities	
Cardiogenic Shock (ICD-9 Code 785.51)	7.51 (5.43-10.38)
History of Prior CABG or Valve Surgery	1.54 (0.81-2.94)
Pneumonia (CC 111-113)	1.61 (1.17-2.22)
Obesity/Disorders of Thyroid, Cholesterol, Lipids (CC 24)	0.57 (0.43-0.76)
Protein-Calorie Malnutrition (CC 21)	0.59 (0.29-1.17)
Renal Failure (CC 131)	3.23 (2.37-4.39)
COPD (CC 108)	1.23 (0.92-1.64)
End-Stage Renal Disease Or Dialysis (CC 130)	1.56 (0.91-2.68)
Liver and Biliary Disease (CC 25-30)	1.76 (1.12-2.77)
Congestive Heart Failure (CC 80)	1.25 (0.93-1.68)
Other Gastrointestinal Disorders (CC 36)	0.63 (0.46-0.87)
Unstable Angina And Other Acute Ischemic Heart Disease (CC 82)	0.96 (0.71-1.28)
Coronary Atherosclerosis/Other Chronic Ischemic Heart Disease (CC 84)	1.41 (1.06-1.87)
Hypertension (CC 91)	1.25 (0.92-1.69)
Acute Myocardial Infarction (CC 81)	0.92 (0.64-1.31)
Angina Pectoris/Old Myocardial Infarction (CC 83)	1.07 (0.81-1.42)
Vascular or Circulatory Disease (CC 104-106)	1.59 (1.22-2.08)
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	0.41 (0.17-1.00)
Cancer (CC 7-12)	0.84 (0.44-1.60)
Stroke (CC 95-96)	2.03 (1.20-3.43)
Hemiplegia, Paraplegia, Paralysis, Functional Disability (CC 67-69, 100-102, 177-178)	1.24 (0.75-2.05)
Dementia or Senility (CC 49-50)	1.51 (0.79-2.89)

Table 2b. Odds Ratios for Risk Factors in CABG Readmission Measure for All Patients 18+ Years (Logistic Regression Model, N=14,635, C Statistic=0.66)

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Description	OR (95% CI)
Demographics	
Age-65 (Continuous)	1.01 (1.01-1.02)
Male	0.69 (0.62-0.76)
Comorbidities	
History of Prior CABG or Valve Surgery	0.84 (0.59-1.18)
Cardiogenic Shock (ICD-9 Code 785.51)	1.27 (0.98-1.63)
COPD (CC 108)	1.27 (1.13-1.42)
Renal Failure (CC 131)	1.40 (1.24-1.59)
Diabetes and DM Complications (CC 15-20, 119, 120)	1.45 (1.31-1.60)
Obesity/Disorders of Thyroid, Cholesterol, Lipids (CC 24)	0.97 (0.86-1.09)
Congestive Heart Failure (CC 80)	1.34 (1.20-1.50)
Arrhythmias (CC 92-93)	1.20 (1.09-1.33)
Other Lung Disorders (CC 115)	0.95 (0.83-1.09)
Major Psychiatric Disorders (CC 54-56)	1.49 (1.09-2.05)
Vascular or Circulatory Disease (CC 104-106)	1.08 (0.97-1.21)
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	1.18 (1.05-1.33)
Pneumonia (CC 111-113)	1.19 (1.01-1.39)
Cerebrovascular Disease (CC 97-99, 103)	1.13 (0.96-1.34)
Polyneuropathy (CC 71)	1.21 (1.00-1.47)
Protein-Calorie Malnutrition (CC 21)	1.14 (0.83-1.56)
Severe Hematological Disorders (CC 44)	2.00 (0.94-4.26)
Fibrosis Of Lung And Other Chronic Lung Disorders (CC 109)	1.41 (0.99-2.01)
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	1.29 (0.95-1.75)
End-Stage Renal Disease Or Dialysis (CC 130)	1.15 (0.87-1.51)
Hemiplegia, Paraplegia, Paralysis, Functional Disability (CC 67-69, 100-102)	1.38 (1.11-1.71)
Stroke (CC 95-96)	1.05 (0.78-1.41)
Dementia or Senility (CC 49-50)	1.46 (1.06-2.00)
Cancer (CC 7-12)	0.94 (0.73-1.21)

Table 3a. CABG Mortality Model Performance for Models with All 18+ Patients and by Subgroups of Patients

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Model with*	N	Unadjusted Mortality Rate (%)	C statistic	SE	Lower C statistic	Upper C-statistic	Predictive ability#, % (lowest decile – highest decile)
All 65+	8,460	2.5	0.84	0.02	0.81	0.87	0.4 - 14.2
FFS, 65+	4,673	2.6	0.83	0.02	0.79	0.88	0.4 - 15.6
Non-FFS, 65+	3,787	2.4	0.85	0.02	0.80	0.89	0.3 - 12.7
All 18-64	6,429	1.0	0.79	0.04	0.72	0.86	0.0 - 5.3
All 18+ (overall)	14,889	1.8	0.84	0.01	0.81	0.87	0.5 - 10.7

*Note that a single overall model for all 18+ is applied to the subgroups of patients.
#Mean observation mortality in the lowest and the highest decile of the predicted mortality.

Table 3b. CABG Readmission Model Performance for Models with All 18+ Patients and by Subgroups of Patients

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Model with*	N	Unadjusted Readmission Rate (%)	C statistic	SE	Lower C statistic	Upper C statistic	Predictive ability#, % (lowest decile – highest decile)
All 65+	8,258	15.9	0.65	0.01	0.63	0.66	7.3 -30.3
FFS, 65+	4,552	15.8	0.64	0.01	0.62	0.66	7.7 - 27.0
Non-FFS, 65+	3,706	16.0	0.66	0.01	0.63	0.68	7.0 - 34.3
All 18-64	6,377	12.8	0.67	0.01	0.65	0.69	6.7 - 30.9
All 18+ (overall)	14,635	14.5	0.66	0.01	0.65	0.67	6.4 - 30.2

*Note that a single overall model for all 18+ is applied to the subgroups of patients.
#Mean observation readmission in the lowest and highest decile of the predicted readmission

Table 4a. Distribution of Pearson Chi-Square Residuals for CABG Mortality Model by Patient Subgroups

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

	All 18+ (TOTAL) N (%)	All 65+ N (%)	FFS 65+ N (%)	Non-FFS 65+ N (%)	All 18-64 N (%)
Residual < -2	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
-2 <= Residual < 0	14,619 (98.2)	8,252 (97.5)	4,554 (97.5)	3,698 (97.7)	6,367 (99.0)
0 <= Residual < 2	49 (0.3)	43 (0.5)	28 (0.6)	15 (0.4)	6 (0.1)
Residual >= 2	221 (1.5)	165 (2.0)	91 (2.0)	74 (2.0)	56 (0.9)

Table 4b. Distribution of Pearson Chi-Square Residuals for CABG Readmission Model by Patient Subgroups

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

	All 18+ (TOTAL) N (%)	All 65+ N (%)	FFS 65+ N (%)	Non-FFS 65+ N (%)	All 18-64 N (%)
Residual < -2	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
-2 <= Residual < 0	12,507 (85.5)	6,944 (84.1)	3,831 (84.2)	3,113 (84.0)	5,563 (87.2)
0 <= Residual < 2	718 (4.9)	505 (6.1)	270 (5.9)	235 (6.3)	213 (3.3)
Residual >= 2	1,410 (9.6)	809 (9.8)	451 (9.9)	358 (9.7)	601 (9.4)

Table 5a. Odds Ratios for Risk Factors in CABG Mortality Measure – Stratified Results for FFS Patients 65+, Non-FFS Patients 65+, All Patients 65+, and All Patients 18-64 Years of Age

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Risk Factor	OR (95% CI) for All 65+ (N=8,460, C statistic=0.84)	OR (95% CI) for FFS 65+ (N=4,673, C statistic=0.84)	OR (95% CI) for Non-FFS 65+ (N=3,787, C statistic= 0.86)	OR (95% CI) for All 18-64 (N=6,429, C statistic=0.82)
Demographics				
Age-65 (Continuous)	1.07 (1.04-1.09)	1.08 (1.04-1.11)	1.05 (1.01-1.09)	1.00 (0.96-1.05)
Male	0.71 (0.52-0.97)	0.87 (0.57-1.33)	0.54 (0.33-0.87)	0.60 (0.34-1.05)
Comorbidities				
Cardiogenic Shock (ICD-9 Code 785.51)	7.40 (5.07-10.80)	8.02 (4.85-13.28)	7.25 (4.01-13.12)	7.60 (3.93-14.69)
History of Prior CABG or Valve Surgery	1.96 (0.98-3.91)	0.43 (0.10-1.92)	5.50 (2.31-13.14)	0.56 (0.07-4.49)
Pneumonia (CC 111-113)	1.78 (1.24-2.55)	1.80 (1.12-2.89)	1.63 (0.93-2.87)	1.01 (0.47-2.18)
Obesity/Disorders of Thyroid, Cholesterol, Lipids (CC 24)	0.56 (0.40-0.78)	0.64 (0.41-0.99)	0.47 (0.28-0.78)	0.70 (0.38-1.31)
Protein-Calorie Malnutrition (CC 21)	0.68 (0.33-1.38)	0.78 (0.32-1.86)	0.60 (0.17-2.18)	<0.001 (<0.001->999.999)
Renal Failure (CC 131)	3.35 (2.35-4.76)	3.36 (2.09-5.42)	3.37 (1.98-5.73)	3.21 (1.66-6.21)
COPD (CC 108)	1.48 (1.07-2.05)	1.79 (1.17-2.74)	1.29 (0.76-2.19)	0.54 (0.26-1.13)
End-Stage Renal Disease Or Dialysis (CC 130)	1.81 (0.93-3.51)	1.57 (0.67-3.70)	2.07 (0.69-6.22)	1.39 (0.51-3.78)
Liver and Biliary Disease (CC 25-30)	1.65 (0.95-2.86)	1.70 (0.84-3.46)	1.38 (0.55-3.47)	2.03 (0.89-4.65)
Congestive Heart Failure (CC 80)	1.29 (0.92-1.81)	1.26 (0.80-1.96)	1.40 (0.84-2.34)	1.14 (0.62-2.09)
Other Gastrointestinal Disorders (CC 36)	0.65 (0.45-0.93)	0.63 (0.39-1.01)	0.61 (0.34-1.09)	0.52 (0.25-1.08)
Unstable Angina And Other Acute Ischemic Heart Disease (CC 82)	0.99 (0.71-1.38)	0.93 (0.60-1.46)	1.05 (0.62-1.77)	0.78 (0.42-1.44)
Coronary Atherosclerosis/Other Chronic Ischemic Heart Disease (CC 84)	1.24 (0.89-1.72)	1.37 (0.88-2.12)	1.09 (0.66-1.80)	2.05 (1.10-3.81)
Hypertension (CC 91)	1.32 (0.93-1.88)	1.55 (0.96-2.49)	1.08 (0.63-1.86)	1.17 (0.63-2.18)
Acute Myocardial Infarction (CC 81)	0.83 (0.54-1.26)	0.64 (0.35-1.19)	1.09 (0.60-2.00)	1.18 (0.60-2.33)
Angina Pectoris/Old Myocardial Infarction (CC 83)	1.10 (0.79-1.53)	1.07 (0.69-1.67)	1.10 (0.67-1.83)	1.06 (0.59-1.91)
Vascular or Circulatory Disease (CC 104-106)	1.49 (1.09-2.02)	1.48 (0.98-2.22)	1.56 (0.98-2.51)	2.18 (1.25-3.81)
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	0.50 (0.19-1.34)	0.96 (0.30-3.04)	0.19 (0.02-1.47)	0.24 (0.03-1.94)
Cancer (CC 7-12)	0.73 (0.36-1.51)	1.18 (0.53-2.62)	0.21 (0.03-1.63)	1.75 (0.40-7.70)
Stroke (CC 95-96)	1.92 (1.03-3.57)	1.58 (0.69-3.64)	3.21 (1.21-8.50)	2.60 (0.91-7.43)
Hemiplegia, Paraplegia, Paralysis, Functional Disability (CC 67-69, 100-102, 177-178)	1.43 (0.79-2.58)	1.35 (0.63-2.88)	1.23 (0.44-3.43)	0.91 (0.33-2.49)
Dementia or Senility (CC 49-50)	1.02 (0.47-2.23)	1.17 (0.46-2.98)	0.68 (0.15-3.24)	8.20 (2.44-27.59)

Table 5b. Odds Ratios for Risk Factors in CABG Readmission Measure – Stratified Results for FFS Patients 65+, Non-FFS Patients 65+, All Patients 65+, and All Patients 18-64 Years of Age

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Risk Factor	OR (95% CI) for All 65+ (N=8,258, C statistic=0.65)	OR (95% CI) for FFS 65+ (N=4,552, C statistic=0.65)	OR (95% CI) for Non-FFS 65+ (N=3,706, C statistic=0.67)	OR (95% CI) for All 18-64 (N= 6,377, C statistic=0.67)
Demographics				
Age-65 (Continuous)	1.03 (1.02-1.04)	1.03 (1.01-1.04)	1.03 (1.01-1.05)	1.00 (0.98-1.01)
Male	0.72 (0.64-0.82)	0.73 (0.61-0.87)	0.71 (0.59-0.87)	0.64 (0.54-0.76)
Comorbidities				
History of Prior CABG or Valve Surgery	0.68 (0.43-1.07)	0.48 (0.24-0.94)	0.89 (0.47-1.68)	1.19 (0.71-2.01)
Cardiogenic Shock (ICD-9 Code 785.51)	1.25 (0.90-1.73)	1.49 (0.96-2.30)	1.08 (0.65-1.78)	1.30 (0.87-1.95)
COPD (CC 108)	1.26 (1.09-1.46)	1.34 (1.10-1.63)	1.21 (0.96-1.52)	1.34 (1.11-1.62)
Renal Failure (CC 131)	1.37 (1.17-1.59)	1.48 (1.20-1.82)	1.26 (1.00-1.58)	1.45 (1.16-1.81)
Diabetes and DM Complications (CC 15-20, 119, 120)	1.38 (1.21-1.57)	1.35 (1.14-1.61)	1.43 (1.18-1.73)	1.65 (1.40-1.95)
Obesity/Disorders of Thyroid, Cholesterol, Lipids (CC 24)	0.96 (0.82-1.11)	0.97 (0.79-1.18)	0.97 (0.77-1.23)	1.03 (0.84-1.26)
Congestive Heart Failure (CC 80)	1.33 (1.15-1.53)	1.16 (0.96-1.42)	1.55 (1.27-1.91)	1.35 (1.12-1.62)
Arrhythmias (CC 92-93)	1.17 (1.04-1.33)	1.22 (1.03-1.44)	1.14 (0.94-1.37)	1.23 (1.04-1.46)
Other Lung Disorders (CC 115)	0.92 (0.77-1.09)	0.87 (0.69-1.10)	0.96 (0.74-1.24)	1.03 (0.83-1.28)
Major Psychiatric Disorders (CC 54-56)	1.28 (0.82-1.99)	1.24 (0.70-2.20)	1.38 (0.68-2.83)	1.77 (1.12-2.80)
Vascular or Circulatory Disease (CC 104-106)	1.04 (0.91-1.20)	1.05 (0.87-1.26)	1.06 (0.86-1.30)	1.15 (0.94-1.39)
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	1.20 (1.03-1.38)	1.03 (0.85-1.26)	1.44 (1.16-1.80)	1.14 (0.94-1.39)
Pneumonia (CC 111-113)	1.20 (0.99-1.46)	0.96 (0.73-1.26)	1.54 (1.16-2.05)	1.18 (0.89-1.55)
Cerebrovascular Disease (CC 97-99, 103)	1.20 (0.99-1.45)	1.33 (1.03-1.70)	1.07 (0.80-1.44)	1.00 (0.72-1.38)
Polyneuropathy (CC 71)	0.94 (0.72-1.24)	0.90 (0.61-1.31)	0.99 (0.66-1.48)	1.53 (1.16-2.01)
Protein-Calorie Malnutrition (CC 21)	1.22 (0.85-1.77)	1.48 (0.92-2.38)	0.98 (0.54-1.79)	0.90 (0.48-1.72)
Severe Hematological Disorders (CC 44)	1.50 (0.57- 3.94)	2.84 (0.98-8.23)	<0.001 (<0.001->999.999)	2.95 (0.88-9.95)
Fibrosis Of Lung And Other Chronic Lung Disorders (CC 109)	1.22 (0.79-1.88)	1.08 (0.60-1.96)	1.60 (0.85-3.02)	2.03 (1.08-3.82)
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	1.21 (0.79-1.84)	1.45 (0.80-2.64)	0.94 (0.51-1.74)	1.38 (0.88-2.16)
End-Stage Renal Disease Or Dialysis (CC 130)	1.34 (0.91-1.99)	1.39 (0.85-2.29)	1.41 (0.74-2.71)	0.97 (0.66-1.45)
Hemiplegia, Paraplegia, Paralysis, Functional Disability (CC 67-69, 100-102)	1.37 (1.03-1.82)	1.10 (0.75-1.60)	1.80 (1.16-2.81)	1.38 (0.99-1.92)
Stroke (CC 95-96)	1.03 (0.71-1.49)	1.24 (0.78-1.97)	0.84 (0.45-1.55)	1.16 (0.70-1.93)
Dementia or Senility (CC 49-50)	1.66 (1.17-2.36)	1.48 (0.92-2.38)	1.98 (1.18-3.32)	0.79 (0.35-1.78)
Cancer (CC 7-12)	0.90 (0.68-1.21)	1.25 (0.88-1.77)	0.55 (0.32-0.93)	1.15 (0.68-1.93)

Table 6a. CABG Mortality Model with Interaction Terms – Logistic Regression Model (N=14,889, C Statistic=0.85)

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Description	Estimate	Standard Error	Wald Chi-Square	P value	OR	LOR	UOR
Demographics							
Age-65 (Continuous)	0.05	0.01	21.75	0.00	1.05	1.03	1.08
Male	-0.51	0.29	3.13	0.08	0.60	0.34	1.06
Comorbidities							
Cardiogenic Shock (ICD-9 Code 785.51)	2.07	0.34	37.63	0.00	7.94	4.09	15.38
History of Prior CABG or Valve Surgery	-0.62	1.06	0.34	0.56	0.54	0.07	4.28
Pneumonia (CC 111-113)	0.01	0.39	0.00	0.98	1.01	0.47	2.18
Obesity/Disorders of Thyroid, Cholesterol, Lipids (CC 24)	-0.36	0.32	1.25	0.26	0.70	0.38	1.31
Protein-Calorie Malnutrition (CC 21)	-13.11	364.90	0.00	0.97	0.00	0.00	999.99
Renal Failure (CC 131)	1.13	0.34	11.18	0.00	3.09	1.60	5.99
COPD (CC 108)	-0.66	0.38	3.01	0.08	0.52	0.25	1.09
End-Stage Renal Disease Or Dialysis (CC 130)	0.30	0.51	0.34	0.56	1.35	0.49	3.70
Liver and Biliary Disease (CC 25-30)	0.78	0.42	3.45	0.06	2.19	0.96	4.99
Congestive Heart Failure (CC 80)	0.12	0.31	0.16	0.69	1.13	0.62	2.08
Other Gastrointestinal Disorders (CC 36)	-0.69	0.37	3.40	0.07	0.50	0.24	1.04
Unstable Angina And Other Acute Ischemic Heart Disease (CC 82)	-0.26	0.31	0.68	0.41	0.77	0.42	1.43
Coronary Atherosclerosis/Other Chronic Ischemic Heart Disease (CC 84)	0.76	0.32	5.78	0.02	2.14	1.15	3.98
Hypertension (CC 91)	0.13	0.32	0.17	0.68	1.14	0.61	2.13
Acute Myocardial Infarction (CC 81)	0.17	0.35	0.23	0.63	1.18	0.60	2.35
Angina Pectoris/Old Myocardial Infarction (CC 83)	0.06	0.30	0.05	0.83	1.07	0.59	1.91
Vascular or Circulatory Disease (CC 104-106)	0.73	0.28	6.68	0.01	2.08	1.19	3.63
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	-1.45	1.07	1.82	0.18	0.24	0.03	1.92
Cancer (CC 7-12)	0.52	0.76	0.46	0.50	1.68	0.38	7.43
Stroke (CC 95-96)	0.90	0.54	2.80	0.09	2.45	0.86	7.00
Hemiplegia, Paraplegia, Paralysis, Functional Disability (CC 67-69, 100-102, 177-178)	-0.11	0.51	0.04	0.84	0.90	0.33	2.45
Dementia or Senility (CC 49-50)	2.01	0.62	10.54	0.00	7.45	2.22	25.02
Age interaction							
Variables with interaction term							
Demographics							

Description	Estimate	Standard Error	Wald Chi-Square	P value	OR	LOR	UOR
Older (Age >=65)	-0.19	0.58	0.11	0.74	0.82	0.26	2.58
Older and Male	0.16	0.33	0.23	0.63	1.17	0.61	2.25
Comorbidities							
Older and Cardiogenic Shock (ICD-9 Code 785.51)	-0.06	0.39	0.03	0.87	0.94	0.44	2.01
Older and History of Prior CABG or Valve Surgery	1.28	1.11	1.31	0.25	3.58	0.40	31.84
Older and Pneumonia (CC 111-113)	0.57	0.43	1.70	0.19	1.76	0.75	4.13
Older and Obesity/Disorders of Thyroid, Cholesterol, Lipids (CC 24)	-0.24	0.36	0.45	0.50	0.79	0.39	1.59
Older and Protein-Calorie Malnutrition (CC 21)	12.73	364.90	0.00	0.97	339,286.20	0.00	.
Older and Renal Failure (CC 131)	0.09	0.38	0.05	0.82	1.09	0.52	2.31
Older and COPD (CC 108)	1.04	0.41	6.31	0.01	2.83	1.26	6.37
Older and End-Stage Renal Disease Or Dialysis (CC 130)	0.25	0.62	0.16	0.69	1.28	0.38	4.27
Older and Liver and Biliary Disease (CC 25-30)	-0.31	0.51	0.37	0.54	0.74	0.27	1.98
Older and Congestive Heart Failure (CC 80)	0.14	0.35	0.16	0.69	1.15	0.57	2.30
Older and Other Gastrointestinal Disorders (CC 36)	0.26	0.42	0.40	0.53	1.30	0.58	2.94
Older and Unstable Angina And Other Acute Ischemic Heart Disease (CC 82)	0.25	0.36	0.49	0.49	1.28	0.64	2.59
Older and Coronary Atherosclerosis/Other Chronic Ischemic Heart Disease (CC 84)	-0.54	0.36	2.28	0.13	0.58	0.29	1.17
Older and Hypertension (CC 91)	0.14	0.37	0.15	0.70	1.15	0.56	2.36
Older and Acute Myocardial Infarction (CC 81)	-0.36	0.41	0.77	0.38	0.70	0.31	1.56
Older and Angina Pectoris/Old Myocardial Infarction (CC 83)	0.03	0.34	0.01	0.94	1.03	0.52	2.01
Older and Vascular or Circulatory Disease (CC 104-106)	-0.34	0.32	1.09	0.30	0.71	0.38	1.35
Older and Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	0.73	1.18	0.38	0.54	2.07	0.20	21.05
Older and Cancer (CC 7-12)	-0.82	0.84	0.95	0.33	0.44	0.08	2.30
Older and Stroke (CC 95-96)	-0.25	0.62	0.16	0.69	0.78	0.23	2.65
Older and Hemiplegia, Paraplegia, Paralysis, Functional Disability (CC 67-69, 100-102, 177-178)	0.44	0.59	0.55	0.46	1.56	0.49	4.99
Older and Dementia or Senility (CC 49-50)	-1.97	0.74	7.14	0.01	0.14	0.03	0.59

Table 6b. CABG Readmission Model with Interaction Terms – Logistic Regression Model (N=14,635, C statistic= 0.66)

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Description	Estimate	Standard Error	Wald Chi-Square	P value	OR	LOR	UOR
Demographics							
Age-65 (Continuous)	0.01	0.00	11.66	0.00	1.01	1.01	1.02
Male	-0.44	0.09	25.48	0.00	0.64	0.54	0.76
Comorbidities							
History of Prior CABG or Valve Surgery	0.16	0.27	0.37	0.55	1.18	0.70	1.99
Cardiogenic Shock (ICD-9 Code 785.51)	0.28	0.21	1.79	0.18	1.32	0.88	1.97
COPD (CC 108)	0.27	0.10	7.93	0.00	1.31	1.09	1.59
Renal Failure (CC 131)	0.36	0.11	10.21	0.00	1.44	1.15	1.79
Diabetes and DM Complications (CC 15-20, 119, 120)	0.50	0.08	35.17	0.00	1.65	1.40	1.95
Obesity/Disorders of Thyroid, Cholesterol, Lipids (CC 24)	0.02	0.10	0.04	0.85	1.02	0.83	1.25
Congestive Heart Failure (CC 80)	0.30	0.09	10.34	0.00	1.35	1.13	1.63
Arrhythmias (CC 92-93)	0.19	0.09	4.69	0.03	1.20	1.02	1.42
Other Lung Disorders (CC 115)	0.03	0.11	0.06	0.81	1.03	0.83	1.28
Major Psychiatric Disorders (CC 54-56)	0.59	0.23	6.38	0.01	1.80	1.14	2.84
Vascular or Circulatory Disease (CC 104-106)	0.12	0.10	1.59	0.21	1.13	0.93	1.37
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	0.14	0.10	1.92	0.17	1.15	0.94	1.40
Pneumonia (CC 111-113)	0.17	0.14	1.44	0.23	1.19	0.90	1.56
Cerebrovascular Disease (CC 97-99, 103)	-0.04	0.17	0.05	0.82	0.96	0.69	1.34
Polyneuropathy (CC 71)	0.43	0.14	9.39	0.00	1.53	1.17	2.02
Protein-Calorie Malnutrition (CC 21)	-0.11	0.33	0.10	0.75	0.90	0.47	1.71
Severe Hematological Disorders (CC 44)	1.09	0.62	3.08	0.08	2.96	0.88	9.97
Fibrosis Of Lung And Other Chronic Lung Disorders (CC 109)	0.73	0.32	5.17	0.02	2.08	1.11	3.92
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	0.33	0.23	2.05	0.15	1.39	0.89	2.17
End-Stage Renal Disease Or Dialysis (CC 130)	-0.02	0.20	0.01	0.94	0.98	0.66	1.46
Hemiplegia, Paraplegia, Paralysis, Functional Disability (CC 67-69, 100-102)	0.31	0.17	3.38	0.07	1.37	0.98	1.91
Stroke (CC 95-96)	0.15	0.26	0.32	0.57	1.16	0.70	1.93
Dementia or Senility (CC 49-50)	-0.29	0.42	0.48	0.49	0.75	0.33	1.70
Cancer (CC 7-12)	0.12	0.27	0.20	0.65	1.13	0.67	1.90
Age interaction							
Variables with interaction term							
Demographics							

Description	Estimate	Standard Error	Wald Chi-Square	P value	OR	LOR	UOR
Older (Age >=65)	0.07	0.18	0.17	0.68	1.08	0.76	1.53
Older and Male	0.11	0.11	0.94	0.33	1.11	0.90	1.38
Comorbidities	-0.56	0.36	2.47	0.12	0.57	0.28	1.15
Older and History of Prior CABG or Valve Surgery	-0.05	0.12	0.17	0.68	0.95	0.75	1.21
Older and Cardiogenic Shock (ICD-9 Code 785.51)	-0.04	0.14	0.08	0.77	0.96	0.73	1.26
Older and COPD (CC 108)	-0.07	0.13	0.33	0.57	0.93	0.72	1.20
Older and Renal Failure (CC 131)	-0.01	0.12	0.01	0.92	0.99	0.78	1.25
Older and Diabetes and DM Complications (CC 15-20, 119, 120)	-0.01	0.11	0.00	0.96	0.99	0.81	1.22
Older and Obesity/Disorders of Thyroid, Cholesterol, Lipids (CC 24)	-0.11	0.14	0.65	0.42	0.89	0.67	1.18
Older and Congestive Heart Failure (CC 80)	-0.05	0.27	0.03	0.86	0.95	0.57	1.60
Older and Arrhythmias (CC 92-93)	-0.36	0.32	1.21	0.27	0.70	0.37	1.32
Older and Other Lung Disorders (CC 115)	-0.08	0.12	0.42	0.52	0.93	0.73	1.17
Older and Major Psychiatric Disorders (CC 54-56)	0.04	0.13	0.12	0.73	1.04	0.82	1.34
Older and Vascular or Circulatory Disease (CC 104-106)	0.02	0.17	0.01	0.91	1.02	0.73	1.43
Older and Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	0.23	0.19	1.36	0.24	1.25	0.86	1.83
Older and Pneumonia (CC 111-113)	-0.49	0.20	6.25	0.01	0.61	0.41	0.90
Older and Cerebrovascular Disease (CC 97-99, 103)	0.32	0.38	0.70	0.40	1.37	0.65	2.89
Older and Polyneuropathy (CC 71)	-0.67	0.79	0.72	0.40	0.51	0.11	2.41
Older and Protein-Calorie Malnutrition (CC 21)	-0.53	0.39	1.84	0.18	0.59	0.27	1.27
Older and Severe Hematological Disorders (CC 44)	-0.16	0.31	0.25	0.62	0.85	0.46	1.58
Older and Fibrosis Of Lung And Other Chronic Lung Disorders (CC 109)	0.28	0.28	1.00	0.32	1.33	0.76	2.32
Older and Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	-0.01	0.22	0.00	0.98	0.99	0.64	1.54
Older and End-Stage Renal Disease Or Dialysis (CC 130)	-0.12	0.32	0.15	0.70	0.88	0.47	1.66
Older and Hemiplegia, Paraplegia, Paralysis, Functional Disability (CC 67-69, 100-102)	0.82	0.45	3.29	0.07	2.28	0.94	5.55
Older and Stroke (CC 95-96)	-0.21	0.30	0.49	0.48	0.81	0.44	1.47
Older and Dementia or Senility (CC 49-50)	0.07	0.18	0.17	0.68	1.08	0.76	1.53
Older and Cancer (CC 7-12)	0.11	0.11	0.94	0.33	1.11	0.90	1.38

Table 7a. CABG Mortality Model Performance for Models with Interaction Terms by Patient Subgroups

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Model with	N	C statistic	SE	Lower C statistic	Upper C statistic	Predictive Ability*
All 65+	8,460	0.84	0.015	0.81	0.87	0.4 - 14.3
FFS, 65+	4,673	0.84	0.02	0.80	0.88	0.4 - 15.4
Non-FFS, 65+	3,787	0.85	0.02	0.80	0.89	0.3 - 12.9
All 18-64	6,429	0.81	0.03	0.75	0.87	0.0 - 5.3
All 18+	14,889	0.85	0.01	0.82	0.87	0.1 - 10.7

*Mean observation readmission in the lowest and the highest decile of the predicted mortality.

Table 7b. CABG Readmission Model Performance for Models with Interaction Terms by Patient Subgroups

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Model with	N	C statistic	SE	Lower C statistic	Upper C statistic	Predictive Ability*
All 65+	8,258	0.65	0.01	0.64	0.67	7.2 - 30.4
FFS, 65+	4,552	0.64	0.01	0.62	0.67	7.0 - 27.9
Non-FFS, 65+	3,706	0.66	0.01	0.64	0.68	6.7 - 35.7
All 18-64	6,377	0.67	0.01	0.65	0.69	6.3 - 31.1
All 18+	14,635	0.66	0.01	0.65	0.68	6.0 - 31.2

*Mean observation readmission in the lowest and the highest decile of the predicted readmission.

Table 8a. Reclassification Table of Risk Categories for CABG Mortality Model *With* and *Without* Interaction Terms

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Model With Interaction	Model Without Interaction				
	Risk Category				
Risk Category	≤15%	15% to <20%	20% to <25%	≥25%	Total
Among All 18+ Patients (overall agreement = 99.2%)					
0 to <15%	14,605	24	1	3	**14,633**
15% to <20%	38	37	12	9	**87**
20% to <25%	3	15	21	9	**48**
>=25%	2	4	7	108	**121**
Total	**14,648**	**80**	**41**	**120**	**14,889**
In All 65+ Patients (overall agreement = 99.1%)					
0 to <15%	8,233	17	0	0	**8,250**
15% to <20%	25	33	9	0	**67**
20% to <25%	0	12	18	9	**39**
>=25%	0	1	5	98	**104**
Total	**8,258**	**63**	**32**	**107**	**8,460**
In FFS 65+ Patients (overall agreement = 98.9%)					
0 to <15%	4,535	12	0	0	**4,547**
15% to <20%	18	18	5	0	**41**
20% to <25%	0	8	7	3	**18**
>=25%	0	1	3	63	**67**
Total	**4,553**	**39**	**15**	**66**	**4,673**
In Non-FFS 65+ Patients (overall agreement = 99.3%)					
0 to <15%	3,698	5	0	0	**3,703**
15% to <20%	7	15	4	0	**26**
20% to <25%	0	4	11	6	**21**
>=25%	0	0	2	35	**37**
Total	**3,705**	**24**	**17**	**41**	**3,787**
In All 18-64 Patients (overall agreement = 99.4%)					
0 to <15%	6,372	7	1	3	**6,383**
15% to <20%	13	4	3	0	**20**
20% to <25%	3	3	3	0	**9**
>=25%	2	3	2	10	**17**
Total	**6,390**	**17**	**9**	**13**	**6,429**

Table 8b. Reclassification Table of Risk Categories for CABG Readmission Model *With* and *Without* Interaction Terms

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Model With Interaction	Model Without Interaction				
	Risk Category				
Risk Category	≤15%	15% to <20%	20% to <25%	≥25%	Total
Among All 18+ Patients (overall agreement = 88.5%)					
0 to <15%	9,165	312	9	1	**9,487**
15% to <20%	415	1,823	244	21	**2,503**
20% to <25%	14	262	790	192	**1,258**
>=25%	0	15	196	1,176	**1,387**
Total	**9,594**	**2412**	**1,239**	**1,390**	**14,635**
In All 65+ Patients (overall agreement = 88.6%)					
0 to <15%	4,505	229	3	0	**4,737**
15% to <20%	179	1,358	207	17	**1,761**
20% to <25%	0	84	607	167	**858**
>=25%	0	0	56	846	**902**
Total	**4,684**	**1,671**	**873**	**1,030**	**8,258**
In FFS 65+ Patients (overall agreement = 89.0%)					
0 to <15%	2,446	117	1	0	**2,564**
15% to <20%	100	769	109	10	**988**
20% to <25%	0	44	342	88	**474**
>=25%	0	0	31	495	**526**
Total	**2,546**	**930**	**483**	**593**	**4,552**
In Non-FFS 65+ Patients (overall agreement = 88.1%)					
0 to <15%	2,059	112	2	0	**2,173**
15% to <20%	79	589	98	7	**773**
20% to <25%	0	40	265	79	**384**
>=25%	0	0	25	351	**376**
Total	**2,138**	**741**	**390**	**437**	**3,706**
In All 18-64 Patients (overall agreement = 85.3%)					
0 to <15%	4,460	83	6	1	**4,750**
15% to <20%	236	465	37	4	**742**
20% to <25%	14	178	183	25	**400**
>=25%	0	15	140	330	**485**
Total	**4,910**	**741**	**366**	**360**	**6,377**

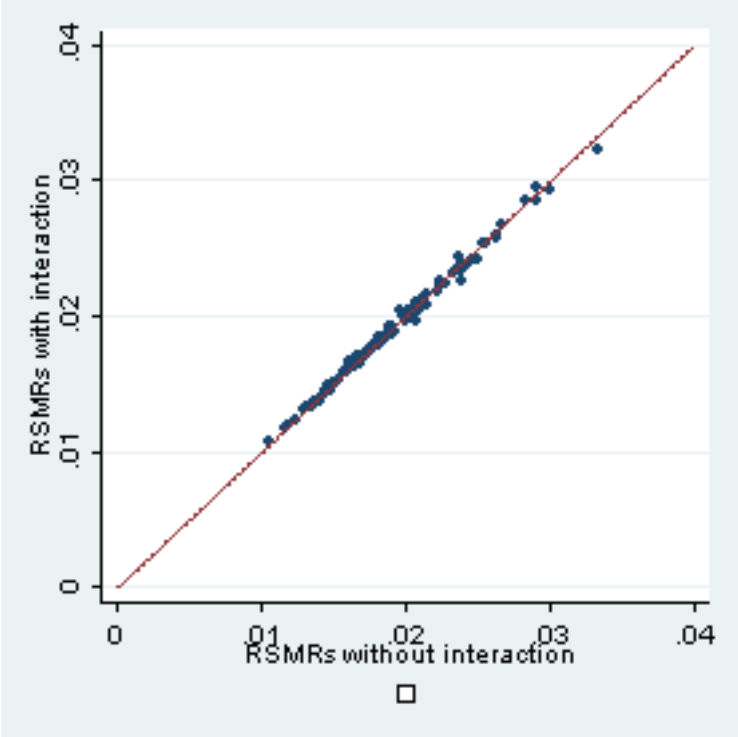
Table 9a. CABG Mortality Model Performance for Models *With* and *Without* Interaction Terms (N = 14,889)

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

CABG Mortality Model	C statistic	SE	Lower C statistic	Upper C statistic
With interaction terms	0.85	0.013	0.821	0.873
Without interaction terms	0.84	0.014	0.813	0.867

Figure 1a. Scatterplot of CABG Risk-Standardized Mortality Rates (RSMRs) from Models *With* and *Without* Interaction Terms

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals



Intra-class Correlation Coefficient (ICC): 0.998

Note: 1) RSMRs are presented as proportions.
2) Diagonal line represents the line of equality.

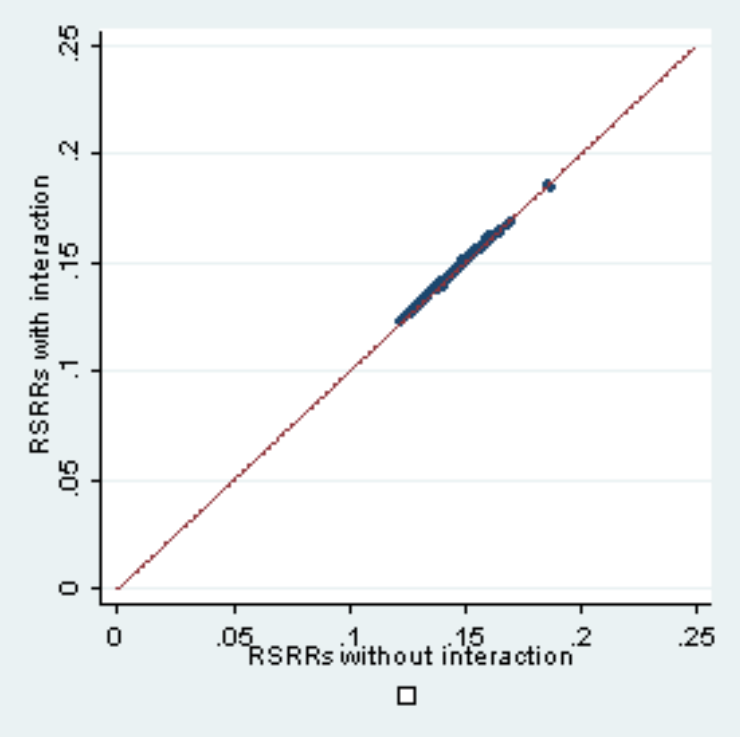
Table 9b. CABG Readmission Model Performance for Models *With* and *Without* Interaction Terms (N =14,635)

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

CABG Readmission Model	C statistic	SE	Lower C statistic	Upper C statistic
With interaction terms	0.66	0.006	0.650	0.675
Without interaction terms	0.66	0.006	0.648	0.673

Figure 1b. Scatterplot of CABG Risk-Standardized Readmission Rates (RSRRs) from Models *With* and *Without* Interaction Terms

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals



Intra-class Correlation Coefficient (ICC): 0.998

Note: 1) RSRRs are presented as proportions.
2) Diagonal line represents the line of equality.