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Hospital 30-Day Risk-Standardized Readmission Rates following
Percutaneous Coronary Intervention (PCI)
Measure # 0695

2013 Measure Specifications Report..... I

**This report is an addendum to the 2009 Measure Methodology Report.*

2009 Measures Methodology Report II

2013 Measure Specifications Report:
**Hospital 30-Day Readmission Following Percutaneous
Coronary Intervention Measure**

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Introduction

Under contract to the Centers for Medicare & Medicaid Services (CMS), the Yale New Haven Health Services Corporation – Center for Outcomes Research and Evaluation (YNHHSC/CORE), in partnership with the American College of Cardiology (ACC), developed a measure of hospital 30-day all-cause readmission following percutaneous coronary intervention (PCI). This measure primarily uses clinical data submitted to the ACC National Cardiovascular Data Registry® (NCDR) CathPCI Registry® by participating hospitals and also uses Medicare claims to identify readmissions. The National Quality Forum (NQF) endorsed the measure in 2011.

This report is an addendum to the 2009 PCI Readmission Measure Methodology Report. This report describes four measure revisions and their rationale. In brief, the model has been updated by:

1. Adapting CMS's *Planned Readmission Algorithm Version 2.1—General Population* for the PCI readmission measure and applying it to expand the number and type of readmissions identified as planned and not counted in the measure outcome;
2. Incorporating Version 4.3.1 of the NCDR® CathPCI Registry® to include the most current model variable definitions and revising the approach to linking the NCDR® CathPCI Registry® data and Medicare claims data to include the use of social security numbers (SSNs);
3. Specifying the claims-based codes in International Classification of Diseases, 10th Revision, Clinical Modification and Procedure Coding System (ICD-10-CM/PCS) as well as International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) in preparation for the transition to ICD-10-CM/PCS in October 2014; and
4. Incorporating ICD-9-CM and Current Procedure Terminology (CPT) coding updates.

In addition, we have conducted additional testing to assess measure score reliability as well as disparities in measure performance by socioeconomic status (SES) and race.

Updates

1. Planned Readmission Algorithm - Update to Section 2.3.2 of 2009 Methodology Report

CMS has worked with experts in the medical community as well as other stakeholders to identify planned readmissions for procedures and treatments, and we do not count them in readmission measures. In 2011, CMS contracted with YNHHSC/CORE to develop a Planned Readmission Algorithm that can be used to identify planned readmissions across its readmission measures; CMS has applied the algorithm to each of the publicly reported measures. The algorithm is a set of criteria for classifying readmissions as planned using Medicare claims. The algorithm identifies admissions that are typically planned and may occur within 30 days of discharge from the hospital.

We based the Planned Readmission Algorithm on three principles:

1. A few specific, limited types of care are always considered planned (obstetric delivery, transplant surgery, maintenance chemotherapy/radiotherapy/ immunotherapy, and rehabilitation);
2. Otherwise, a planned readmission is defined as a non-acute readmission for a scheduled procedure; and
3. Admissions for acute illness or for complications of care are never planned.

The *Planned Readmission Algorithm Version 2.1 – General Population* is a set of criteria for classifying readmissions as planned among the general Medicare population using Medicare administrative claims. The algorithm identifies admissions that are typically planned and may occur within 30 days of discharge from the hospital. The details of the *index* admission (diagnosis or procedures) are not considered when determining whether a readmission is planned. For more information on the development of the algorithm, please refer to the *Centers for Medicare & Medicaid Services Planned Readmission Algorithm Version 2.1: General Population* [report](#).

Customization for PCI Readmission Measure

YNHHSC/CORE updated the approach to identifying planned readmissions in the PCI readmission measure by replacing the original NQF-endorsed approach, which only identified revascularization procedures as planned, with a more comprehensive planned readmission algorithm. The revised approach uses a modified version of the *Planned Readmission Algorithm Version 2.1 – General Population* that has been customized for the PCI patient population. The approach takes into account differences in the likelihood that a procedure is planned depending on whether a coronary stent was implanted during the index PCI procedure.

A working group of YNHHSC/CORE cardiologists and clinicians that developed the Planned Readmission Algorithm reviewed the list of potentially planned procedures in the context of the PCI population. Patients who receive a stent during their PCI require at least four weeks of therapy with aspirin and a platelet inhibitor. During that time period, it is unusual to perform procedures that would require interruption of dual antiplatelet therapy (DAP). In contrast, if no stent is deployed, DAP is not required, and patients are more likely to undergo planned surgical procedures. Given these considerations, the working group developed different sets of potentially planned procedures for patients with and without stent implantation.

Final Algorithm

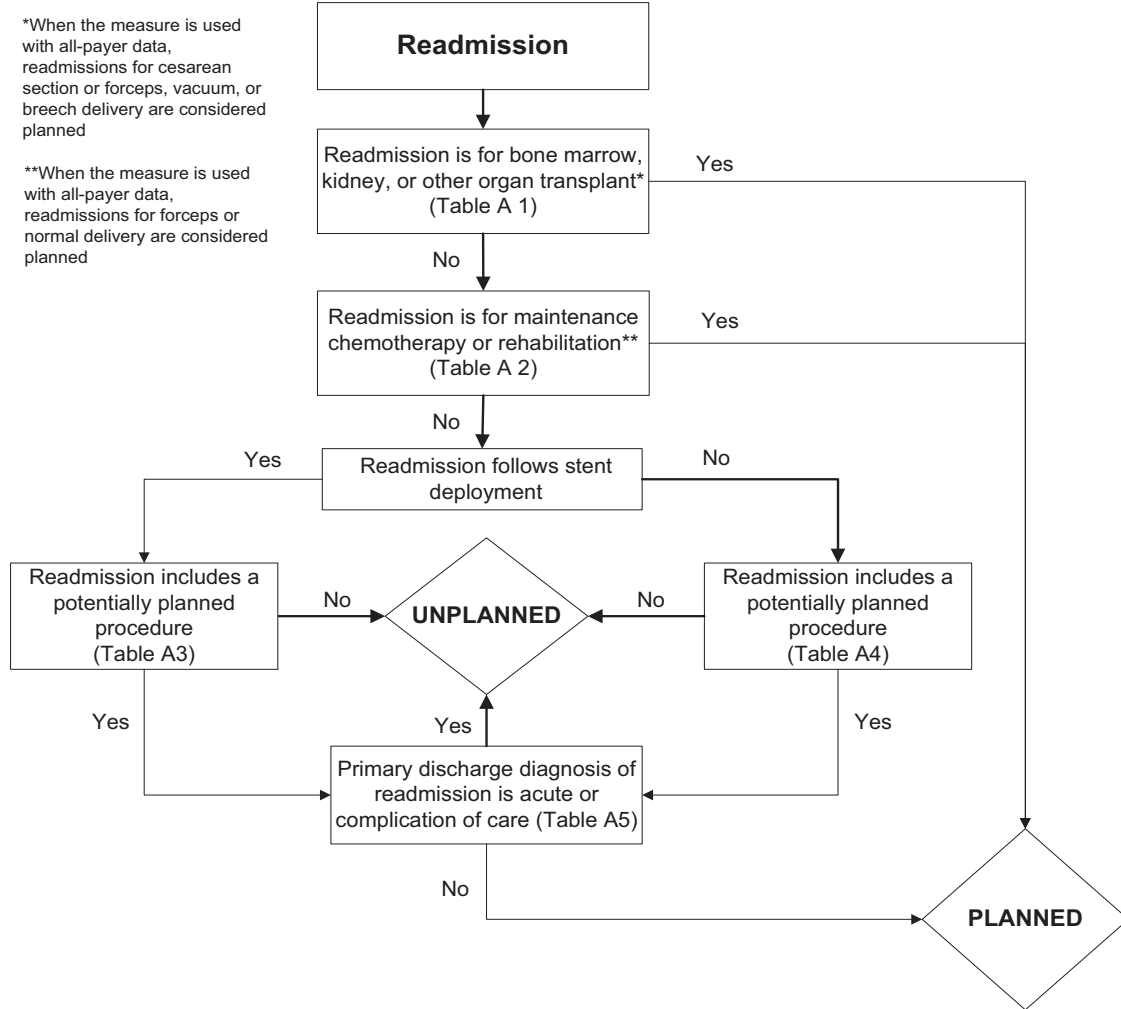
The flow chart ([Figure 1](#)) demonstrates the algorithm's sequence for characterizing readmissions as planned. In the first two steps ([Table PR1](#) and [Table PR2](#)), the algorithm identifies readmissions for procedures and diagnoses that are always considered planned (for example, chemotherapy or organ transplantation). The lists of these procedures and diagnoses are identical to those used in the *Planned Readmission Algorithm Version 2.1 – General Population*.

In the third step, the approach changes depending on whether or not a patient received a stent during the index PCI procedure. If a stent was deployed, the algorithm uses a more limited set of potentially planned procedures ([Table PR3](#)) than if a stent was not deployed ([Table PR4](#)). The list of potentially planned procedures for patients without stents in [Table PR4](#) is identical to that used in the *Planned Readmission Algorithm Version 2.1 – General Population* with the exception of the removal of the Agency for Healthcare Research & Quality (AHRQ) Procedure Clinical Classifications Software (CCS) 47 – Cardiac catheterization, as that is unlikely to be planned within 30 days of any PCI procedure in the absence of a staged PCI.

The list of potentially planned procedures for patients that had a stent deployed during their index PCI in [Table PR3](#) also omits AHRQ Procedure CCS 47 – Cardiac catheterization, for the reasons outlined above. Additionally, the revised list of potentially planned procedures for this patient population does not include most surgical procedures (with the exception of vascular surgery) because we would not expect the planned admission of patients for such surgeries that would interrupt their DAP therapy within 30 days of PCI with stent placement.

All potentially planned procedures identified in both patient populations are then checked for an accompanying principal discharge diagnosis that would reflect an acute condition or complication of care ([Table PR5](#)). The list of acute diagnoses in this table is identical to that used in the *Planned Readmission Algorithm Version 2.1 – General Population*.

Figure 1. Planned Readmission Algorithm Version 2.1 (Adapted for PCI Readmission Measure)



Effect on Measure

To assess the effect of updating the measure with the planned readmission algorithm, we compared the results of the original, NQF-endorsed and updated measures. We applied the measures to admissions in 2010. There were 141,467 index admissions for PCI at 1,094 hospitals.

The updated algorithm identified 3,440 planned readmissions. The top ten procedures among planned readmissions after PCI with and without stent identified by the updated measure are presented in [Table 1](#) and [Table 2](#) respectively.

Table 1. Top 10 Planned Procedures among Planned Readmissions Following PCI Discharge (with Stent)

Procedure CCS	Procedure Description	Number of Planned Procedures
45	Percutaneous transluminal coronary angioplasty (PTCA)	2161
48	Insertion; revision; replacement; removal of cardiac pacemaker or cardioverter/defibrillator	477
44	Coronary artery bypass graft (CABG)	300
49	Other OR heart procedures	126
62	Other diagnostic cardiovascular procedures	120
59	Other OR procedures on vessels of head and neck	102
51	Endarterectomy; vessel of head and neck	98
157	Amputation of lower extremity	55
52	Aortic resection; replacement or anastomosis	55
43	Heart valve procedures	48

Table 2. Top 10 Planned Procedures among Planned Readmissions Following PCI Discharge (without Stent)

Procedure CCS	Procedure Description	Number of Planned Procedures
44	Coronary artery bypass graft (CABG)	221
45	Percutaneous transluminal coronary angioplasty (PTCA)	169
48	Insertion; revision; replacement; removal of cardiac pacemaker or cardioverter/defibrillator	73
49	Other OR heart procedures	33
51	Endarterectomy; vessel of head and neck	15
99	Other OR gastrointestinal therapeutic procedures	14
59	Other OR procedures on vessels of head and neck	14
62	Other diagnostic cardiovascular procedures	13
84	Cholecystectomy and common duct exploration	12
43	Heart valve procedures	12

Using the method in the original, NQF-endorsed measure, the crude 30-day unplanned readmission rate was 12.3% and the planned readmission rate was 2.0%. The updated algorithm decreased the number of readmissions counted in the outcome by identifying additional readmissions as planned. For the updated measure, the crude 30-day unplanned readmission rate was 11.8%. Thus, in the updated measure, the rate of planned readmissions increased to 2.4%, an absolute increase of 0.4% from the method in the original measure.

Although the rate of planned readmissions was higher for the updated measure, some readmissions considered as planned in the original, NQF-endorsed measure were identified as unplanned in the

updated measure. This reflects the fact that the planned readmission algorithm contains a more complete list of acute diagnosis categories ([Table PR5](#)) that disqualified some readmissions with a potentially planned procedure from being considered planned. Roughly 2% of readmissions identified as planned in the original, NQF-endorsed measure were no longer considered planned in the updated measure.

2. Respecification for CathPCI Registry® Updates

CathPCI Registry® Versions - Update to Section 2.4.1 of 2009 Methodology Report

Initial development and specification of the measure used variables collected in Version 3.04 (Version 3) of the CathPCI Registry®. In July 2009, the NCDR® introduced Version 4.3.1 (Version 4) of the CathPCI Registry® that included modifications of previously collected data elements, addition of new data fields, and updated data definitions. In order to calculate the measure using current registry data, we re-specified the model variables to reflect changes in the data collection form. We assessed the impact of this change to confirm that simple re-specification of the variables in Version 4 was a valid approach.

We crosswalked the data elements that we used to define the final model variables in Version 3 and Version 4 of the NCDR® CathPCI Registry®. We compared the data element names and definitions to ensure that we could successfully apply the model to data that was collected using the new data collection forms and the data dictionaries of both versions. To evaluate model performance after the re-specification to Version 4 variables, we compared the odds ratios (OR) and c-statistics from models based on 2008 Version 3 data and 2010 Version 4 data.

The complete crosswalk of the PCI readmission model variables from Version 3 to Version 4 of the CathPCI Registry® is provided in [Appendix B](#). Overall, re-specification of the model variables from Version 3 to Version 4 was straightforward.

The c-statistics for the models were similar for the 2010, Version 4 model (0.680) and the 2008, Version 3 model (0.676). ORs in the models for both data years were comparable ([Table 3](#)), indicating that the re-specification of the model variables did not significantly alter model performance. The current model can use the Version 4 registry data.

Table 3. Comparison of Odds Ratios (OR) and 95% Confidence Intervals (CI) between Version 3 and Version 4 for the PCI Readmission Model Variables

PCI Readmission Risk-Variable as Specified in Measure	OR and 95% CI Version 4 (2010)	OR and 95% CI Version 3 (2008)
Age	1.28 (1.24 - 1.31)	1.23 (1.20 - 1.27)
Female	1.24 (1.20 - 1.29)	1.23 (1.19 - 1.28)
Body Mass Index	0.90 (0.88 - 0.93)	0.87 (0.85 - 0.90)
Heart failure-previous history	1.32 (1.26 - 1.38)	1.33 (1.27 - 1.40)
Previous valvular surgery	1.25 (1.12 - 1.39)	1.20 (1.07 - 1.34)
Cerebrovascular Disease	1.17 (1.12 - 1.23)	1.17 (1.12 - 1.23)
Peripheral Vascular Disease	1.20 (1.15 - 1.26)	1.18 (1.13 - 1.24)
Chronic Lung Disease	1.45 (1.39 - 1.51)	1.49 (1.43 - 1.55)
Diabetes - No diabetes	<i>Reference</i>	<i>Reference</i>
Diabetes - Non-insulin diabetes	1.13 (1.08 - 1.18)	1.12 (1.07 - 1.17)
Diabetes - Insulin diabetes	1.43 (1.36 - 1.51)	1.40 (1.33 - 1.48)
Glomerular Filtration Rate (GFR) - Not measured	1.05 (0.97 - 1.13)	0.99 (0.89 - 1.09)
GFR<30	1.67 (1.53 - 1.82)	1.58 (1.45 - 1.72)
30≤GFR<60	1.18 (1.13 - 1.23)	1.19 (1.15 - 1.24)
60≤GFR<90	<i>Reference</i>	<i>Reference</i>
GFR≥90	1.06 (0.99 - 1.13)	1.04 (0.97 - 1.10)
Renal failure - dialysis	1.56 (1.41 - 1.74)	1.63 (1.45 - 1.83)
Hypertension	1.17 (1.11 - 1.24)	1.10 (1.04 - 1.15)
History of tobacco use	1.10 (1.05 - 1.16)	1.03 (0.98 - 1.09)
Previous PCI	0.91 (0.88 - 0.95)	0.91 (0.87 - 0.94)
Heart failure – current status	1.34 (1.27 - 1.41)	1.39 (1.33 - 1.46)
No MI on admission	0.93 (0.88 - 0.97)	0.95 (0.90 - 1.00)
MI within 24 hours of admission	<i>Reference</i>	<i>Reference</i>
MI after 24 hours of admission	1.02 (0.92 - 1.13)	1.05 (0.98 - 1.13)
Ejection Fraction (EF) Percentage - Not measured	1.08 (1.04 - 1.13)	1.16 (1.12 - 1.21)
EF<30	1.50 (1.39 - 1.62)	1.55 (1.44 - 1.67)
30≤EF<45	1.14 (1.08 - 1.20)	1.27 (1.20 - 1.33)
EF≥45	<i>Reference</i>	<i>Reference</i>
PCI Procedure – Elective	<i>Reference</i>	<i>Reference</i>
PCI Procedure - Urgent	1.43 (1.37 - 1.49)	1.40 (1.34 - 1.46)
PCI Procedure - Emergency	1.55 (1.44 - 1.66)	1.60 (1.49 - 1.72)
PCI Procedure - Salvage	1.42 (0.93 - 2.19)	1.87 (1.32 - 2.65)
Highest risk lesion - pRCA/mLAD/pCIRC	1.01 (0.97 - 1.05)	1.07 (1.03 - 1.11)
Highest risk lesion - pLAD	1.04 (0.99 - 1.09)	1.07 (1.02 - 1.12)
Highest risk lesion - Left main	1.16 (1.06 - 1.27)	1.06 (0.95 - 1.18)
Highest risk lesion – Other	<i>Reference</i>	<i>Reference</i>
Highest pre-procedure TIMI flow: none	1.06 (1.00 - 1.12)	1.08 (1.01 - 1.15)

Linking Strategy - Update to Section 2.5 of 2009 Methodology Report

The PCI readmission measure requires that data from the NCDR® CathPCI Registry® be linked with corresponding Medicare claims data to determine readmissions following hospital discharge. At the time of measure development, NCDR® did not require® CathPCI Registry® participants to submit direct patient identifiers. In the absence of direct patient identifiers, measure developers originally developed the measure using a probabilistic match that linked PCI patients in both registry and Medicare claims data using the following indirect identifiers: hospital Medicare Provider Number (MPN), patient age, gender, date of admission, and date of discharge.

NCDR® has since modified its business associate agreements with participating hospitals to allow for the use of identified data for quality improvement efforts. In addition, starting in July 2009, the NCDR® asked hospitals to voluntarily submit direct patient identifiers, including SSN.

We developed a five-step linking strategy using direct and indirect patient identifiers. The following linking strategy maximized the number of matches while minimally compromising accuracy: In step 1, SSN is used to identify the patient, discharge date is used to identify the visit, and MPN is used to identify the correct facility. In this step, all nine SSN digits, discharge date, and MPN must match. Remaining steps are carried out sequentially on patients who were unmatched after the previous step. Steps 2-4 capture patients with inaccurate SSN. Since SSN discrepancies are allowed in these steps, age and gender are used as additional indirect patient identifiers. In step 5, SSN is removed from consideration, and date of birth (DOB) is used with gender, discharge date, and MPN to identify patients in both datasets.

This linking strategy yielded a 94.0% match rate of hospital stays in 2010 for hospitals that appeared in both data sources. The strategy matched 77% of hospital stays using SSN, which was expected given that roughly 22% of hospital stays had a missing or invalid SSN. The strategy matched roughly 16% of hospital stays matched using DOB, gender, and dates of hospital service ([Table 4](#)).

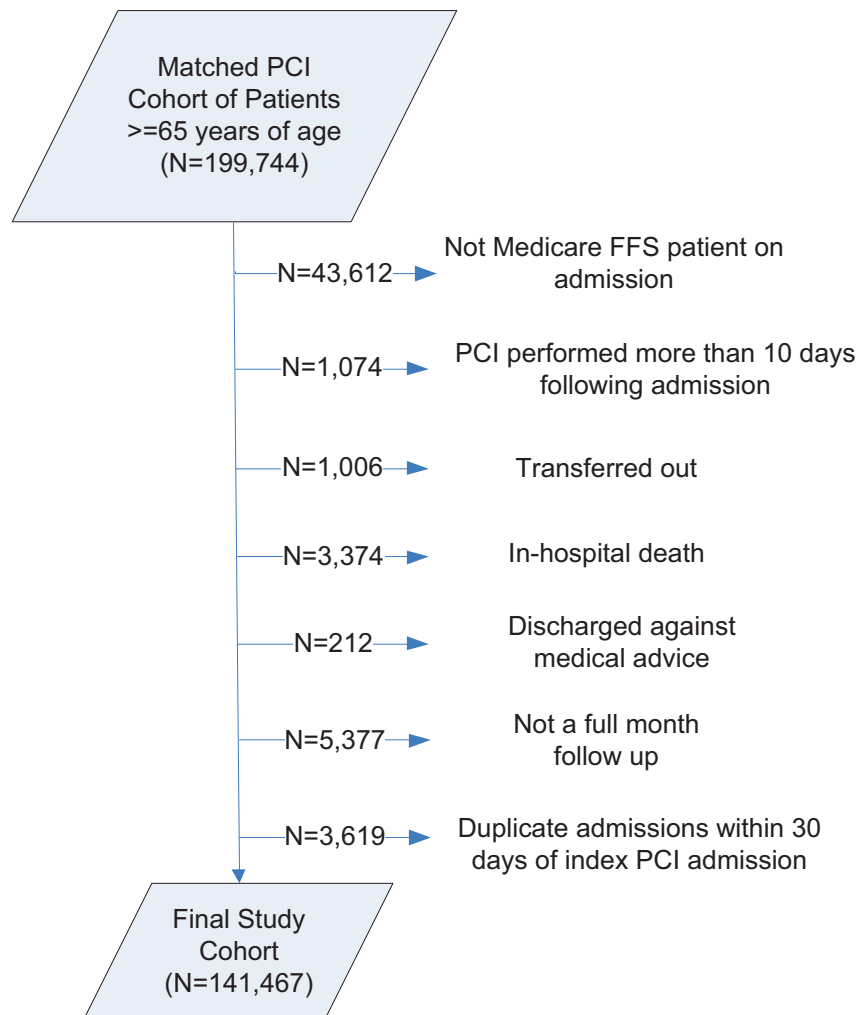
Using complete SSNs alone to link registry and administrative claims data would have resulted in the exclusion of more than 20% of cases and roughly 10% of hospitals from the measure. The use of a five-step strategy to link the datasets substantially increased the match rate and improves the generalizability of the resulting risk-standardized readmission rates (RSRRs).

Table 4. Match Rate after Linking CathPCI Data to CMS Claims Data using a Five-Step Approach (2010)

Linking Steps and Matching Criteria	Hospital Stays	Marginal %	Cumulative %
<i>Initial CMS Cohort</i>	212,728	<i>n/a</i>	<i>n/a</i>
Step 1. 9/9 SSN digits, discharge date, MPN	164,579	77.4	77.4
Step 2. 8/9 SSN digits, age, gender, discharge date, MPN	1,635	0.8	78.2
Step 3. 7/9 SSN digits, age, gender, discharge date, MPN	412	0.2	78.4
Step 4. Last 4 SSN digits, age, gender, discharge date, MPN	35	0.0	78.4
Step 5. Date of birth, gender, discharge date, MPN	33,083	15.6	94.0
Total	199,744	n/a	94.0

[Figure 2](#) describes the derivation of the final PCI measure study cohort. We identified 199,744 admissions in which patients received a PCI during their hospital stay and were discharged in 2010; were aged 65 years or over when they arrived at the hospital; and had a record in the CathPCI Registry® that met NCDR® data quality threshold criteria and was linked to the corresponding Medicare fee-for-service (FFS) claim. Next, we identified admissions meeting each of seven exclusion criteria: 43,612 admissions were for patients not enrolled in Medicare FFS at the time of the PCI procedure; 1,074 admissions in which the PCI procedure was performed more than 10 days following admission; 1,006 admissions in which the patient was transferred to another acute care facility; 3,374 admissions in which the patient died during their initial hospitalization for a PCI procedure; 212 admissions in which patients were discharged against medical advice; 5,377 admissions in which the patient did not have 30 days of follow-up data available in the Medicare FFS data; 3,619 admissions in which patients had duplicate admissions for a PCI procedure within 30 days of an index PCI admission. The final study cohort, after all inclusion and exclusion criteria were applied, included 141,467 admissions.

Figure 2. Inclusion and Exclusion Criteria (Numbers of Admissions Based on 2010 Data)



3. General Equivalence Mapping Crosswalk between ICD-9-CM to ICD-10-CM/PCS

In January 2009, the Department of Health and Human Services (HHS) issued a final rule to transition from coding ICD-9-CM to ICD-10-CM/PCS. HHS issued a final rule for mandatory implementation of ICD-10 by October 1, 2014. Operationally, this requires all outpatient claims with dates of service and inpatient claims with dates of discharge on and after October 1, 2014 to utilize ICD-10-CM/PCS codes.

In 2012, we used the General Equivalence Mappings (GEM) crosswalk between ICD-9-CM and ICD-10-CM/PCS to create specifications for the PCI readmission measure cohort in ICD-10-CM/PCS. The planned readmission algorithm has not yet been mapped to ICD-10-CM/PCS because the algorithm was not finalized at the time of this crosswalk.

Our process for mapping procedural codes in the measures to ICD-10-CM consisted of a detailed clinical review, including manual review of related ICD-10-CM codes to determine that all

appropriate codes are included, rather than relying exclusively on the GEM. To conduct the crosswalk, we created a database to effectively use the mapping tables provided by CMS. We then compiled a list of ICD-9-CM codes that define PCI during hospitalization. Measure developers used these ICD-9-CM codes to build queries to extract the GEM results from the mapping table in the database. We then applied those ICD-10-CM codes to the ICD-10-CM to ICD-9-CM mapping table to see if the reverse query produced ICD-9-CM codes that were not in the original measure specifications.

Our clinicians reviewed these results in detail and determined that many ICD-10-CM codes that should be included in our cohort were not being captured by the GEMs. We confirmed this by consulting the ICD-10-CM draft procedural codebook and identifying the ICD-10-CM codes that our clinicians felt should be included in our cohort. In [Table C1](#) and [Table C2](#), we provide the ICD-9-CM to ICD-10-CM crosswalk.

4. Update to Cohort Codes

In 2013, we updated the codes defining the PCI readmission cohort by the assignment of new codes and the removal of retired codes. We added one new ICD-9-CM code (17.55 “transluminal coronary atherectomy”) to identify services rendered in the cohort of the PCI readmission measure. Some ICD-9-CM codes in the original cohort definition were retired. After confirming in the 2010 data that these codes were no longer in use, we removed the ICD-9-CM codes 36.01, 36.02, and 36.05 from the cohort definition. The 2013 cohort codes defining the PCI readmission measure’s cohort in the administrative claims data are shown in [Table 5](#).

Table 5: Cohort Codes in PCI Readmission Measures

Code Type	Code	Description
ICD-9-CM	00.66	Percutaneous transluminal coronary angioplasty or coronary atherectomy
ICD-9-CM	17.55	Transluminal coronary atherectomy
ICD-9-CM	36.06	Insertion of non-drug-eluting coronary artery stent(s)
ICD-9-CM	36.07	Insertion of drug-eluting coronary artery stent(s)
CPT	92973	Percutaneous transluminal coronary thrombectomy
CPT	92980	Coronary Stents [single vessel]
CPT	92981	Coronary Stents [each additional vessel]
CPT	92982	Coronary Balloon Angioplasty [single vessel]
CPT	92984	Coronary Balloon Angioplasty [each additional vessel]
CPT	92995	Percutaneous Atherectomy
CPT	92996	Percutaneous Atherectomy

Disparities and Reliability Analyses

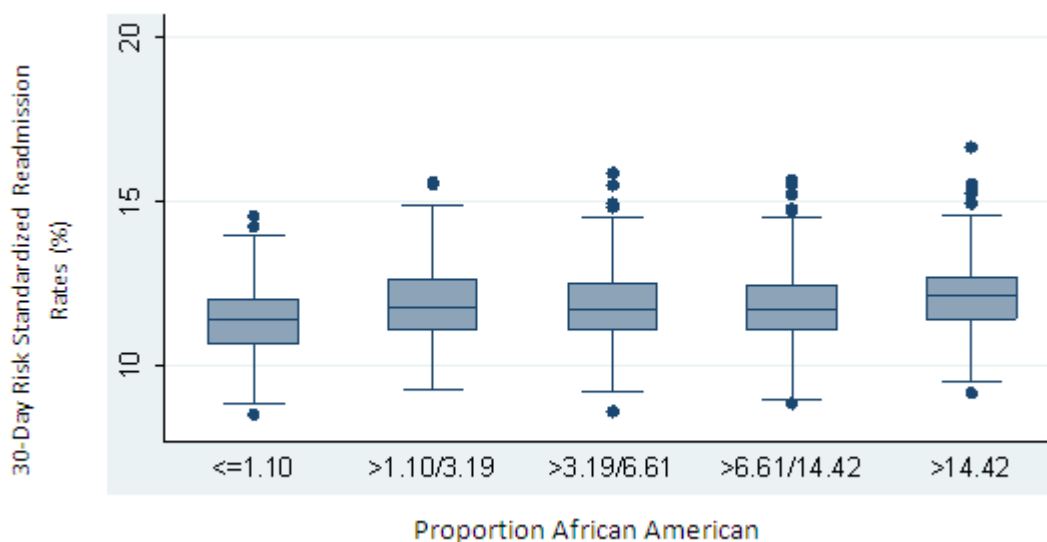
We conducted additional measure testing. Specifically, we examined (1) disparities in care and (2) the measure score reliability.

1. Disparities Analyses

We reviewed evidence in the published literature to determine whether disparities in care for patients receiving PCI procedures have previously been documented. No studies have previously identified disparities in readmission following PCI. However, studies have suggested that disparities in the treatment of PCI patients exist. A study of 43,317 patients with high-risk non-ST segment elevation acute coronary syndromes, in which nearly 13% were black, reported that black patients were less likely than white patients to receive recommended and ideal care.¹ Another study examined 1.2 million black and white Medicare patients with AMI and demonstrated that black patients admitted to hospitals with and without coronary revascularization services were less likely than white patients to receive recommended care and more likely to experience death within 1 year of admission for AMI.² To expand on that review, we conducted analyses to explore disparities in hospitals' performance on each measure by race and SES.

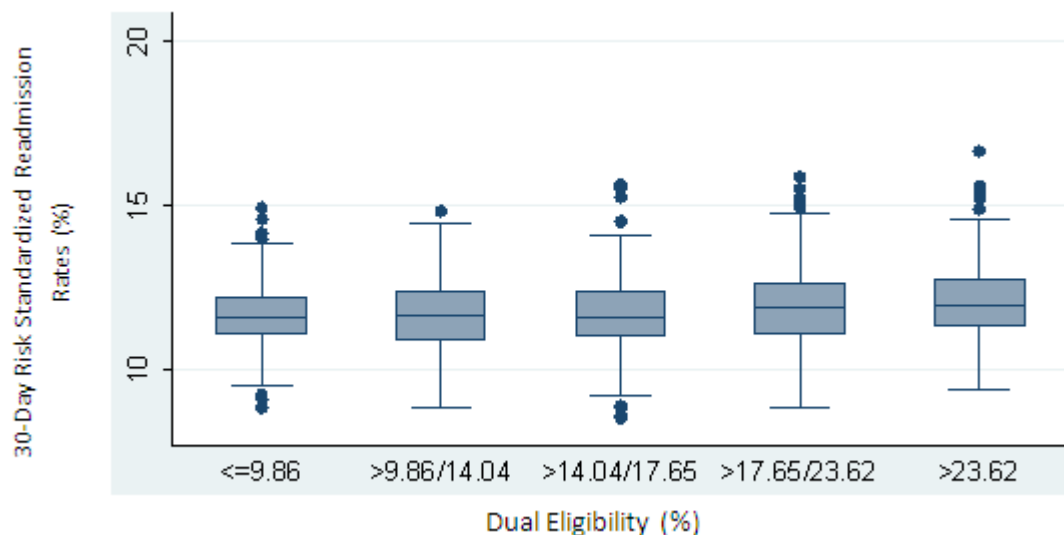
We used the Medicare Provider Analysis and Review (MEDPAR) File for 2010 to calculate the percentage of African-American patients treated at each hospital, using all patients admitted to each hospital. We examined hospital-level RSRRs across hospitals grouped by quintile of the proportion of African-American patients. Overall, there were modest differences in the RSRRs by quintile. Specifically, the median RSRR for hospitals with the highest proportion of African-American patients was 12.4% compared with 11.2% for hospitals with the lowest proportion of African-American patients. In comparison to the registry average of 11.8%, hospitals with high proportions of African-American patients have modestly higher 30-day RSRRs. However, the distributions for the RSRRs overlapped across hospital quintiles ([Figure 3](#)), and many hospitals caring for the highest percentage of African-American patients performed well on the measures.

Figure 3. Distributions of Hospital RSRRs by Proportion of African Americans



We used the MEDPAR File for 2010 to calculate the percentage of patients 65 or older and eligible for both Medicare and Medicaid (dual eligible patients) treated at each hospital. The proportion of dual eligible patients was used as a marker for determining the SES status of hospitals' patients because this is a low income and vulnerable population. Similar to our analyses above, we examined hospital-level RSRRs across quintiles of dual eligible patients treated. There were no differences in RSRRs across income quintile. The median RSRR for hospitals in the top quintile of dual eligible patients was 12.3% compared with 11.6% for hospitals in the bottom quintile of dual eligible patients. In comparison to the registry average of 11.8%, hospitals that treat a high percentage of dual eligible patients have moderately higher 30-day RSRRs. However, the distributions for the RSRRs overlapped ([Figure 4](#)), and many hospitals in the highest quintile of dual eligible patients performed well on the measure.

Figure 4. Distributions of Hospital RSRRs by Proportion of Dual Eligible Patients



2. Measure 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, the measured entity is naturally 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 in the same time period 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 calculate the agreement of the two resulting performance measures across hospitals.

For test-retest reliability of the measure in Medicare FFS patients aged 65 and older, we combined index admissions from two years (2010-2011) into a single 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 reliable. As a metric of agreement we calculated the intra-class correlation coefficient, and assessed the values according to conventional standards.

Specifically, we used a combined 2010-2011 sample that had been linked with Medicare FFS claims data and randomly split it into two approximately equal subsets of patients. We then 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. Using two independent samples provides an honest estimate of the measure's reliability, compared with using two random but potentially overlapping samples, which likely would overestimate the agreement. Of note, because our final measure is derived using hierarchical logistic regression, a known property of hierarchical logistic regression models is that smaller volume hospitals contribute less 'signal'. As such a split sample using a single measurement period likely introduces extra noise; potentially underestimating the actual test-retest reliability that would be achieved if the measures were reported using additional years of data. Furthermore, the measure is specified for the entire PCI population, but we tested it only in the subset of Medicare FFS patients for whom information about vital status was available. This reduced the cohort available for testing by approximately 40%.

There were 277,512 admissions in the combined two-year sample, with 138,756 in each randomly selected sample. The agreement between the two RSRRs for each hospital was 0.3711, which according to the conventional interpretation is "Fair."³

References

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Appendix A: Planned Readmission Algorithm (Version 2.1 – PCI Population)

Table PR1: Procedure Categories that are Always Planned (Version 2.1 – PCI Population)

Procedure CCS ¹	Description
64	Bone marrow transplant
105	Kidney transplant
134	Cesarean section ²
135	Forceps; vacuum; and breech delivery ²
176	Other organ transplantation

Table PR2: Diagnosis (Dx) Categories that are Always Planned (Version 2.1 – PCI Population)

Diagnosis CCS ²	Description
45	Maintenance chemotherapy
194	Forceps delivery ²
196	Normal pregnancy and/or delivery ²
254	Rehabilitation

¹ CCS: Clinical Classification Software, developed by the Agency for Healthcare Research and Quality (AHRQ). The software creates clinically-coherent, mutually-exclusive condition categories (diagnosis groups) and procedure categories.

² 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: Potentially Planned Procedure Categories (Version 2.1 – PCI Population with Stent)

Procedure CCS	Description
43	Heart valve procedures
44	Coronary artery bypass graft (CABG)
45	Percutaneous transluminal coronary angioplasty (PTCA)
48	Insertion; revision; replacement; removal of cardiac pacemaker or cardioverter/defibrillator
49	Other OR heart procedures
51	Endarterectomy; vessel of head and neck
52	Aortic resection; replacement or anastomosis
55	Peripheral vascular bypass
56	Other vascular bypass and shunt; not heart
59	Other OR procedures on vessels of head and neck
62	Other diagnostic cardiovascular procedures
107	Extracorporeal lithotripsy; urinary
157	Amputation of lower extremity
169	Debridement of wound; infection or burn
211	Therapeutic radiology for cancer treatment
224	Cancer chemotherapy
ICD-9 Codes	Description
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: Potentially Planned Procedure Categories (Version 2.1 – PCI Population without Stent)

Procedure CCS ³	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
43	Heart valve procedures
44	Coronary artery bypass graft (CABG)
45	Percutaneous transluminal coronary angioplasty (PTCA)
48	Insertion; revision; replacement; removal of cardiac pacemaker or cardioverter/defibrillator
49	Other OR heart procedures
51	Endarterectomy; vessel of head and neck
52	Aortic resection; replacement or anastomosis
53	Varicose vein stripping; lower limb
55	Peripheral vascular bypass
56	Other vascular bypass and shunt; not heart
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
79	Local excision of large intestine lesion (not endoscopic)
84	Cholecystectomy and common duct exploration
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

³ CCS: Clinical Classification Software, developed by the Agency for Healthcare Research and Quality (AHRQ). The software creates clinically-coherent, mutually-exclusive condition categories (diagnosis groups) and procedure categories.

Procedure CCS ³	Description
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
142	Partial excision bone
152	Arthroplasty knee
153	Hip replacement; total and partial
154	Arthroplasty other than hip or knee
157	Amputation of lower extremity
158	Spinal fusion
159	Other diagnostic procedures on musculoskeletal system
166	Lumpectomy; quadrantectomy of breast
167	Mastectomy
169	Debridement of wound; infection or burn
170	Excision of skin lesion
172	Skin graft
211	Therapeutic radiology for cancer treatment
224	Cancer chemotherapy
ICD-9-CM 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)
38.18	Endarterectomy leg vessel (from Proc CCS 60- Embolectomy and endarterectomy of lower limbs)
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 PR5: Acute Diagnosis Categories (Version 2.1 – PCI Population)

Diagnosis CCS ⁴	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
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

⁴ CCS: Clinical Classification Software, developed by the Agency for Healthcare Research and Quality (AHRQ). The software creates clinically-coherent, mutually-exclusive condition categories (diagnosis groups) and procedure categories.

Diagnosis CCS ⁴	Description
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

Diagnosis CCS ⁴	Description
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-CM codes	Description

Acute ICD-9-CM codes within Dx CCS 97: Peri-; endo-; and myocarditis; cardiomyopathy

03282	Diphtheritic myocarditis
03640	Meningococcal carditis nos
03641	Meningococcal pericarditis
03642	Meningococcal endocarditis
03643	Meningococcal myocarditis
07420	Coxsackie carditis nos
07421	Coxsackie pericarditis
07422	Coxsackie endocarditis
07423	Coxsackie myocarditis
11281	Candidal endocarditis
11503	Histoplasma capsulatum pericarditis

Diagnosis CCS ⁴	Description
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-CM codes within Dx CCS 105: Conduction disorders

4260	Atrioventricular block complete
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

Diagnosis CCS ⁴	Description
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-CM 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-CM 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	Unpec 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

Appendix B: NCDR® CathPCI Registry® Version Update Crosswalk

Table B1. NCDR® CathPCI Registry® Version Update Crosswalk

Risk Variable in PCI Readmission Measure	Version 3.04 NCDR® Number	Version 3.04 Variable Name	Version 3.04 Variable Definition	Version 4.3.1 NCDR® Number	Version 4.3.1 Variable Name	Version 4.3.1 Variable Definition
Age	252	Patient Age	Patient age in years, at time of admission. This should be calculated from the date of birth and the date of admission, according to the convention used in the USA (the number of birthdate anniversaries reached by the date of admission).	2050	Birth Date	Coding Instructions: Indicate the patient's date of birth. Target Value: The value on arrival at this facility
Age				3000	Arrival Date	
Female	260	Gender	Indicate the patient's gender at birth as either male or female. Choose one of the following: Male, Female	2060	Sex	Coding Instructions: Indicate the patient's sex at birth. Target Value: The value on arrival at this facility Selections: Male, Female
Body Mass Index (BMI)	410	Height (cm)	Indicate the patient's height in centimeters.	4055	Height	Coding Instructions: Indicate the patient's height in centimeters. Target Value: First value between arrival at this facility and discharge
BMI	412	Weight (kg)	Indicate the weight of the patient in kilograms.	4060	Weight	Coding Instructions: Indicate the patient's weight in kilograms. Target Value: Last value between arrival at this facility and first procedure

Risk Variable in PCI Readmission Measure	Version 3.04 NCDR® Number	Version 3.04 Variable Name	Version 3.04 Variable Definition	Version 4.3.1 NCDR® Number	Version 4.3.1 Variable Name	Version 4.3.1 Variable Definition
History of Heart Failure (HF)	424	CHF - Previous History	<p>Indicate if the patient has a history of congestive heart failure (CHF) documented in the medical record. History is defined as any time prior to two weeks before the current date of admission.</p> <p>Besides physician documentation of the CHF history, CHF can also be defined by one of the following:</p> <ol style="list-style-type: none"> 1. Paroxysmal nocturnal dyspnea (PND); 2. Dyspnea on exertion (DOE) due to heart failure; or 3. Chest X-Ray (CXR) showing pulmonary congestion. 4. Pedal edema or dyspnea treated with medical therapy for heart failure. <p>Choose one of the following:</p> <ul style="list-style-type: none"> - No - Yes 	4025	Prior Heart Failure	<p>Coding Instructions: Indicate if there is a previous history of heart failure</p> <p>Note(s): A previous hospital admission with principal diagnosis of heart failure is considered evidence of heart failure history.</p> <p>Target Value: Any occurrence between birth and arrival at this facility</p> <p>Selections: No, Yes</p> <p>Supporting Definitions: Heart Failure: Heart failure is defined as physician documentation or report of any of the following clinical symptoms of heart failure described as unusual dyspnea on light exertion, recurrent dyspnea occurring in the supine position, fluid retention; or the description of rales, jugular venous distension, pulmonary edema on physical exam, or pulmonary edema on chest x-ray. A low ejection fraction alone, without clinical evidence of heart failure does not qualify as heart failure. *Note: Killip Class 2 is defined as rales covering 50% or less of the lung fields or the presence of an S3.</p> <p>Killip Class 3 is defined as rales covering more than 50% of the lung fields. Either class would qualify as a "yes."</p> <p>Source Acute Coronary Syndromes Data Standards (JACC 2001 38: 2114 - 30), The Society of Thoracic Surgeons</p>
Previous valvular surgery	426	Previous Valvular Surgery	<p>Indicate if the patient had a previous surgical replacement and/or repair of a cardiac valve, by any approach prior to the current admission. Choose one of the following:</p> <ul style="list-style-type: none"> - Yes - No 	4030	Prior Valve Surgery/ Procedure	<p>Coding Instructions: Indicate if the patient had a previous surgical replacement and/or repair of a cardiac valve, by any approach prior to arrival.</p> <p>Target Value: Any occurrence between birth and arrival at this facility</p> <p>Selections: No, Yes</p> <p>Note(s): This also includes percutaneous valve procedures and valvuloplasty.</p>

Risk Variable in PCI Readmission Measure	Version 3.04 NCDR® Number	Version 3.04 Variable Name	Version 3.04 Variable Definition	Version 4.3.1 NCDR® Number	Version 4.3.1 Variable Name	Version 4.3.1 Variable Definition
Cerebrovascular disease	450	Cerebrovascular Disease	<p>Indicate if the patient has a history of cerebrovascular disease, documented by any one of the following:</p> <ol style="list-style-type: none"> 1. Unresponsive Coma greater than 24 hours: Patient experienced complete mental unresponsiveness and no evidence of psychological or physiologically appropriate responses to stimulation. 2. Cerebrovascular Accident (CVA): Patient has a history of stroke, i.e., loss of neurological function with residual symptoms at least 72 hours after onset. 3. Reversible Ischemic Neurologic Deficit (RIND): Patient has a history of loss of neurological function with symptoms at least 24 hours after onset but with complete return of function within 72 hours. 4. Transient Ischemic Attack (TIA): Patient has a history of loss of neurological function that was abrupt in onset but with complete return of function within 24 hours. 5. Non-invasive/invasive carotid test with greater than 75% occlusion. 6. Previous carotid artery surgery. <p>This does not include neurological disease processes such as metabolic and/or anoxic ischemic encephalopathy. Choose one of the following: Yes, No</p>	4070	Cerebrovascular Disease	<p>Coding Instructions: Indicate if the patient has a history of cerebrovascular disease. Target Value: Any occurrence between birth and arrival at this facility Selections: No, Yes Supporting Definitions: Cerebrovascular Disease: Cerebrovascular Disease documented by any one of the following:</p> <ol style="list-style-type: none"> 1. Cerebrovascular Accident (CVA): Patient has a history of stroke, i.e., loss of neurological function with residual symptoms at least 24 hrs after onset, presumed to be from vascular etiology. 2. Transient Ischemic Attack (TIA): Patient has a history of loss of neurological function that was abrupt in onset but with complete return of function within 24 hrs, presumed to be due to vascular etiology 3. Non-invasive/invasive carotid test with > 79% occlusion. 4. Previous carotid artery surgery/intervention for carotid artery stenosis. This does not include neurological disease processes such as metabolic and/or anoxic ischemic encephalopathy. <p>Source Acute Coronary Syndromes Data Standards (JACC 2001 38: 2114-30), The Society of Thoracic Surgeons</p>

Risk Variable in PCI Readmission Measure	Version 3.04 NCDR® Number	Version 3.04 Variable Name	Version 3.04 Variable Definition	Version 4.3.1 NCDR® Number	Version 4.3.1 Variable Name	Version 4.3.1 Variable Definition
Peripheral Vascular Disease	452	Peripheral Vascular Disease	<p>Indicate if the patient has a history of peripheral vascular disease. This can include:</p> <ol style="list-style-type: none"> 1. Claudication either with exertion or at rest. 2. Amputation for arterial vascular insufficiency. 3. Aorto-iliac occlusive disease reconstruction, peripheral vascular bypass surgery, angioplasty or stent; or percutaneous intervention to the extremities. 4. Documented AAA repair or stent. 5. Positive non-invasive/invasive test. <p>This does not include procedures such as vein stripping, carotid disease, or procedures originating above the diaphragm.</p> <p>Choose one of the following:</p> <ul style="list-style-type: none"> - Yes - No 	4075	Peripheral Arterial Disease	<p>Coding Instructions: Indicate if the patient has a history of peripheral arterial disease (PAD) (includes upper and lower extremity, renal, mesenteric, and abdominal aortic systems).</p> <p>Target Value: Any occurrence between birth and arrival at this facility</p> <p>Selections: No, Yes</p> <p>Supporting Definitions: PAD: Peripheral arterial disease can include:</p> <ol style="list-style-type: none"> 1. Claudication, either with exertion or at rest. 2. Amputation for arterial vascular insufficiency. 3. Vascular reconstruction, bypass surgery, or percutaneous intervention to extremities (excluding dialysis fistulas & vein stripping) 4. Documented aortic aneurysm with or without repair. 5. Positive non-invasive test (e.g., ankle brachial index ≤ 0.9); ultrasound, magnetic resonance, computed tomography, or angiographic imaging of $> 50\%$ diameter stenosis in any peripheral artery (e.g., renal, subclavian, femoral, iliac). <p>For purposes of the Registry, peripheral arterial disease excludes disease in the carotid and cerebrovascular arteries.</p> <p>Source ACC Clinical Data Standards, The Society of Thoracic Surgeons</p>
Chronic Lung Disease	454	Chronic Lung Disease	<p>Indicate if the patient has a documented history of chronic lung disease (i.e. chronic obstructive pulmonary disease, asthma, bronchitis), or has been or is currently treated with pharmacologic therapy. Choose one of the following:</p> <ul style="list-style-type: none"> - Yes - No 	4080	Chronic Lung Disease	<p>Coding Instructions: Indicate if the patient has a history of chronic lung disease</p> <p>Target Value: Any occurrence between birth and arrival at this facility</p> <p>Selections: No, Yes</p> <p>Supporting Definitions: Chronic Lung Disease: Chronic lung disease can include patients with chronic obstructive pulmonary disease, chronic bronchitis, or emphysema. It can also include a patient who is currently being chronically treated with inhaled or oral pharmacological therapy (e.g., beta-adrenergic agonist, anti-inflammatory agent, leukotriene receptor antagonist, or steroid). Patients with asthma or seasonal allergies are not considered to have chronic lung disease.</p> <p>Source NCDR®</p>

Risk Variable in PCI Readmission Measure	Version 3.04 NCDR® Number	Version 3.04 Variable Name	Version 3.04 Variable Definition	Version 4.3.1 NCDR® Number	Version 4.3.1 Variable Name	Version 4.3.1 Variable Definition
Diabetes	430	Diabetes	A history of diabetes, regardless of duration of disease, or need for anti-diabetic agents. This includes diagnosis on admission or pre-procedure. It does not include gestational diabetes. Choose one of the following: Yes, No	4085	Diabetes Mellitus	<p>Coding Instructions: Indicate if the patient has a history of diabetes mellitus regardless of duration of disease or need for antidiabetic agents.</p> <p>Note(s): If the patient is diagnosed within 24 hours of arrival, code "yes."</p> <p>Target Value: Any occurrence between birth and arrival at this facility</p> <p>Selections: No, Yes</p> <p>Supporting Definitions: Diabetes Mellitus: Diabetes mellitus is diagnosed by a physician or can be defined as a fasting blood sugar greater than 7 mmol/l or 126 mg/dL. It does not include gestational diabetes.</p> <p>Source Acute Coronary Syndromes Data Standards (JACC 2001 38: 2114-30), The Society of Thoracic Surgeons</p>
Diabetes	432	Diabetes Control	<p>Code the control method patient presented with on admission. Patients placed on a pre-procedure diabetic pathway of insulin drip but at admission were controlled with diet or oral method are not coded as insulin dependent. Choose one of the following:</p> <ul style="list-style-type: none"> - None: No treatment for diabetes - Diet: Diet treatment only - Oral: Oral agent treatment (includes oral agent with/without diet treatment) - Insulin: Insulin treatment (includes any combination with insulin) 	4090	Diabetes Therapy	<p>Indicate the most aggressive therapy the patient Coding Instructions: presented with.</p> <p>Note(s): Patients placed on a pre-procedure diabetic pathway of insulin drip after arrival but were not on insulin therapy (treated by diet or oral method) are not coded as insulin treatment. If a patient had a pancreatic transplant, code "other", since the insulin from the new pancreas is not exogenous insulin.</p> <p>Target Value: The value on arrival at this facility</p> <p>Selections:</p> <ul style="list-style-type: none"> None - No treatment for diabetes Diet - Diet treatment only Oral - Oral agent treatment (includes oral agent with/without diet treatment) Insulin - Insulin treatment (includes any combination with insulin) Other - Other adjunctive treatment, non-oral/insulin/diet
GFR	252	Patient Age	See Above	2050	Birth Date	See Above
GFR	260	Gender	See Above	2060	Sex	See Above

Risk Variable in PCI Readmission Measure	Version 3.04 NCDR® Number	Version 3.04 Variable Name	Version 3.04 Variable Definition	Version 4.3.1 NCDR® Number	Version 4.3.1 Variable Name	Version 4.3.1 Variable Definition
GFR	270	Race/ Ethnicity	Patient race as determined by the patient/family. Choose one of the following: - Caucasian - Black - Hispanic - Asian - Native American - Other	2071	Race - Black or African American	Coding Instructions: Indicate if the patient is Black or African American as determined by the patient/family. Note(s): If the patient has multiple race origins, specify them using the other race selections in addition to this one. Target Value: The value on arrival at this facility Selections: No, Yes Supporting Definitions: Black/African American (Race): Having origins in any of the black racial groups of Africa. Terms such as "Haitian" or "Negro" can be used in addition to "Black or African American." Source U.S. Census Bureau
GFR				2072	Race - Asian	Coding Instructions: Indicate if the patient is Asian as determined by the patient/family. Note(s): If the patient has multiple race origins, specify them using the other race selections in addition to this one. Target Value: The value on arrival at this facility Selections: No, Yes Supporting Definitions: Asian (Race): Having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam. Source U.S. Census Bureau
GFR				2073	Race - American Indian or Alaskan Native	Coding Instructions: Indicate if the patient is American Indian or Alaskan Native as determined by the patient/family. Note(s): If the patient has multiple race origins, specify them using the other race selections in addition to this one. Target Value: The value on arrival at this facility Selections: No, Yes Supporting Definitions: American Indian or Alaskan Native (Race): Having origins in any of the original peoples of North and South America (including Central America), and who maintains tribal affiliation or community attachment. Source U.S. Census Bureau

Risk Variable in PCI Readmission Measure	Version 3.04 NCDR® Number	Version 3.04 Variable Name	Version 3.04 Variable Definition	Version 4.3.1 NCDR® Number	Version 4.3.1 Variable Name	Version 4.3.1 Variable Definition
GFR				2074	Race - Native Hawaiian or Pacific Islander	Coding Instructions: Indicate if the patient is Native Hawaiian or Pacific Islander as determined by the patient/family. Note(s): If the patient has multiple race origins, specify them using the other race selections in addition to this one. Target Value: The value on arrival at this facility Selections: No, Yes Supporting Definitions: Native Hawaiian or Pacific Islander (Race): Having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands. Source U.S. Census Bureau
GFR				2076	Race - Hispanic of Latino Ethnicity	Coding Instructions: Indicate if the patient is of Hispanic or Latino ethnicity as determined by the patient/family. Target Value: The value on arrival at this facility Selections: No, Yes Supporting Definitions: Hispanic or Latino Ethnicity: A person of Cuban, Mexican, Puerto Rican, Cuban, South or Central American, or other Spanish culture or origin, regardless of race. The term, "Spanish origin," can be used in addition to "Hispanic or Latino." Source U.S. Office of Management and Budget. Classification of Federal Data on Race and Ethnicity
GFR	439	Creatinine Assessed on Admission	Indicate if the patient's creatinine level was assessed prior to day of procedure. Choose one of the following: Yes, No	7315	Pre-Procedure Creatinine	Coding Instructions: Indicate the patient's most recent creatinine level in mg/dL. Target Value: The last value between 1 month prior to arrival and current procedure
GFR				7316	Pre-Procedure Creatinine Not Drawn	Coding Instructions: Indicate if the patient's creatinine level was not collected. Selections: No, Yes - Code "yes" when pre-procedure Creatinine level was not collected.
GFR	440	Last Creatinine	Indicate the patient's most recent creatinine level prior to day of procedure. Creatinine should be collected on all patients for consistency, even if they have no prior history of renal failure.	7340	Post-Procedure Creatinine	Coding Instructions: Indicate the post-procedure creatinine level in mg/dL. If more than one level is available, code the peak level. Note(s): For patients with extended hospital stays, restrict coding of post-procedure creatinine to 30 days after the last procedure. Target Value: The highest value between current procedure and until next procedure or discharge

Risk Variable in PCI Readmission Measure	Version 3.04 NCDR® Number	Version 3.04 Variable Name	Version 3.04 Variable Definition	Version 4.3.1 NCDR® Number	Version 4.3.1 Variable Name	Version 4.3.1 Variable Definition
GFR				7341	Post-Procedure Creatinine Not Drawn	Coding Instructions: Indicate if a post-procedure creatinine level was not collected. Note(s): For patients with extended hospital stays, restrict coding of post-procedure creatinine to 30 days after the last procedure. Selections: No, Yes - Code "yes" when pre-procedure Creatinine level was not collected.
Renal Failure - Dialysis	444	Renal Failure - Dialysis	Indicate if the patient received dialysis as a result of his/her renal failure. Choose one of the following: - Yes - No	4065	Currently on Dialysis	Coding Instructions: Indicate if the patient is currently undergoing either hemodialysis or peritoneal dialysis on an ongoing basis as a result of renal failure. Note(s): If a patient is on receiving continuous veno-venous hemofiltration (CVVH) as a result of renal failure (and not as treatment to remove fluid for heart failure), code "yes." Target Value: The value on arrival at this facility Selections: No, Yes
Hypertension	456	Hypertension	Indicate if the patient has hypertension as documented by one of the following: 1. History of hypertension diagnosed and treated with medication, diet and/or exercise. 2. Blood pressure greater than 140 systolic or 90 diastolic on at least 2 occasions. 3. Currently on antihypertensive pharmacologic therapy. Choose one of the following: - Yes - No	4005	Hypertension	Coding Instructions: Indicate if the patient has a current diagnosis of hypertension. Note(s): If the patient is diagnosed within 24 hours of arrival, code "yes." Target Value: Any occurrence between birth and arrival at this facility Selections: No, Yes Supporting Definitions: Hypertension: Hypertension is defined by any one of the following: 1. History of hypertension diagnosed and treated with medication, diet and/or exercise 2. Prior documentation of blood pressure greater than 140 mm Hg systolic and/or 90 mm Hg diastolic for patients without diabetes or chronic kidney disease, or prior documentation of blood pressure greater than 130 mm Hg systolic and/or 80 mm Hg diastolic on at least two occasions for patients with diabetes or chronic kidney disease 3. Currently on pharmacologic therapy for treatment of hypertension. Source Acute Coronary Syndromes Data Standards (JACC 2001 38: 2114 - 30), The Society of Thoracic Surgeons

Risk Variable in PCI Readmission Measure	Version 3.04 NCDR® Number	Version 3.04 Variable Name	Version 3.04 Variable Definition	Version 4.3.1 NCDR® Number	Version 4.3.1 Variable Name	Version 4.3.1 Variable Definition
History of Tobacco Use	460	History of Tobacco Use	Indicate if the patient has a history confirming any form of tobacco use in the past. This includes cigarettes, cigar, tobacco chew, etc. Choose one of the following: - Yes, Current: Use of tobacco within one month of this admission. - Yes, Former: Use of tobacco greater than one month prior to this admission. - Never	4000	Current/Recent Smoker (w/in 1 year)	Coding Instructions: Indicate if the patient has smoked cigarettes anytime during the year prior to arrival at your facility. Target Value: Any occurrence between 1 year prior to arrival at this facility and arrival at this facility Selections: No, Yes
Previous PCI	490	Previous PCI	Indicate if the patient had a previous percutaneous coronary intervention (even if unsuccessful) of any type (balloon angioplasty, stent or other), performed prior to the current admission. Choose one of the following: - Yes - No	4035	Prior PCI	Coding Instructions: Indicate if the patient had a previous percutaneous coronary intervention. Note(s): Timeframe does NOT include PCIs performed after arrival. Target Value: Any occurrence between birth and arrival at this facility Selections: No, Yes Supporting Definitions: PCI: Percutaneous coronary intervention (PCI) is the placement of an angioplasty guide wire, balloon, or other device (e.g. stent, atherectomy, brachytherapy, or thrombectomy catheter) into a native coronary artery or coronary artery bypass graft for the purpose of mechanical coronary revascularization. Source NCDR®

Risk Variable in PCI Readmission Measure	Version 3.04 NCDR® Number	Version 3.04 Variable Name	Version 3.04 Variable Definition	Version 4.3.1 NCDR® Number	Version 4.3.1 Variable Name	Version 4.3.1 Variable Definition
Heart Failure - Current Status	500	CHF - Current Status	<p>Indicate whether, within 2 weeks prior to the first procedure, a physician has diagnosed that the patient is currently in congestive heart failure (CHF). CHF can be diagnosed bases on careful history and physical exam, or by one of the following criteria:</p> <ol style="list-style-type: none"> 1. Paroxysmal nocturnal dyspnea (PND) and/or fatigue; 2. Dyspnea on exertion (DOE) due to heart failure; or 3. Chest X-Ray (CXR) showing pulmonary congestion. 4. Pedal edema or dyspnea treated with medical therapy for heart failure. <p>Choose one of the following:</p> <ul style="list-style-type: none"> - Yes - No 	5040	Heart Failure w/in 2 Weeks	<p>Coding Instructions: Indicate if there is physician documentation or report that the patient has been in a state of heart failure within the past 2 weeks.</p> <p>Note(s): If this is a subsequent episode of care (within 2 weeks), do not code the Heart Failure w/in 2 Weeks (5040) from the previous episode of care.</p> <p>Target Value: Any occurrence between 2 weeks prior to current procedure and current procedure</p> <p>Selections: No, Yes</p> <p>Supporting Definitions: Heart failure: Heart failure is defined as physician documentation or report of any of the following clinical symptoms of heart failure described as unusual dyspnea on light exertion, recurrent dyspnea occurring in the supine position, fluid retention; or the description of rales, jugular venous distension, pulmonary edema on physical exam, or pulmonary edema on chest x-ray presumed to be cardiac dysfunction. A low ejection fraction alone, without clinical evidence of heart failure does not qualify as heart failure. *Note: Killip Class 2 is defined as rales covering 50% or less of the lung fields or the presence of an S3. Killip Class 3 is defined as rales covering more than 50% of the lung fields. Either class would qualify as a "yes."</p> <p>Source: Acute Coronary Syndromes Data Standards (JACC 2001 38: 2114 - 30), The Society of Thoracic Surgeons</p>

Risk Variable in PCI Readmission Measure	Version 3.04 NCDR® Number	Version 3.04 Variable Name	Version 3.04 Variable Definition	Version 4.3.1 NCDR® Number	Version 4.3.1 Variable Name	Version 4.3.1 Variable Definition
Symptoms Present on Admission	550	Admission Sx Presentation	<p>Indicate the patient's symptom presentation or angina type on admission. Choose one of the following:</p> <ul style="list-style-type: none"> - No Symptoms or Angina. - Atypical Chest Pain: Pain, pressure or discomfort in the chest, neck or arms not clearly exertional or not otherwise consistent with pain or discomfort of myocardial ischemic origin. - Stable Angina: Angina without a change in frequency or pattern for the six weeks prior to this cath lab visit. Angina is controlled by rest and/or oral or transcutaneous medications. - Acute Coronary Syndrome (ACS) - Unstable Angina. - Acute Coronary Syndrome (ACS) - Non-ST Elevation MI (Non-STEMI). - Acute Coronary Syndrome (ACS) - ST Elevation MI (STEMI). <hr/> <p>UNSTABLE ANGINA is defined as: The patient was hospitalized for unstable angina documented in the medical record with serial ECG's and biochemical profiles. One of the following criteria are necessary:</p> <ol style="list-style-type: none"> 1. Angina at rest (usually prolonged >20 minutes). 2. New onset angina (<2 months) exertional angina of at least Canadian Cardiovascular Society Classification (CCSC) Class III. 	5000	CAD Presentation	<p>Coding Instructions: Indicate the patient's coronary artery disease (CAD) presentation. Choose the worst status. Target Value: The highest value between 2 weeks prior to arrival and current procedure Selections: Note(s): If the patient presents with atypical symptoms of myocardial ischemia (i.e. only shortness of breath, upper abdominal pain, left arm pain, etc.) that is known and documented to be myocardial ischemia, and is considered to be an anginal equivalent, code the selection that fits their presentation. If these symptoms are not thought to be or have not been proven to be the anginal equivalent, code "Symptom unlikely to be ischemic." If this is a subsequent episode of care (within 2 weeks), do not code the CAD Presentation from the previous episode of care. For STEMI and NSTEMI, code the highest value within 1 week of the current procedure. If this is a repeat visit to the cath lab during the same episode of care, code the CAD presentation based on the patients clinical status prior to the subsequent procedure. <i>Selection Text Definition</i> No symptom, no angina No symptoms, No angina. Symptom unlikely to be ischemic. Pain, pressure or discomfort in the chest, neck</p>

Risk Variable in PCI Readmission Measure	Version 3.04 NCDR® Number	Version 3.04 Variable Name	Version 3.04 Variable Definition	Version 4.3.1 NCDR® Number	Version 4.3.1 Variable Name	Version 4.3.1 Variable Definition
			<p>3. *new per guidelines* Increasing angina - previously diagnosed angina that has become distinctly more frequent, longer in duration, or lower in threshold (i.e., increased by greater than or equal to 1 CCS class to at least CCS Class III severity).</p> <hr/> <p>NON ST ELEVATION MYOCARDIAL INFARCTION (Non-STEMI) is defined as: The patient was hospitalized for a myocardial infarction documented in the medical record. AT LEAST ONE OF THE FOLLOWING BIOCHEMICAL INDICATORS for detecting myocardial necrosis must be present (see below for a definition of Reference Control Limits):</p> <p>1) Troponin T or I: a) Maximal concentration of troponin T or I > the MI decision limit on at least one occasion during the first 24 hours after the index clinical event.</p> <p>2) CK-MB: a) Maximal value of CK-MB > 2 x the upper limit of normal on one occasion during the first hours after the index clinical event. OR b) Maximal value of CK-MB, preferable CK-MB mass, > upper limit of normal on two successive samples.</p> <p>3) Total CK: a) In the absence of availability of a troponin or CK-MB assay, total CK > 2</p>			<p>or arms NOT clearly exertional or NOT otherwise consistent with pain or discomfort of myocardial ischemic origin. This includes patients with non-cardiac pain (e.g.pulmonary embolism, musculoskeletal, or esophageal discomfort), or cardiac pain not caused by myocardial ischemia (e.g., acute pericarditis).</p> <p>Stable angina Angina without a change in frequency or pattern for the 6 weeks prior to this cath lab visit. Angina is controlled by rest and/or oral ortranscutaneous medications.</p> <p>Unstable angina There are three principal presentations of unstable angina: 1. Rest angina (occurring at rest and prolonged, usually >20 minutes); 2. Newonset angina (within the past 2 months, of at least Canadian Cardiovascular Society Class III severity); or 3. Increasing angina (previously diagnosed angina that has become distinctly more frequent, longer in duration, or increased by 1 or more Canadian Cardiovascular Society class to at least CCS III severity).</p> <p>Non-STEMI The patient was hospitalized for a non-ST elevation myocardial infarction (STEMI) as documented in the medical record. Non-STEMIs are characterized by the presence of both criteria: a. Cardiac biomarkers (creatinine kinase-</p>

Risk Variable in PCI Readmission Measure	Version 3.04 NCDR® Number	Version 3.04 Variable Name	Version 3.04 Variable Definition	Version 4.3.1 NCDR® Number	Version 4.3.1 Variable Name	Version 4.3.1 Variable Definition
			<p>x the upper limit of normal, or the B fraction of CK may be employed, but these last two biomarkers are considerably less satisfactory than CK-MB. AND ONE OF THE FOLLOWING:</p> <p>1) Either ST segment depression or T wave abnormalities; or</p> <p>2) Ischemic symptoms in the presence or absence of chest discomfort. Ischemic symptoms may include:</p> <p>a) unexplained nausea and vomiting; or</p> <p>b) persistent shortness of breath secondary to left ventricular failure; or</p> <p>c) unexplained weakness, dizziness, lightheadedness, or syncope.</p> <p>-----</p> <p>ST ELEVATION MYOCARDIAL INFARCTION (STEMI) is defined as:</p> <p>Indicate whether the patient was hospitalized for an ST Elevation Myocardial Infarction (STEMI) documented in the medical record.</p> <p>AT LEAST ONE OF THE FOLLOWING BIOCHEMICAL INDICATORS for detecting myocardial necrosis must be present (see below for a definition of Reference Control Limits):</p> <p>1) Troponin T or I:</p> <p>a) Maximal concentration of troponin T or I > the MI decision limit on at</p>			<p>myocardial band, Troponin T or I) exceed the upper limit of normal according to the individual hospital's laboratory parameters a clinical presentation which is consistent or suggestive of ischemia which is consistent or suggestive of ischemia. Note: For purposes of the Registry, ST elevation in the posterior chest leads (V7 through V9), or ST depression that is maximal in V1-3, without ST-segment elevation in other leads, demonstrating posterobasal myocardial infarction, is considered a STEMI equivalent and qualifies the patient for reperfusion therapy.</p>

Risk Variable in PCI Readmission Measure	Version 3.04 NCDR® Number	Version 3.04 Variable Name	Version 3.04 Variable Definition	Version 4.3.1 NCDR® Number	Version 4.3.1 Variable Name	Version 4.3.1 Variable Definition
			<p>least one occasion during the first 24 hours after the index clinical event.</p> <p>2) CK-MB:</p> <p>a) Maximal value of CK-MB > 2 x the upper limit of normal on one occasion during the first hours after the index clinical event; OR</p> <p>b) Maximal value of CK-MB, preferable CK-MB mass, > upper limit of normal on two successive samples.</p> <p>3) Total CK</p> <p>a) In the absence of availability of a troponin or CK-MB assay, total CK > 2 x the upper limit of normal, or the B fraction of CK may be employed, but these last two biomarkers are considerably less satisfactory than CK-MB. AND ONE OF THE FOLLOWING ECG CHANGES: 1) ST-segment elevation: New or presumed new ST segment elevation at the J point in two or more contiguous leads with the cut-off points ≥ 0.2 mV in leads V1, V2, or V3, or ≥ 0.1 mV in other leads; OR</p> <p>2) Development of any Q wave in leads V1 through V3, or the development of a Q-wave \geq or = to 30 ms (0.03s) in leads I, II, aVL, aVF, V4, V5, or V6. (Q wave changes must be present in any two contiguous leads, and be \geq or = to 1mm in depth.)</p>			
			<p>Defining Reference Control Values (MI Diagnostic Limit and Upper Limit of Normal):</p> <p>Reference values must be determined in each laboratory by studies using specific assays with appropriate quality control, as reported in peer-reviewed journals. Acceptable imprecision (coefficient of variation) at the 99th percentile for each assay should be defined as \leq or = to 10%. Each individual laboratory should confirm the range of reference values in their specific setting.</p>			

Risk Variable in PCI Readmission Measure	Version 3.04 NCDR® Number	Version 3.04 Variable Name	Version 3.04 Variable Definition	Version 4.3.1 NCDR® Number	Version 4.3.1 Variable Name	Version 4.3.1 Variable Definition
Symptoms Present on Admission	560	Time Period: Sx Onset to Admission	MI Patients Only: Indicate the time from the documented onset of symptoms of acute MI to the time of admission to your facility. Choose one of the following: - Less than or equal to 6 hours: - Greater than 6 hours and less than or equal to 12 hours: - Greater than 12 hours and less than or equal to 24 hours: - Greater than 24 hours and less than or equal to 48 hours: - Greater than 48 hours and less than or equal to 7 days: - No time period noted. Patient presented as a silent MI.	5005	Symptom Onset Date and Time	Coding Instructions: Indicate the date the patient first noted ischemic symptoms lasting greater than or equal to 10 minutes. Note(s): If the patient had intermittent ischemic symptoms, record the date and time of the most recent ischemic symptoms prior to hospital presentation. Symptoms may include jaw pain, arm pain, shortness of breath, nausea, vomiting, fatigue/malaise, or other equivalent discomfort suggestive of a myocardial infarction. In the event of stuttering symptoms, Acute Coronary Syndrome (ACS) symptom onset is the time at which symptoms became constant in quality or intensity. Target Value: The first value between 1 week prior to current procedure and current procedure
Symptoms Present on Admission				5006	Symptom Onset Time	Coding Instructions: Indicate the time the patient first noted ischemic symptoms lasting greater than or equal to 10 minutes. Note(s): If an estimated symptom onset time is recorded, code "Symptom Onset Time Estimated" as "Yes." Indicate the time (hours: minutes) using the military 24-hour clock, beginning at midnight (0000 hours). If the symptom onset time is not specified in the medical record, it may be recorded as 0700 for morning; 1200 for lunchtime; 1500 for afternoon; 1800 for dinnertime; 2200 for evening and 0300 if awakened from sleep. Target Value: The first value between 1 week prior to current procedure and current procedure
Ejection Fraction Percentage	654	Ejection Fraction Done	Indicate whether the patient had Ejection Fraction assessed before or during the cath lab visit via invasive (i.e. LV gram) or non-invasive testing (i.e. Echo). Choose one of the following: - Yes - No	7026	Pre-PCI Left Ventricular Ejection Fraction Not Assessed	Coding Instructions: Indicate whether the left ventricular ejection fraction was not assessed. Target Value: The last value between 6 months prior to current procedure and prior to the intervention Selections: No, Yes

Risk Variable in PCI Readmission Measure	Version 3.04 NCDR® Number	Version 3.04 Variable Name	Version 3.04 Variable Definition	Version 4.3.1 NCDR® Number	Version 4.3.1 Variable Name	Version 4.3.1 Variable Definition
Ejection Fraction Percentage	656	Ejection Fraction Percentag e	The percentage of the blood emptied from the ventricle at the end of the contraction. Use the most recent determination during or prior to intervention. Enter a percentage in the range of 01 - 99.	7025	Pre-PCI Left Ventricula r Ejection Fraction	<p>Coding Instructions: Code the best estimate of current left ventricular ejection fraction.</p> <p>Note(s): If only a range is reported, report the median of the range (i.e. 50-55%, is reported as 53%). If only a descriptive value is reported (i.e. normal), enter the corresponding percentage value from the list below: Normal = 60% Good function = 50% Mildly reduced = 45% Fair function = 40% Moderately reduced = 30% Poor function = 25% Severely reduced = 20%</p> <p>The Left Ventricular Ejection Fraction can be assessed via invasive (i.e. LV gram) or non-invasive (i.e. Echo, MR, CT or Nuclear) testing. If an ejection fraction is not measured during this admission and prior to the PCI, and their clinical status has not changed, it is acceptable to code an ejection fraction that was obtained prior to arrival.</p> <p>Target Value: The last value between 6 months prior to current procedure and prior to the intervention</p> <p>Selection Definitions: LVEF: The left ventricular ejection fraction is the percentage of the blood emptied from the left ventricle at the end of the contraction.</p> <p>Source: ACC Clinical Data Standards, The Society of Thoracic Surgeons</p>

Risk Variable in PCI Readmission Measure	Version 3.04 NCDR® Number	Version 3.04 Variable Name	Version 3.04 Variable Definition	Version 4.3.1 NCDR® Number	Version 4.3.1 Variable Name	Version 4.3.1 Variable Definition
PCI Status	804	PCI Status	<p>Indicate the status of the PCI. Choose one of the following:</p> <ul style="list-style-type: none"> - Elective: The patient's cardiac function has been stable in the days or weeks prior to the procedure. The procedure could be deferred without increased risk of compromised cardiac outcome. - Urgent: ALL of the following conditions are met: <ul style="list-style-type: none"> a. Not elective status. b. Not emergency status. c. Procedure required during same hospitalization in order to minimize chance of further clinical deterioration. d. Worsening, sudden chest pain, CHF, acute myocardial infarction (AMI), anatomy, IABP, unstable angina (USA) with intravenous (IV) nitroglycerin (TNG) or rest angina (but stabilized patient) may be included. - Emergency: The patient's clinical status includes any of the following: <ul style="list-style-type: none"> a. Ischemic dysfunction (any of the following): <ol style="list-style-type: none"> (1) Ongoing ischemia including rest angina despite maximal medical therapy (medical and/or IABP)); (2) Acute Evolving Myocardial Infarction within 24 hours before Cardiac Cath Lab Procedure; or (3) pulmonary edema requiring intubation. 	7020	PCI Status	<p>Coding Instructions: Indicate the status of the PCI. The status is determined at the time the operator decides to perform a PCI.</p> <p>Target Value: The highest value on current procedure</p> <p>Selections:</p> <p>Elective - The procedure can be performed on an outpatient basis or during a subsequent hospitalization without significant risk of infarction or death. For stable inpatients, the procedure is being performed during this hospitalization for convenience and ease of scheduling and NOT because the patient's clinical situation demands the procedure prior to discharge. If the diagnostic catheterization was elective and there were no complications, the PCI would also be elective.</p> <p>Urgent - The procedure should be performed on an inpatient basis and prior to discharge because of significant concerns that there is risk of ischemia, infarction and/or death. Patients who are outpatients or in the emergency department at the time that the cardiac catheterization is requested would warrant an admission based on their clinical presentation.</p> <p>Emergency - The procedure should be performed as soon as possible because of substantial concerns that ongoing ischemia and/or infarction could lead to death. "As soon as possible" refers to a</p>
			<ul style="list-style-type: none"> b. Mechanical dysfunction (either of the following): <ol style="list-style-type: none"> (1) shock with circulatory support; or (2) shock without circulatory support. - Emergent Salvage: The patient is undergoing CPR en route to the Cardiac Cath Lab or prior to procedure. 			<p>patient who is of sufficient acuity that you would cancel a scheduled case to perform this procedure immediately in the next available room during business hours, or you would activate the on-call team were this to occur during off-hours.</p> <p>Salvage - The procedure is a last resort. The patient is in cardiogenic shock when the PCI begins (i.e. at the time of introduction into a coronary artery or bypass graft of the first guidewire or intracoronary device for the purpose of mechanical revascularization). Within the last ten minutes prior to the start of the case or during the diagnostic portion of the case, the patient has also received chest compressions for a total of at least sixty seconds or has been on unanticipated extracorporeal circulatory support (e.g. extracorporeal mechanical oxygenation, or cardiopulmonary support).</p>

Risk Variable in PCI Readmission Measure	Version 3.04 NCDR® Number	Version 3.04 Variable Name	Version 3.04 Variable Definition	Version 4.3.1 NCDR® Number	Version 4.3.1 Variable Name	Version 4.3.1 Variable Definition
Highest Lesion Location	902	Segment Number	<p>Use the following numeric reference points to identify segments where procedures were attempted and its proximal reference number.</p> <p>1 Proximal right coronary artery conduit segment - pRCA 2 Mid-right coronary artery conduit segment - mRCA 3 Distal right coronary artery conduit segment - dRCA 4 Right posterior descending artery segment - rPDA 5 Right posterior atrioventricular segment - rPAV 6 First right posterolateral segment - 1st RPL 7 Second right posterolateral segment - 2nd RPL 8 Third right posterolateral segment - 3rd RPL 9 Posterior descending septal perforators segment - pDSP 10 Acute marginal segment(s) - aMarg 11 Left main coronary artery segment - LM 12 Proximal LAD artery segment - pLAD 13 Mid-LAD artery segment - mLAD 14 Distal LAD artery segment - dLAD 15 First diagonal branch segment - 1st Diag 15a Lateral first diagonal branch segment - Lat 1st Diag 16 Second diagonal branch segment - 2nd</p>	7105	Segment Number	<p>Coding Instruction: Indicate the segment(s) that the current lesion spans (a lesion can span one or more segments). Use the following numeric reference points to identify segments where procedures were attempted and its proximal reference number.</p> <p>1 Proximal right coronary artery conduit segment - pRCA 2 Mid-right coronary artery conduit segment - mRCA 3 Distal right coronary artery conduit segment - dRCA 4 Right posterior descending artery segment - rPDA 5 Right posterior atrioventricular segment - rPAV 6 First right posterolateral segment - 1st RPL 7 Second right posterolateral segment - 2nd RPL 8 Third right posterolateral segment - 3rd RPL 9 Posterior descending septal perforators segment - pDSP 10 Acute marginal segment(s) - aMarg 11 Left main coronary artery segment - LM 12 Proximal LAD artery segment - pLAD 13 Mid-LAD artery segment - mLAD 14 Distal LAD artery segment - dLAD 15 First diagonal branch segment - 1st Diag</p>

Risk Variable in PCI Readmission Measure	Version 3.04 NCDR® Number	Version 3.04 Variable Name	Version 3.04 Variable Definition	Version 4.3.1 NCDR® Number	Version 4.3.1 Variable Name	Version 4.3.1 Variable Definition
			2nd Diag 16a Lateral second diagonal branch segment - Lat 2nd Diag 17 LAD septal perforator segments - LAD SP 18 Proximal circumflex artery segment - pCIRC 19 Mid-circumflex artery segment - mCIRC 19a Distal circumflex artery segment - dCIRC 20 First obtuse marginal branch segment - 1st OM 20a Lateral first obtuse marginal branch segment - Lat 1st OM 21 Second obtuse marginal branch segment - 2nd OM 21a Lateral second obtuse marginal branch segment - Lat 2nd OM 22 Third obtuse marginal branch segment - 3rd OM 22a Lateral third obtuse marginal branch segment - Lat 3rd OM 23 Circumflex artery AV groove continuation segment - CIRC AV 24 First left posterolateral branch segment - 1st LPL 25 Second left posterolateral branch segment - 2nd LPL 26 Third posterolateral descending artery segment - 3rd LPL 27 Left posterolateral descending artery segment - LPDA 28 Ramus intermedius segment - Ramus			15a Lateral first diagonal branch segment - Lat 1st Diag 16 Second diagonal branch segment - 2nd Diag 16a Lateral second diagonal branch segment - Lat 2nd Diag 17 LAD septal perforator segments - LAD SP 18 Proximal circumflex artery segment - pCIRC 19 Mid-circumflex artery segment - mCIRC 19a Distal circumflex artery segment - dCIRC 20 First obtuse marginal branch segment - 1st OM 20a Lateral first obtuse marginal branch segment - Lat 1st OM 21 Second obtuse marginal branch segment - 2nd OM 21a Lateral second obtuse marginal branch segment - Lat 2nd OM 22 Third obtuse marginal branch segment - 3rd OM 22a Lateral third obtuse marginal branch segment - Lat 3rd OM 23 Circumflex artery AV groove continuation segment - CIRC AV 24 First left posterolateral branch segment - 1st LPL 25 Second left posterolateral branch segment - 2nd LPL 26 Third posterolateral descending artery segment - 3rd LPL

Risk Variable in PCI Readmission Measure	Version 3.04 NCDR® Number	Version 3.04 Variable Name	Version 3.04 Variable Definition	Version 4.3.1 NCDR® Number	Version 4.3.1 Variable Name	Version 4.3.1 Variable Definition
			28a Lateral ramus intermedius segment - Lat Ramus 29 Third diagonal branch segment - 3rd Diag 29a Lateral third diagonal branch segment - Lat 3rd Diag ----- Note: For T or Y grafts connected to 2 areas of the native vessels, code using the most dominant vessel or the first one addressed in the procedure.			27 Left posterolateral descending artery segment – LPDA 28 Ramus intermedius segment - Ramus 28a Lateral ramus intermedius segment - Lat Ramus 29 Third diagonal branch segment - 3rd Diag 29a Lateral third diagonal branch segment - Lat 3rd Diag Note(s): A segment is a defined region of a coronary artery, as illustrated in the CathPCI Registry® coronary anatomy segment diagram. If the target lesion is in a bypass graft, indicate the segment location of the first anastomosis distal to the lesion (and if it's above a Y graft, indicate the segment location of the most important distal vessel). If a PCI of a left subclavian supplying a LIMA is performed, it is not considered a PCI. Supporting Definitions: Lesion: A target lesion is defined as a stenosis within a coronary artery or coronary artery bypass graft on which mechanical coronary revascularization is attempted. Source NCDR®
Pre Procedure TIMI Flow: none	920	Pre-Procedure TIMI Flow	Indicate for the segment identified the pre-procedure TIMI flow. Choose one of the following: - TIMI-0: No flow/no perfusion. - TIMI-1: Slow penetration without perfusion. - TIMI-2: Partial flow/partial perfusion (greater than TIMI-1 but less than TIMI-3). - TIMI-3: Complete and brisk flow/complete perfusion.	7140	Pre-Procedure TIMI Flow	Coding Instruction: Indicate the pre-procedure TIMI flow value. Note(s): If a lesion spans multiple segments with different TIMI flows, coded the lowest TIMI flow within the entire lesion. Target Value: Any occurrence on current procedure Selections: TIMI - 0 No flow/no perfusion TIMI - 1 Slow penetration without perfusion TIMI - 2 Partial flow/partial perfusion (greater than TIMI-1 but less than TIMI-3). TIMI - 3 Complete and brisk flow/complete perfusion.

Appendix C: ICD-9-CM to ICD-10-CM/PCS Crosswalk

Table C1: PCI Readmission Cohort ICD-9 Codes

ICD-9-CM code	Description
00.66	Percutaneous transluminal coronary angioplasty or coronary atherectomy
36.06	Insertion of non-drug-eluting coronary artery stent(s)
36.07	Insertion of drug-eluting coronary artery stent(s)

Table C2: PCI Readmission Cohort ICD-10 Codes

ICD-10-CM code	Description
Ø27Ø346	Dilation of Coronary Artery, One Site, Bifurcation, with Drug-eluting Intraluminal Device, Percutaneous Approach
Ø27Ø34Z	Dilation of Coronary Artery, One Site with Drug-eluting Intraluminal Device, Percutaneous Approach
Ø27Ø3D6	Dilation of Coronary Artery, One Site, Bifurcation, with Intraluminal Device, Percutaneous Approach
Ø27Ø3DZ	Dilation of Coronary Artery, One Site with Intraluminal Device, Percutaneous Approach
Ø27Ø3T6	Dilation of Coronary Artery, One Site, Bifurcation, with Radioactive Intraluminal Device, Percutaneous Approach
Ø27Ø3TZ	Dilation of Coronary Artery, One Site with Radioactive Intraluminal Device, Percutaneous Approach
Ø27Ø3Z6	Dilation of Coronary Artery, One Site, Bifurcation, Percutaneous Approach
Ø27Ø3ZZ	Dilation of Coronary Artery, One Site, Percutaneous Approach
Ø271346	Dilation of Coronary Artery, Two Sites, Bifurcation, with Drug-eluting Intraluminal Device, Percutaneous Approach
Ø27134Z	Dilation of Coronary Artery, Two Sites with Drug-eluting Intraluminal Device, Percutaneous Approach
Ø2713D6	Dilation of Coronary Artery, Two Sites, Bifurcation, with Intraluminal Device, Percutaneous Approach
Ø2713DZ	Dilation of Coronary Artery, Two Sites with Intraluminal Device, Percutaneous Approach
Ø2713T6	Dilation of Coronary Artery, Two Sites, Bifurcation, with Radioactive Intraluminal Device, Percutaneous Approach
Ø2713TZ	Dilation of Coronary Artery, Two Sites with Radioactive Intraluminal Device, Percutaneous Approach
Ø2713Z6	Dilation of Coronary Artery, Two Sites, Bifurcation, Percutaneous Approach
Ø2713ZZ	Dilation of Coronary Artery, Two Sites, Percutaneous Approach
Ø272346	Dilation of Coronary Artery, Three Sites, Bifurcation, with Drug-eluting Intraluminal Device, Percutaneous Approach
Ø27234Z	Dilation of Coronary Artery, Three Sites with Drug-eluting Intraluminal Device, Percutaneous Approach
Ø2723D6	Dilation of Coronary Artery, Three Sites, Bifurcation, with Intraluminal Device, Percutaneous Approach
Ø2723DZ	Dilation of Coronary Artery, Three Sites with Intraluminal Device, Percutaneous Approach
Ø2723T6	Dilation of Coronary Artery, Three Sites, Bifurcation, with Radioactive Intraluminal Device, Percutaneous Approach
Ø2723TZ	Dilation of Coronary Artery, Three Sites with Radioactive Intraluminal Device, Percutaneous Approach
Ø2723Z6	Dilation of Coronary Artery, Three Sites, Bifurcation, Percutaneous Approach
Ø2723ZZ	Dilation of Coronary Artery, Three Sites, Percutaneous Approach
Ø273346	Dilation of Coronary Artery, Four or More Sites, Bifurcation, with Drug-eluting Intraluminal Device, Percutaneous

ICD-10-CM code	Description
	Approach
Ø27334Z	Dilation of Coronary Artery, Four or More Sites with Drug-eluting Intraluminal Device, Percutaneous Approach
Ø2733D6	Dilation of Coronary Artery, Four or More Sites, Bifurcation, with Intraluminal Device, Percutaneous Approach
Ø2733DZ	Dilation of Coronary Artery, Four or More Sites with Intraluminal Device, Percutaneous Approach
Ø2733T6	Dilation of Coronary Artery, Four or More Sites, Bifurcation, with Radioactive Intraluminal Device, Percutaneous Approach
Ø2733TZ	Dilation of Coronary Artery, Four or More Sites with Radioactive Intraluminal Device, Percutaneous Approach
Ø2733Z6	Dilation of Coronary Artery, Four or More Sites, Bifurcation, Percutaneous Approach
Ø2733ZZ	Dilation of Coronary Artery, Four or More Sites, Percutaneous Approach
Ø2QØ3ZZ	Repair Coronary Artery, One Site, Percutaneous Approach
Ø2QØ4ZZ	Repair Coronary Artery, One Site, Percutaneous Endoscopic Approach
Ø2Q13ZZ	Repair Coronary Artery, Two Sites, Percutaneous Approach
Ø2Q14ZZ	Repair Coronary Artery, Two Sites, Percutaneous Endoscopic Approach
Ø2Q23ZZ	Repair Coronary Artery, Three Sites, Percutaneous Approach
Ø2Q24ZZ	Repair Coronary Artery, Three Sites, Percutaneous Endoscopic Approach
Ø2Q33ZZ	Repair Coronary Artery, Four or More Sites, Percutaneous Approach
Ø2Q34ZZ	Repair Coronary Artery, Four or More Sites, Percutaneous Endoscopic Approach
Ø2CØ3ZZ	Extirpation of Matter from Coronary Artery, One Site, Percutaneous Approach
Ø2CØ4ZZ	Extirpation of Matter from Coronary Artery, One Site, Percutaneous Endoscopic Approach
Ø2C13ZZ	Extirpation of Matter from Coronary Artery, Two Sites, Percutaneous Approach
Ø2C14ZZ	Extirpation of Matter from Coronary Artery, Two Sites, Percutaneous Endoscopic Approach
Ø2C23ZZ	Extirpation of Matter from Coronary Artery, Three Sites, Percutaneous Approach
Ø2C24ZZ	Extirpation of Matter from Coronary Artery, Three Sites, Percutaneous Endoscopic Approach
Ø2C33ZZ	Extirpation of Matter from Coronary Artery, Four or More Sites, Percutaneous Approach
Ø2C34ZZ	Extirpation of Matter from Coronary Artery, Four or More Sites, Percutaneous Endoscopic Approach

Hospital 30-Day Readmission Following Percutaneous Coronary Intervention Measure

Measure Methodology Report

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1. INTRODUCTION

1.1 Overview of Measure

Approximately one in seven Medicare patients who undergo percutaneous coronary intervention (PCI) is readmitted within 30 days of hospital discharge, and readmission rates vary across hospitals (Curtis, Schreiner et al. 2009). This variation in readmission rates following PCI (herein referred to as PCI readmission) is clinically significant and may in part reflect variations in quality of care. The Medicare Payment Advisory Committee (MedPAC) previously concluded that many readmissions following the performance of percutaneous transluminal coronary angioplasty (PTCA), used in this report as a synonym for PCI, are preventable and has recommended consideration of a PTCA readmission measure (MedPAC, 2006).

The Centers for Medicare & Medicaid Services (CMS) publicly report outcomes and efficiency measures on the consumer Web site, Hospital Compare (<http://www.hospitalcompare.hhs.gov>), as mandated by the 2005 Deficit Reduction Act. Consistent with this mandate and reflecting the importance of PCI readmission, CMS contracted with Yale New-Haven Health Services Corporation/Center for Outcomes Research and Evaluation (YNNHSC/CORE) to develop a PCI readmission measure. To pursue this measure Yale worked in partnership with the American College of Cardiology Foundation (ACCF), the Society for Cardiovascular Angiography and Interventions (SCAI), and the National Cardiovascular Data Registry (NCDR). This effort builds on YNNHSC/CORE and ACC's recent effort to develop CMS 30-day all-cause PCI mortality measures for PCI in two distinct cohorts (patients with ST elevation MI or cardiogenic shock and all other patients). These measures, which utilize the robust clinical data collected by the NCDR's CathPCI Registry, are suitable for public reporting and were recently endorsed by the National Quality Forum (NQF).

The goal of the present work is to improve patient outcomes by providing patients, physicians, and hospitals with information about risk adjusted readmission rates following PCI. All-cause PCI readmission is a patient-centered measure not focused solely on procedural issues or other processes of care, but rather on patients and the need for broad improvement in the transitions of care. Using registry data for the measure has several advantages for reaching this goal, including more robust risk adjustment and direct engagement of the clinicians and professional societies who have developed these registries.

We developed a model that estimates hospital-specific, risk-standardized, 30-day all-cause readmission rates following PCI. The measures were developed using data from the CathPCI Registry linked with CMS Medicare Part A claims and enrollment data using a probabilistic match. This approach is consistent with that previously

used for the PCI mortality measures (YNHHSC/CORE PCI Mortality Measures Methodology Report 2008). Clinical registry data were used for risk adjustment and the Medicare data for ascertainment of readmissions.

To account for the clustering of observations within hospitals and differences in the number of patient admissions across hospitals, risk-standardized readmission rates (RSRRs) were estimated with hierarchical logistic regression models. The hierarchical model has properties that make it appropriate to estimate rates for national public reporting. The development of the model proceeded with two assumptions about how it would be implemented. First, the model was derived with hospitals participating in NCDR, but the parameters would need to be re-estimated using the entire cohort of Medicare Fee-For-Service patients undergoing PCI. Second, direct identifiers would be required to link registry and claims data.

This report conveys the goals of the measure, development methodology, and results. First, we describe the purpose of the measure and its function in public reporting. Second, we present the methodology used to develop the measure and results of key preliminary analyses and the results of both the final risk adjustment model and the validation model. Next, we discuss a preliminary approach to implementation of the measure. Finally, we summarize the main findings of this project.

1.2 Purpose of the Measure

PCI is a cardiac procedure commonly performed on patients with coronary artery disease (CAD), a prevalent and costly condition. The intent of PCI is to improve coronary blood flow by treating obstructive epicardial coronary artery disease. In appropriately selected patients, PCI improves quality of life, increases exercise capacity, and reduces the burden of angina. Furthermore, in the emergency treatment of certain types of heart attacks, PCI improves survival and reduces the risk of adverse cardiovascular outcomes such as myocardial infarction, heart failure, and cardiac arrhythmias. Although a number of technologies are used to perform PCI, the most commonly used approach includes the dilation of a blockage with a small balloon followed by the deployment of a coronary stent (a slotted metal tube) used to brace the artery open. Although advances in technology have improved procedural success and safety, the performance of PCI still carries significant risks of short-term adverse outcomes including procedural complications, readmission and death. Many patients undergoing PCI have coexisting illnesses that increase their risk for readmission. Focusing on readmission rates will provide an incentive for hospitals to reduce related risks during hospitalizations in which a PCI is performed. Of note, the proposed measure does not attempt to judge the quality of individual interventional cardiologists who perform PCI procedures, but rather reflects the outcomes achieved by the systems of care within which the procedure is performed. Publicly reporting PCI readmission rates will provide patients, physicians, and

hospitals with information that could be used to understand and improve quality of care and outcomes.

1.3 Why PCI Readmission

PCI is one of the most commonly performed cardiac procedures in the United States. In 2007, an estimated 722,000 inpatient admissions had an associated PCI procedure, and from 1997-2007, the number of PCI procedures increased by 24% (Levit, Wier, et al. 2007). Readmission within 30 days of PCI is often an unplanned, adverse event. Approximately one in seven Medicare patients who undergo PCI is readmitted within 30 days of hospital discharge, and that readmission rates vary substantially across hospitals (Curtis, Schreiner et al. 2009). Readmission rates for many conditions and procedures are influenced by the quality of inpatient and outpatient care, as well as hospital system characteristics, such as bed capacity of the local health care system (Fisher, Wennberg et al. 1994). In addition, specific hospital processes such as discharge planning, medication reconciliation, and coordination of outpatient care have been shown to affect readmission rates (Nelson, Maruish et al. 2000). MedPAC noted that the rate of preventable admissions within 15 days of discharge following PTCA (used in this report as a synonym for PCI), is 10% (44,293 in 2005 at a cost of \$360 million) and has called for hospital-specific public reporting of readmission rates (MedPAC, 2006).

To further assess the need for a PCI readmission measure for Medicare patients, we conducted analyses using 2007 Medicare FFS claims. These analyses confirmed that crude readmission rates following PCI are high and vary significantly across hospitals, from 0% to 100% with a mean (SD) of 15.5% (10.6%) and a median (quartile range) of 14.5% (11.1%, 18.0%). Approximately three-fifths of readmissions are associated with a cardiovascular principal diagnostic code. The most common principal discharge diagnostic code (25.4%) was chronic ischemic heart disease (ICD-9 414.x), and a similar proportion (26.8%) of patients had discharge diagnostic codes consistent with an acute cardiovascular conditions such as acute myocardial infarction, unstable angina, arrhythmia, or heart failure. These findings suggest that the majority of readmissions are for either non-acute cardiac or non-cardiac reasons.

1.4 Core Principles for Hospital Outcomes Models Suitable for Public Reporting

We developed models using an approach that is consistent with the rationale articulated in the AHA scientific statement, “Standards for Statistical Models Used for Public Reporting of Health Outcomes” (Krumholz, Brindis et al. 2006), outlined below in Table 1.

Table 1 – Preferred Attributes of Models Used for Publicly Reported Outcomes

	Preferred Attribute
1	Clear and explicit definition of an appropriate patient sample
2	Clinical coherence of model variables
3	Sufficiently high-quality and timely data
4	Designation of an appropriate reference time before which covariates are derived and after which outcomes are measured
5	Use of an appropriate outcome and a standardized period of outcome assessment
6	Application of an analytical approach that takes into account the multilevel organization of data
7	Disclosure of the methods used to compare outcomes, including disclosure of performance of risk-adjustment methodology in derivation and validation samples

We designed the readmission measure model to reflect all of these attributes. We derived the model using a risk adjustment method that excluded potential complications of care so that the estimated risks adjusted for pre-existing conditions but not complications related to the procedure. To calculate risk-standardized readmission rates (RSRRs), we used a hierarchical logistic regression model, a statistical approach that takes into account the clustering of patients within hospitals and differences in sample size across hospitals. We computed indices that describe model performance in terms of calibration (over-fitting indices), discriminant ability (R-Square, ROC, and predicted vs. observed readmission), and overall fit (residuals, lack of fit, and model chi-square).

2. METHODS

2.1 Overview

We developed a measure of 30-day readmission following PCI using data from the NCDR CathPCI Registry for risk adjustment linked with CMS claims data for outcome information. We developed this model for all inpatient admissions or outpatient services with a PCI procedure (herein referred to as patient stays) that met the cohort criteria (Table 3 & Figure 4) and could be linked to the outcome data. [Note: Only Medicare FFS patients could be linked.] We fit a hierarchical generalized linear model (HGLM) that estimates hospital-level risk-standardized 30-day readmission rates.

To develop the model, we first used Medicare Part A inpatient and outpatient claims data to identify a cohort of patient stays with PCI between January and December 2007 (index cohort). Using the inpatient claims data, we then identified inpatient readmissions within 30 days of the discharge date of an index admission. We linked the resulting patient cohort with a comparable cohort of patients undergoing PCI included in the NCDR CathPCI Registry's analytic file. Because the current version of the NCDR CathPCI database does not include direct patient identifiers, we linked the two datasets using a probabilistic match. We matched patient admissions using six indirect patient identifiers: hospital Medicare Provider Number (MPN), patient age, gender, admission date, procedure date, and discharge date. In the future, the NCDR registries will contain identifiers such as social security number and/or a health insurance claim number that will allow a direct match between the two sources of data. The performance of the model was validated using a similar cohort of patients who underwent PCI in 2006 ("validation sample"). For both the development and validation models, we computed indices that describe their respective performance in terms of predictive ability, discriminant ability, and overall fit.

2.2 Technical Expert Consultation

Throughout measure development, we obtained expert and stakeholder input via two mechanisms: first, through regular discussions with a Working Group, and second, through a national Technical Expert Panel (TEP).

The working group was assembled and regular conference calls were held throughout the development phase. The working group included individuals from YNHHS/CORE, the ACC, NCDR, and the Society for Cardiovascular

Angiography and Interventions (SCAI). The working group was tailored for this measure development, and included clinicians and other professionals with expertise in interventional cardiology, biostatistics, measure methodology, and quality improvement. The group also included individuals from the NCDR with extensive registry experience as well as experience in the use of registry data to develop the risk adjustment method. The working group meetings were held on a bimonthly basis and addressed key issues surrounding measure development including, detailed discussions regarding the pros and cons of specific decisions (such as the appropriate period of assessment and use of all-cause versus cause-specific readmission), and to ensure the methodological rigor of the measure.

In addition to the working groups, and in alignment with the CMS Measures Management System (MMS), we convened a TEP to provide input and feedback during measure development from a group of recognized experts in relevant fields. To create the TEP, we released a public call for nominations (YNHHSC-CORE TEP Summary Report 2009) and selected individuals in order to provide representation from a range of perspectives including those of physicians, consumers, hospitals, and purchasers. For the PCI readmission measure, we convened three TEP conference calls. In contrast to the working group calls, the TEP calls followed a more structured format consisting of presentation of key issues, relevant data, and our proposed approach. This presentation was followed by open discussion of these issues by the TEP members.

Finally, we solicited public comment on the proposed measure through the MMS Web site (<https://www.cms.hhs.gov/apps/QMIS/publicComment.asp>). Public comments were summarized and publicly posted. The resulting content was taken into consideration during the final stages of measure development.

2.3 Outcome

The outcome for this measure is 30-day all-cause readmission. We define a readmission as a subsequent hospital inpatient admission within 30 days of the discharge date of an admission in the index cohort or claim end date (for patients whose PCI was performed as an outpatient service).

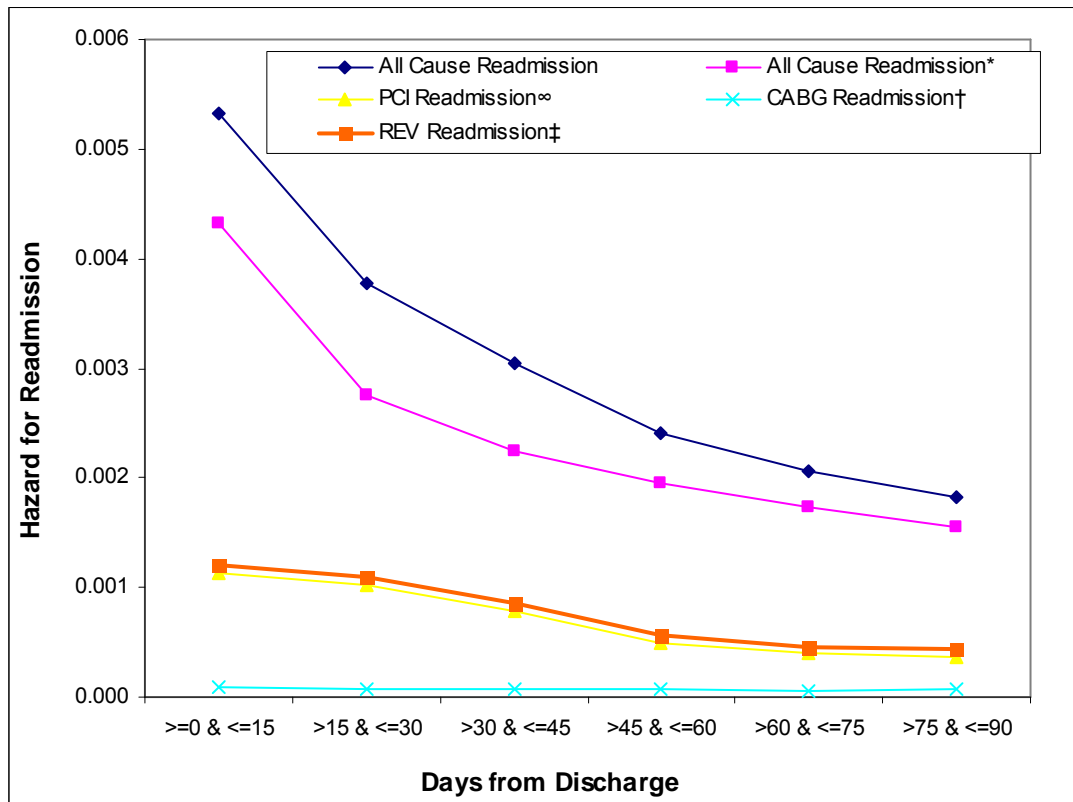
We do not count readmissions associated with a ‘staged’ revascularization procedure, defined as readmissions with PCI or CABG codes that do not have a principal discharge diagnosis code consistent with an acute cardiac event (heart failure, acute myocardial infarction, arrhythmia, unstable angina, and cardiac arrest). The rationale for this exclusion is that physicians caring for patients with multivessel disease may opt to perform the revascularization procedures over multiple visits to the catheterization laboratory, which may

occur during a single or multiple hospitalizations. This readmission exclusion criterion is consistent with that used by the NQF-approved AMI readmission measures. Unadjusted rates of readmissions including staged revascularization may be reported in parallel when the measure is implemented.

2.3.1 30-Day Timeframe

We considered a range of time periods for the outcome and ultimately selected a 30-day timeframe for several reasons. First, we reviewed a preliminary analysis of the hazard of readmission over a 90-day period (Figure 1). The risk of readmission was highest within the first 15 days but remained elevated up to 60 days following discharge. There was, however, the appearance of a plateau that occurred between 30 and 45 days after discharge. These results suggested that a 30-day timeframe would capture the time period at which patients are at highest risk for readmission. Furthermore, readmissions in this time period would more likely be attributable to the care delivered both within an index hospitalization and during the transition from that setting. A shorter timeframe such as 15 days would have an even stronger association with the initial care of the patient, but would miss the substantial number of readmissions occurring between 15 and 30 days. Both the working group and TEP agreed that a 30-day readmission measure had the greatest potential to stimulate better collaboration between hospitals and their surrounding medical communities aimed at reducing readmission rates. These activities may include providing better, safer care during the patient stay, attention to patient's medication needs at discharge, improving communication with patients before and after discharge, improving communication with other providers; reviewing practice patterns; and implementing systems to reduce readmissions. Finally, this timeframe is consistent with the other readmission measures approved by NQF.

Figure 1 – Hazard of Readmission Following PCI (Medicare Part A Inpatient and Outpatient, 2007)



2.3.2 All-Cause Readmission

We used all-cause readmission (except for staged procedures) as opposed to cardiac specific readmission for several reasons. First, from the patient perspective, readmission for any reason is likely to be an undesirable outcome of care. Second, readmissions not associated with a cardiac diagnosis may in fact still be directly related to the care delivered during the index hospitalization. Examples include patients readmitted with acute renal failure due to a contrast nephropathy caused by the initial procedure, or patients readmitted with a pseudoaneurysm or other

* Readmissions with revascularization but without myocardial infarction, heart failure, unstable angina, cardiac arrest or arrhythmia are not counted as readmissions

∞PCI=Percutaneous Coronary Intervention

†CABG=Coronary Artery Bypass Graft

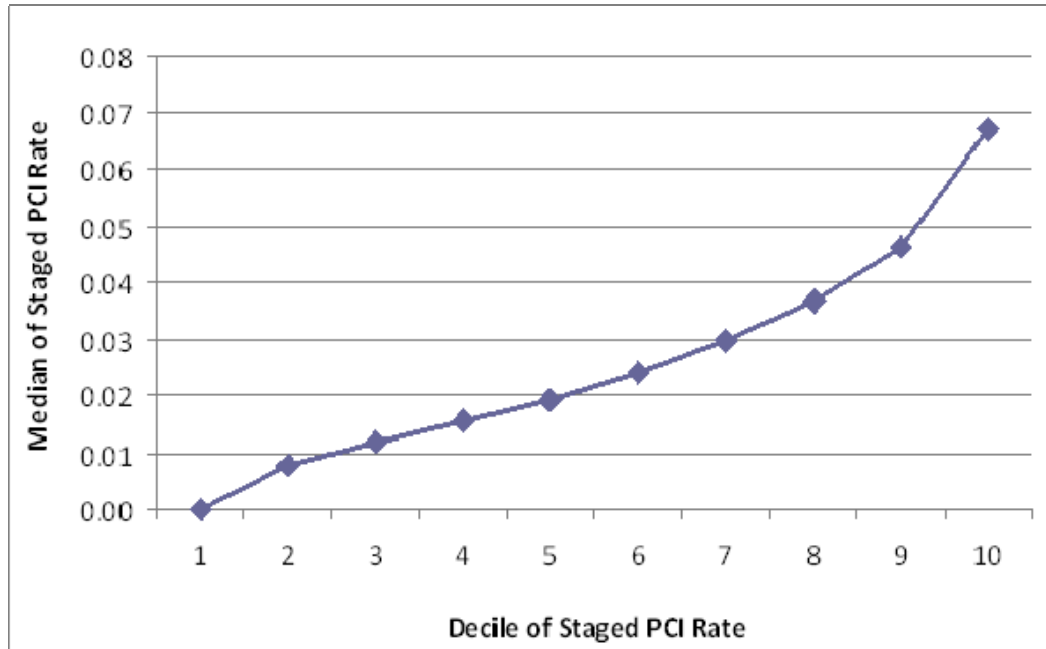
‡REV=Coronary Revascularization

late-presenting vascular complication resulting from the initial procedure. In addition, the range of potentially avoidable readmissions also includes those not directly related to the PCI such as those resulting from poor communication or inadequate follow-up. As such, creating a comprehensive list of potential 'PCI-related' complications would be arbitrary and, ultimately, impossible to implement. Using all-cause readmission, on the other hand, will undoubtedly include a mix of unavoidable and avoidable readmissions as not all readmissions are preventable. Review of the most frequent codes associated with readmissions (Appendices A and B) reveals a wide variety of cardiovascular and non-cardiovascular conditions and procedures. Although there is no reliable way to accurately identify preventable readmissions, there are undoubtedly opportunities to improve care of PCI patients. Thus, the goal of this measure is not to reduce readmissions to zero. Instead, an all cause measure will assess hospital performance relative to what is expected given the performance of other hospitals with similar case mixes.

2.3.3 Readmissions for Staged Procedures not Counted as Readmissions

We identify readmissions for staged PCI procedures and do not count them as readmissions for the index procedure. The rationale for this exclusion is that physicians caring for patients with multivessel disease may opt to perform the revascularization procedures over multiple visits to the catheterization laboratory, which may occur during a single or multiple hospitalizations. Current clinical practice guidelines (King, Smith et al. 2007) and appropriateness criteria (Patel, Dehmer et al. 2009) for PCI do not address the appropriateness of these staging procedures, and there is certainly significant variation in the frequency with which patients are readmitted for staged procedures among hospitals with at least 50 PCI procedures (Figure 2). Although this variation has significant clinical and cost implications, at this time the appropriateness of this approach is controversial and therefore an admission for a staged procedure cannot necessarily be considered an undesirable event. This issue was the topic of much discussion with the working group and Technical Expert Panel. As a result of consensus opinion, the measure will not include readmissions with a PCI or CABG code that do not have a principal discharge diagnosis code consistent with an acute cardiac event (i.e. heart failure, acute myocardial infarction, arrhythmia, unstable angina, and cardiac arrest). These admissions will be viewed as staged revascularizations and will not be included in this readmission measure. The approach to identifying elective revascularizations is comparable to that currently used for the 30-day AMI readmission measure.

Figure 2 – Hospital variation in Readmission for Staged Procedures (Medicare Inpatient Part A, 2007; in hospitals with at least 50 PCI procedures)



2.4 Data Sources

The datasets used to create the measure are described below.

2.4.1 NCDR CathPCI Registry data

The model uses ACC NCDR CathPCI Registry data to adjust for differences in patient risk of readmission. The CathPCI Registry is the largest voluntary cardiovascular data registry in the United States. The registry captures detailed information about patients at least 18 years of age undergoing cardiac catheterization and PCI. Information collected by the registry includes demographics, comorbid conditions, cardiac status, and coronary anatomy. Hospitals that join the CathPCI Registry agree to submit data for 100% of patients undergoing cardiac catheterization and PCI procedures. These data are collected by hospitals and submitted electronically on a quarterly basis to NCDR (the data collection form and the complete list of variables collected and submitted by hospitals can be found at <http://www.ncdr.com>). The patient records submitted to the registry focus on acute episodes of care, from admission to discharge, and

the NCDR does not link patient records longitudinally across episodes of care.

Institutions that participate in the CathPCI Registry reflect the full spectrum of hospitals that perform PCI. We compared characteristics of hospitals that do participate in the CathPCI Registry with hospitals that perform PCI but do not participate in the CathPCI registry using data from the 2007 Medicare claims data linked with 2007 American Hospital Association (AHA) Survey data. Compared with hospitals that do not participate in the CathPCI Registry, hospitals that participate are larger and more likely to be located in the Northeast. Furthermore, a higher proportion of those in the CathPCI Registry are not-for-profit, teaching, and perform open heart surgeries including coronary artery bypass grafting (Table 2).

Table 2 – Comparison of the characteristics of hospitals that perform PCI and participate in the CathPCI Registry with PCI Hospitals that do not participate in the CathPCI Registry (hospitals in both CMS Part A [inpatient & outpatient] and AHA 2007 data)

Description	Total		Non-Participating CathPCI Registry Hospitals		Participating CathPCI Registry Hospitals		P
	#	%	#	%	#	%	
All	1554	100.00	791	100.00	763	100.00	<0.001
Number of beds							
< 300	858	55.21	484	61.19	374	49.02	
300 to 600	545	35.07	242	30.59	303	39.71	
> 600	151	9.72	65	8.22	86	11.27	<0.001
Mean (SD)	325.83	221.19	301.41	227.39	351.14	211.77	
Ownership							
Government	182	11.71	111	14.03	71	9.31	<0.001
Not-for-profit	1072	68.98	493	62.33	579	75.88	
For profit	300	19.31	187	23.64	113	14.81	
Region							<0.001
Associated area	10	0.64	10	1.26	0	0.00	
New England	55	3.54	20	2.53	35	4.59	
Middle Atlantic	171	11.00	104	13.15	67	8.78	
South Atlantic	242	15.57	115	14.54	127	16.64	
East North Central	280	18.02	116	14.66	164	21.49	
East South Central	112	7.21	61	7.71	51	6.68	
West North Central	130	8.37	50	6.32	80	10.48	
West South Central	226	14.54	156	19.72	70	9.17	
Mountain	127	8.17	63	7.96	64	8.39	
Pacific	201	12.93	96	12.14	105	13.76	
Teaching status							<0.001
COTH*	255	16.41	122	15.42	133	17.43	
Teaching	376	24.20	163	20.61	213	27.92	
Non-Teaching	923	59.40	506	63.97	417	54.65	
Cardiac facility							<0.001
CABG** surgery	1123	72.27	511	64.60	612	80.21	

The NCDR possesses a Data Quality Program (DQP) to ensure validity of the data collected. The two main components of the DQP are complementary and consist of the Data Quality Report (DQR) and the Data Audit Program (DAP). The DQR process assesses the completeness and validity of the electronic data submitted by participating hospitals. Hospitals must achieve >95% completeness of specific data elements

* Council of Teaching Hospitals and Health Systems

** Coronary Artery Bypass Graft

identified as 'core fields' to be included in the registry's data warehouse for analysis. The 'core fields' include the variables included in our risk adjustment models. The process is iterative, providing hospitals with the opportunity to correct errors and resubmit data for review and acceptance into the data warehouse. The entire quarter of patient discharge information is not accepted until the DQR completeness thresholds are met for all patient data. The DAP consists of annual on-site chart review and data abstraction. Among participating hospitals that pass the DQR for a minimum of two quarters, at least 5% are randomly selected to participate in the DAP. At individual sites, on-site auditors review up to 50 submitted patient charts. The CathPCI Registry audit focuses on variables used for the existing PCI mortality models. However, the scope of the audit could be expanded to include additional fields. The DAP includes an appeals process that allows hospitals to reconcile audit findings.

For model development, we identified PCI procedures in the CathPCI Registry in which the patient was released from the hospital between January and December 2007. For validation purposes, we identified a comparable cohort of patients released from the hospital following a PCI between January and December 2006.

2.4.2 Medicare Data

The model uses Medicare claims data to identify readmissions

- Part A inpatient and outpatient data
Part A data refers to claims paid for Medicare inpatient hospital care, outpatient services, skilled nursing facility care, some home health agency services, and hospice care. For this measure, we used Part A data to identify patient stays with a PCI performed either as an inpatient admission or outpatient service. For model development, we used 2007 Medicare Part A data to match patient stays associated with a PCI with comparable data from the CathPCI Registry. For validation, we used 2006 Medicare Part A data to match patient stays with a PCI performed with the corresponding 2006 data from the CathPCI Registry.
- Medicare Enrollment Database (EDB)
This database contains Medicare beneficiary demographic, benefit/coverage, and vital status information. This dataset was used to obtain information on several inclusion/exclusion indicators, including in-hospital death, Medicare status on admission, and ability to retrieve a full month follow-up, linking patient Health Insurance Claim (HIC) number to the Part A Data. These data have previously been shown to accurately reflect patient vital status (Fleming, Fisher et al. 1992).

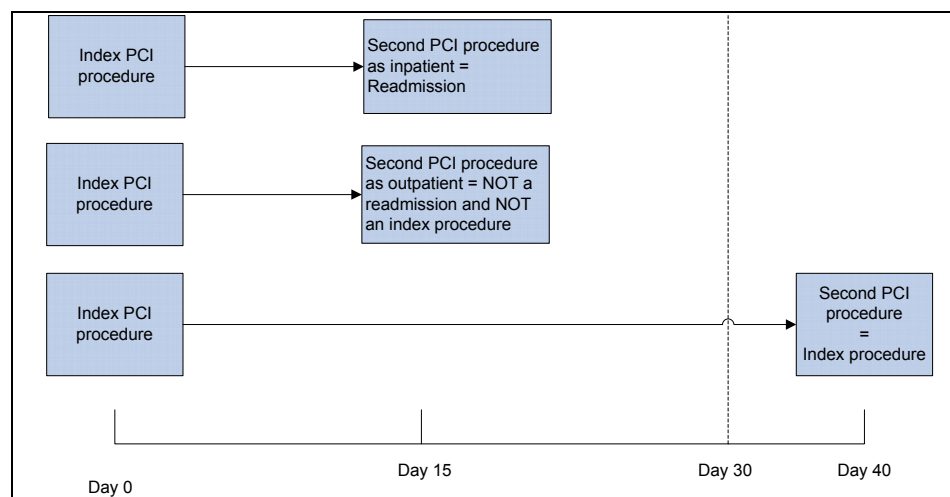
2.5 Cohort Derivation

Both the CathPCI Registry and CMS claims data were used to define the cohort of admissions with a PCI for model development. The algorithm used to derive the cohort is documented in Figure 4.

From the CathPCI Registry data, we identified a patient stay with PCI as a PCI admission using the item 614 (PCI=Yes). When patients underwent multiple PCIs during one hospital stay, the first PCI performed during that stay was considered to be the index PCI admission and only information related to that index PCI was included in the measure. We chose this approach because information obtained from subsequent PCI procedures during one hospital stay may actually reflect complications of care following the initial procedure. Consider the example of a patient who underwent elective PCI and subsequently experienced an acute myocardial infarction (AMI) due to an unrecognized dissection. If the patient had to undergo an emergency repeat PCI, it would be inappropriate to include that information in the risk adjustment process as it reflected a complication of care.

If a patient had more than one PCI during the 30 day outcome period, the subsequent PCI was not considered to be a new index procedure (Figure 3). If a patient underwent more than one PCI procedure within a calendar year, (but not within the same hospitalization) that PCI was eligible for consideration as another index procedure.

Figure 3 – Index Procedure Derivation for Patients with Subsequent PCI Procedures



In the CathPCI Registry, patient stays with PCI are identified by field 614 (PCI=Yes). In the CMS claims data, patient stays with PCI are identified by the International Classification of Diseases, 9th Revision, Clinical

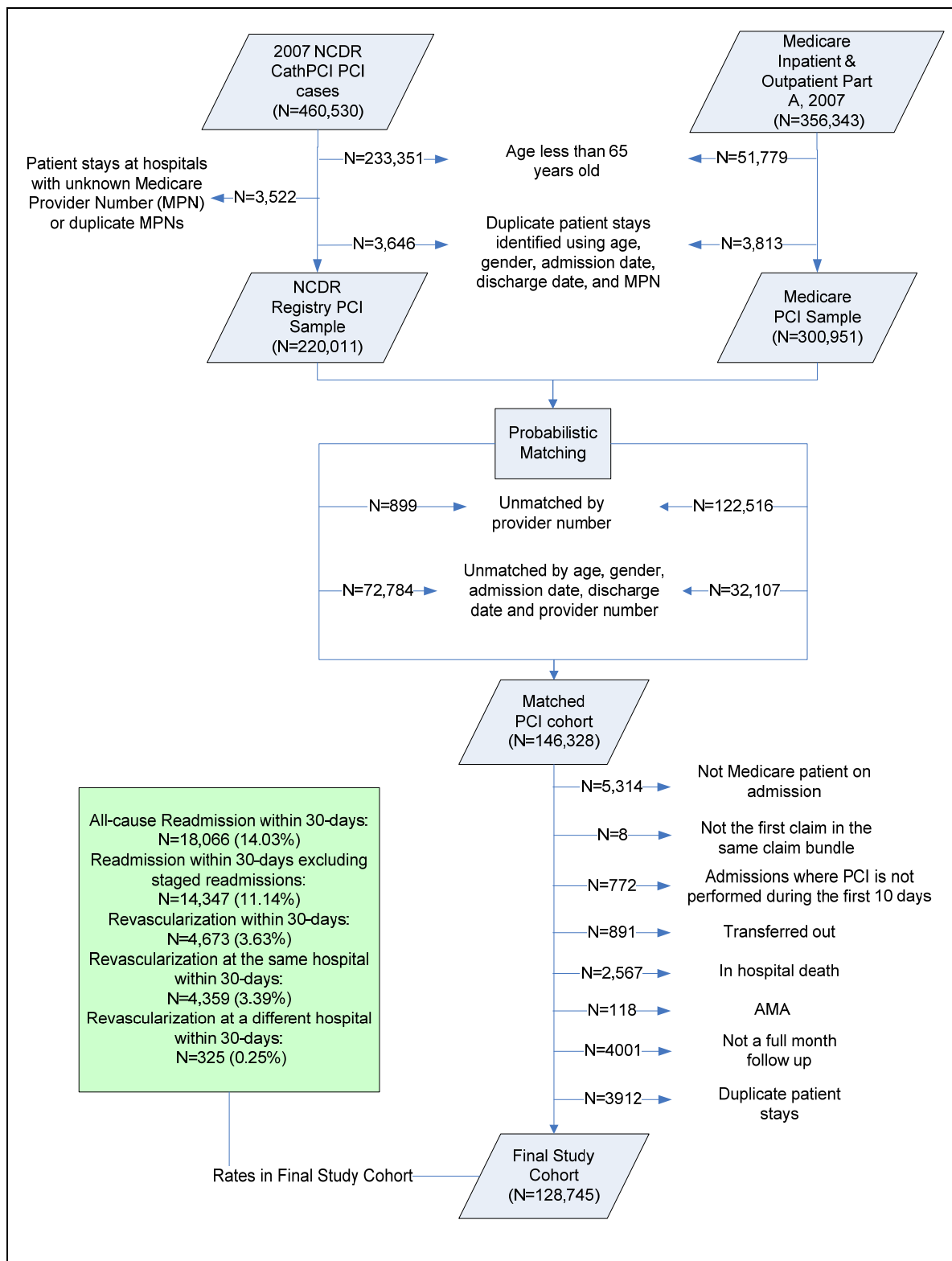
Modification (ICD-9-CM) procedure codes from inpatient and outpatient claims and Healthcare Common Procedure Coding System/Current Procedural Terminology (HCPCS/CPT) procedure codes from outpatient claims shown in Table 3.

Table 3 – ICD-9-CM and CPT Procedure Codes that Define an Admission with PCI in Medicare Inpatient & Outpatient Claims

Code Type	Code	Description
ICD-9-CM	00.66	Percutaneous transluminal coronary angioplasty or coronary atherectomy
ICD-9-CM	36.01	Single vessel PTCA or coronary atherectomy
ICD-9-CM	36.02	Percutaneous transluminal coronary angioplasty or coronary atherectomy with mention of thrombolytic agent
ICD-9-CM	36.05	Multiple vessel PTCA or coronary atherectomy
ICD-9-CM	36.06	Insertion of non-drug-eluting coronary artery stent(s)
ICD-9-CM	36.07	Insertion of drug-eluting coronary artery stent(s)
CPT	92973	Percutaneous transluminal coronary thrombectomy
CPT	92980	Coronary Stents [single vessel]
CPT	92981	Coronary Stents [each additional vessel]
CPT	92982	Coronary Balloon Angioplasty [single vessel]
CPT	92984	Coronary Balloon Angioplasty [each additional vessel]
CPT	92995	Percutaneous Atherectomy
CPT	92996	Percutaneous Atherectomy

We merged PCI admissions in the NCDR CathPCI Registry data and PCI admissions in Medicare claims data to derive cohorts for development (2007) and validation (2006). Figure 4 presents the details of the derivation of the development cohort, which includes the total number of patient stays with PCI, the proportion excluded as a result of each exclusion criterion, and the number included in the final sample as index hospitalizations. The development sample consisted of 128,745 admissions at 766 hospitals. The overall unadjusted all-cause 30-day readmission rate is 14.0%, and after excluding staged procedures, 11.1%.

Figure 4 – Cohort for Model Development*



* AMA= Against Medical Advice; NCDR=National Cardiovascular Data Registry; MPN=Medicare Provider Number; PCI=Percutaneous Coronary Intervention

2.5.1 Probabilistic Matching Methodology for Merging CathPCI Data and CMS Claims Data for Measure Development

Since the CathPCI Registry does not currently capture the direct patient identifiers necessary to make these linkages, we performed a probabilistic matching between patient stays with PCI in the CathPCI Registry and corresponding patient stays in the CMS claims data using the following indirect patient identifiers: hospital Medicare Provider Number (MPN), patient age, gender, date of admission (for Medicare Part-A outpatient claims, this is the claim begin date), and date of discharge (for Medicare Part-A outpatient claims, this is the claim end date). We performed the following steps for linkage:

1. Hospital information assembled from the CathPCI Registry (hospital identification number, name and address) was used to retrieve each hospital's self-reported hospital MPN from the NCDR;
2. MPN was manually searched and confirmed in the CathPCI Registry. Data for hospitals with either no self-reported MPN or a duplicate MPN were excluded;
3. A unique dataset was derived from the CathPCI Registry (including patients' clinical factors) with patient stays determined by hospital MPN, patient age, gender, admission date, and discharge date. Of note, the CathPCI Registry does not distinguish between inpatient and outpatient status; it uses 'admission' date and 'discharge' date for outpatients and inpatients.
4. A comparable dataset was created from CMS claims data by removing direct patient identifiers (i.e. Health Insurance Claim [HIC] number) and the resulting dataset contained unique patient admissions determined by hospital MPN, patient age, gender, admission date (for Medicare Part-A outpatient claims, this is the claim begin date), and discharge date (for Medicare Part-A outpatient claims, this is the claim end date).
5. The two datasets derived in steps 3 and 4 were merged using hospital MPN, patient age, gender, admission date, and discharge date as the linking fields.

Results of the probabilistic match are presented in the Section 2.8.

2.5.2 Exclusion Criteria

We excluded the following patient stays from the measure calculation prior to the merge:

- 1) Age <65 (Medicare and NCDR datasets). Stays for patients less than 65 years old at the time of the patient stay were excluded.
Rationale: Patients younger than 65 in the Medicare dataset represent a distinct population that qualifies for Medicare due to disability. The characteristics and outcomes of these patients may be less representative of the larger population of PCI patients.
- 2) Patient stays at hospitals with missing or duplicate MPN (NCDR dataset). Any patient stays with a missing or duplicate MPN number are excluded.
Rationale: If the MPN number is unreliable, we are unable to match NCDR patients to CMS claims data or assign the readmission to a hospital with certainty.
- 3) Patient stays with duplicate fields (Medicare and NCDR datasets). Patient stays that have identical information indicated for age, gender, admission date, discharge date, and MPN are excluded.
Rationale: Patient stays with identical demographics are excluded to avoid making matching errors upon merging of the two datasets.
- 4) Unmatched patient stays. Patient stays that are not matched based on age, gender, admission date, discharge date, and MPN are excluded.

The following exclusions are applied to the merged dataset:

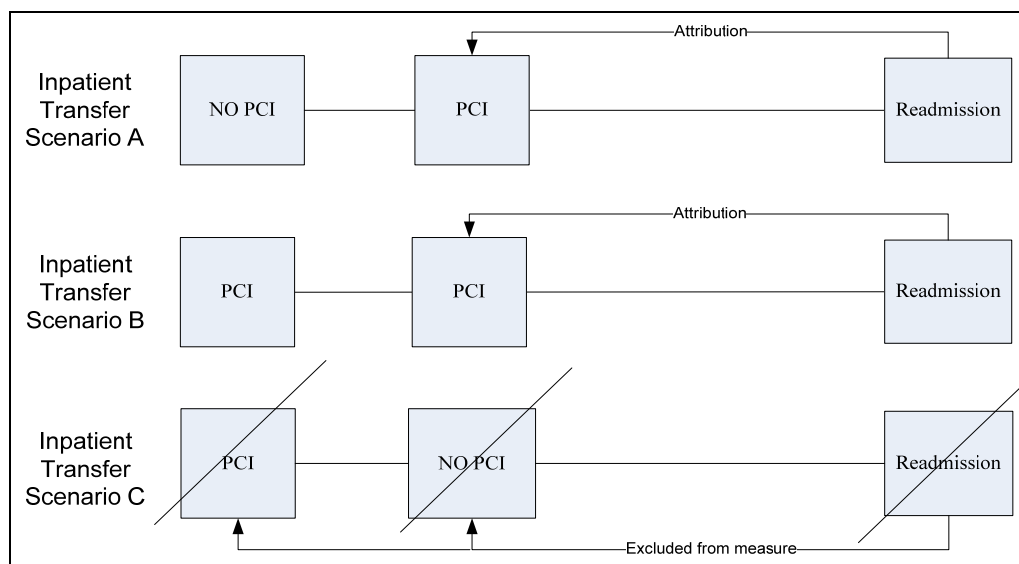
- 1) Patients not enrolled in Medicare fee-for service (FFS) at the start of the episode of care.
Rationale: readmission data is currently available only for Medicare fee-for-service patients.
- 2) Not the first claim in the same claim bundle. Multiple claims from an individual hospital can be bundled together. To ensure that the selected PCI is the index PCI, we exclude those PCI procedures that were not the first claim in a specific bundle.
Rationale: Inclusion of additional claims could lead to double counting of an index PCI procedure.
- 3) Instances when PCI is performed >10 days following admission. Patients with prolonged hospitalizations prior to PCI are excluded.

Rationale: Patients who undergo PCI late into their hospitalization represent an unusual clinical situation in which it is less likely that the care delivered at the time of or following the PCI would be reasonably assumed to be associated with subsequent risk of readmission.

- 4) Transfers out. Patient stays in which the patient received a PCI and was then transferred to another hospital are excluded (Figure 5).

Rationale: In this instance, the hospital that performed the PCI procedure does not provide discharge care and cannot be fairly held responsible for their outcomes following discharge.

Figure 5 – 30-Day PCI Readmission Transfer Attribution Strategy



- 5) The patient dies in the hospital.
Rationale: Subsequent admissions (readmissions) are not possible.
- 6) The patient leaves against medical advice (AMA).
Rationale: Physicians and hospitals do not have the opportunity to deliver the highest quality care.
- 7) PCI in which 30-day follow up is not available. Patients who cannot be tracked for 30 days following their hospital stay are excluded.
Rationale: There will not be adequate follow-up data to assess readmissions.
- 8) Admissions with a PCI occurring within 30-days of a prior PCI already included in the cohort.
Rationale: We do not want to count the same admission as both an index admission and an outcome.

2.6 Observation Period

For model development and validation, we used observations for one calendar year.

2.7 Registry Model Development

2.7.1 Model Overview

We used NCDR CathPCI Registry data that contains hospitalization associated with PCI. We derived the model using PCI hospitalizations for patients treated in 2007 (“development sample”). The performance of the model was then validated using patient stays with PCI for patients discharged in 2006 (“validation sample”). We computed indices that describe model performance in terms of predictive ability, discriminant ability, and overall fit.

2.8 Developmental Dataset

For development, CathPCI Registry data were linked to Medicare data using the probabilistic matching methodology described earlier. Among PCI patients ≥ 65 years old in the CathPCI Registry, 67% were successfully matched to CMS claims data for 2007 data. Results of the match were similar when we varied matching criteria (e.g., removing discharge date as a linking field). This rate is similar to that found during development of the two 30-day PCI mortality measures YNHHS/CORE developed in 2008, and similar to that achieved by other investigators utilizing the same data (Douglas, Brennan et al. 2009). The characteristics and outcomes of matched and unmatched patients were similar, suggesting that the match was adequate for measure development, but not for measure implementation. Although 33% of patients did not match, the observed differences in characteristics of patients who did match and those who did not match were clinically modest (Table 4). Age, for example, was roughly one year higher in the matched group as compared to the unmatched group, which was statistically significant but clinically comparable. One area of concern was race; a much lower percentage of patients who matched were non-white, compared with those who did not match (11% and 16%, respectively). It was speculated during Technical Expert Panel (TEP) meetings that this difference may be due to differences in demographics of patients across participating hospitals that participate in the NCDR, or differences in hospital resources of those hospitals that treat a high proportion of non-white patients.

When we compared the outcomes of patients in the Medicare claims data who did and did not match, the overall readmission and mortality rates were comparable. This finding suggests that the patients included in the derivation cohort are likely representative of the broader population of Medicare patients undergoing PCI (Table 5).

There are several factors that may influence the likelihood of a patient match. First, up to 14% of patients ≥ 65 years of age are enrolled in Medicare Advantage (Friedman, Jiang et al. 2006). Information about Medicare Advantage patients are not included in the FFS claims data and, accordingly, would not be available for matching. In addition, approximately 6-8% of cases submitted to the CathPCI Registry are not included in the analytic file because they did not pass the DQR process. Other contributing factors include patients ineligible for Medicare (e.g., non-U.S. citizens), patients with non-governmental insurance, and inaccuracies in linking fields (e.g., substituting age for date of birth).

Table 4 – Selected Patient Characteristics in NCDR Data for Matched and Unmatched Patients

Description	Not Matched #	Not Matched %	Matched #	Matched %
Demographics				
Age: Mean (SD)	73.87	6.5	74.71	6.6
Gender	28,668	39.4	59,907	40.9
Race: non-white	12,103	16.6	16,931	11.6
History and Risk Factors				
Body Mass Index (BMI)				
unknown	102	0.1	200	0.1
mean (SD)	28.66	5.8	28.57	5.8
Heart failure - previous history	9,679	13.3	20,742	14.2
Previous valvular surgery	1102	1.5	2,460	1.7
Cerebrovascular Disease	10,866	14.9	23,538	16.1
Peripheral Vascular Disease	10,670	14.7	22,942	15.7
Chronic Lung Disease	12,974	17.8	27,518	18.8
Diabetes/control				
No	48,064	66.0	97,813	66.8
Non-insulin diabetes	17,135	23.5	33,233	22.7
Insulin diabetes	7,585	10.4	15,282	10.4
Glomerular Filtration Rate (GFR)*				
not measured	2,612	3.6	5,545	3.8
GFR<30	2,898	4.0	6,704	4.6
30<=GFR<60	26,238	36.0	54,623	37.3
60<=GFR<90	34,609	47.6	67,309	46.0
GFR>=90	6,427	8.8	12,147	8.3
Previous PCI	27,133	37.3	56,012	38.3
Previous CABG	16,591	22.8	35,189	24.0
Cardiac Status				
Heart Failure - current status	8,607	11.8	18,480	12.6
New York Heart Association (NYHA)				
Class I	22,642	31.1	44,995	30.7
Class II	18,181	25.0	35,707	24.4
Class III	19,025	26.1	39,294	26.9
Class IV	12,936	17.8	26,332	18.0
Cardiogenic shock	1,792	2.5	3,551	2.4
Symptoms present on admission				
No MI	54,087	74.3	106,156	72.5
MI within 24 hours	14,445	19.8	31,299	21.4
MI after 24 hours	4,252	5.8	8,873	6.1
Cath Lab Visit				
Ejection fraction (EF) percentage				
not measured	22,397	30.8	43,433	29.7
EF<30	2,870	3.9	6,229	4.3
30<=EF<45	8,083	11.1	17,545	12.0
EF>=45	39,434	54.2	79,121	54.1
PCI Procedure				
PCI status				
Elective	38,165	52.4	74,061	50.6
Urgent	25,602	35.2	52,571	35.9
Emergency	8,782	12.1	19,263	13.2
Salvage	235	0.3	433	0.3
Highest risk lesion: SCAI** lesion class				
I	38,251	52.6	77,769	53.1
II	24,442	33.6	49,575	33.9
III	3,504	4.8	6,719	4.6
IV	6,587	9.1	12,265	8.4

* Calculated using Modification of Diet and Renal Disease (MDRD) equation

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In addition, we examined characteristics and outcomes of the matched and unmatched cohorts derived from the Medicare data (Table 5).

Table 5 – Selected Patient Characteristics and Outcomes in Medicare Data for Matched and Unmatched Patients

Description	Not Matched #	Not Matched %	Matched #	Matched %
Total	32,107		146,328	
Age: Mean (SD)	74.8	6.7	74.7	6.6
Female	13,662	42.6	59,907	40.9
Unstable angina (Index principle code 411)	91	0.3	281	0.2
AMI (Index principle code: 410)	9,302	29.0	42,279	28.9
Coronary Atherosclerosis (Index principle code: 414)	19,503	60.7	91,670	62.7
Heart failure (HF)*	629	2.0	2,329	1.6
Outcome				
In-hospital mortality	676	2.1	2,602	1.8
Mortality within one month of discharge	401	1.3	1,561	1.1
Readmission within one month of discharge	4,466	14.7	19,359	13.7
Readmission** within one month of discharge	3,597	11.8	15,448	11.0

2.9 Candidate and Final Variables

Our goal was to develop a model that included clinically relevant variables that are strongly associated with risk of 30-day readmission.

To select candidate variables, a team of clinicians reviewed the variables collected in the NCDR CathPCI Registry database that were previously considered as candidates in the PCI mortality models. We then modified the list of candidate variables as appropriate for a readmission measure such as the total number of significantly diseased arteries. A copy of the data collection form and the complete list of variables collected and submitted by hospitals can be found at <http://www.ncdr.com>. We excluded variables not deemed appropriate as a quality measure, such as potential complications, certain patient demographics (e.g., race, socioeconomic status), and patients' admission path (e.g., admitted from a skilled nursing facility [SNF]). Variables were also considered ineligible if they were particularly vulnerable to gaming or were deemed to lack clinical relevance. Based on careful review by our

* HF defined by ICD-9 diagnosis codes 428.XX, 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, or 404.93.

** Readmissions with revascularization in patients without myocardial infarction, heart failure, unstable angina, cardiac arrest or arrhythmia were not considered readmissions.

working group members and the TEP, and further informed by a review of the literature, a total of 29 variables were determined to be appropriate for consideration as candidate variables. Our set of candidate variables (see Table 6) included two “demographic” variables (age and gender), 15 “history and risk factor” variables, five “cardiac status” variables, three “cath lab visit” variables, and four “PCI procedure” variables.

For categorical variables with missing values, the value from the reference group was added. The percentage of missing values for all categorical variables was very small (<1%). There were three continuous variables with missing values: body mass index (BMI, 0.1%), glomerular filtration rate (GFR, 3.7%), and left ventricular ejection fraction (LVEF, 28.5%); we considered the missing of GFR and LVEF as an independent category of “unmeasured” and for BMI; we stratified by gender and imputed the missing values to the median of the corresponding groups.

We used logistic regression with stepwise selection (entry $p < 0.05$; retention with $p < 0.01$) for variable selection. We also assessed the direction and magnitude of the regression coefficients. This resulted in a final risk-adjusted readmission model that included 20 variables (Table 7).

Table 6 – PCI Model Candidate Variables

Description	NCDR Item Number	Name
Demographic		
Age	252	Age
Female	260	FEMALE
History and Risk Factors		
BMI*	Derived (410, 412)	BMI
Previous MI	420	PrevMI
Heart Failure-previous history	424	PrCHF
Previous valvular surgery	426	PrValve
Cerebrovascular Disease	450	CVD
Peripheral Vascular Disease	452	PVD
Chronic Lung Disease	454	CLD
Diabetes	Derived (430, 432)	NewDIAB
None	Reference	
Non-insulin diabetes		NEWDIAB1
Insulin diabetes		NEWDIAB2
Glomerular Filtration Rate (GFR)	Derived (252, 260, 270, 439, 440)	GFR
Not measured	Derived	GFRGRP0
GFR<30	Derived	GFRGRP1
30≤GFR<60	Derived	GFRGRP2
60≤GFR<90	Reference	
GFR≥90	Derived	GFRGRP4
Renal failure-dialysis	444	Dialysis
Hypertension	456	Hypertn
History of tobacco use	460	Tobacco
Family history of CAD	480	FHCAD
Previous PCI	490	PrPCI
Previous CABG	494	PrCAB
Cardiac Status		
Heart failure - current status	500	CHF
NYHA	510	ClassNYH
Class I or II	Reference	
Class III	Derived	NYHC3
Class IV	Derived	NYHC4
Cardiogenic shock	520	
ST elevation MI (STEMI)	Derived (550, 560, 812)	STEMI
Symptoms present on admission	Derived (550, 560)	AdmSxPre
No MI		ADMSX1
MI within 24 hours	Reference	
MI after 24 hours		ADMSX3
Cath Lab Visit		
Ejection Fraction (EF) Percentage	Derived (654, 656)	HDEFGRP
Not measured		HDEFGRP1
EF<30		HDEFGRP2
30≤EF<45		HDEFGRP3
EF≥45	Reference	
Left main disease	Derived (660, 661)	LMGT50

* For missing data in BMI, data were stratified by gender first, then set to the median in corresponding groups

Table 6 – PCI Model Candidate Variables (cont.)

Description	NCDR Item Number	Name
Number of vessels with disease	Derived (662 to 671)	VESSELD
≤1	Reference	
2	Derived	VESSELD2
3	Derived	VESSELD3
PCI Procedure		
PCI status	804	PCISat
Elective	Reference	
Urgent	Derived	PCIS2
Emergency	Derived	PCIS3
Salvage	Derived	PCIS4
Highest Lesion location	Derived (900, 902)	NLESLOC
pRCA/mLAD/pCIRC	Derived	NLESLOC1
pLAD	Derived	NLESLOC2
Left main	Derived	NLESLOC3
Other	Derived	
Highest pre-procedure TIMI**flow: none	920	NPRETIMI
Highest risk lesion: SCAI*** lesion class	Derived (910, 950)	NSCAILC
I	Reference	
II	Derived	NSCAILC2
III	Derived	NSCAILC3
IV	Derived	NSCAILC4

** Thrombolysis in Myocardial Infarction

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Table 7 – Final PCI Readmission Model Variables

Variable	Code
Demographic Age Female	Age FEMALE
History and Risk Factors Body Mass Index Heart failure-previous history Previous valvular surgery Cerebrovascular Disease Peripheral Vascular Disease Chronic Lung Disease Diabetes None Non-insulin diabetes Insulin diabetes Glomerular Filtration Rate (GFR) Not measured GFR<30 30≤GFR<60 60≤GFR<90 GFR≥90 Renal failure - dialysis Hypertension History of tobacco use Previous PCI	BMI PRCHF PRVALVE CVD PVD CLD Reference NEWDIAB1 NEWDIAB2 GFRGRP0 GFRGRP1 GFRGRP2 Reference GFRGRP4 DIALYSIS HYPERTN TOBACCO PrPCI
Cardiac Status Heart failure – current status Symptoms present on admission No MI MI within 24 hours MI after 24 hours	CHF ADMSX1 Reference ADMSX3
Cath Lab Visit Ejection Fraction (EF) Percentage Not measured EF<30 30≤EF<45 EF≥45	HDEFGRP1 HDEFGRP2 HDEFGRP3 Reference
PCI Procedure PCI status Elective Urgent Emergency Salvage Highest risk lesion – location pRCA/mLAD/pCIRC pLAD Left main Other Highest pre-procedure TIMI flow: none	Reference PCIS2 PCIS3 PCIS4 NLESLOC1 NLESLOC2 NLESLOC3 Reference

2.10 Statistical Approach to Model Development

We developed the risk adjustment model for the measure using the following methodology:

Because of the natural clustering of the observations within hospitals, we estimated hierarchical generalized linear models (HGLMs). We modeled the log-odds of readmission within 30 days of PCI hospitalization 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 facilities being evaluated lead to systematic differences in outcomes.

We used the above strategy to calculate the hospital-specific readmission rates. We use hierarchical logistic regression modeling to calculate a hospital-specific risk-standardized readmission rates (RSRRs). These rates are calculated as the ratio of predicted number of readmissions to expected number of readmissions, multiplied by the national unadjusted readmission rate. The expected number of readmissions for each hospital was estimated using its patient mix and the average hospital-specific intercept. The predicted number of readmissions in each hospital was estimated given the same patient mix but an estimated hospital-specific intercept. Operationally, the expected number of readmissions for each hospital is obtained by summing the expected readmission rates for all patients in the hospital. The expected readmission rate for each patient is calculated via the hierarchical model by applying the subsequent estimated regression coefficients to the observed patient characteristics and adding the average of the hospital-specific intercepts. The predicted number of readmissions for each hospital is calculated by summing the predicted readmission rates for all patients in the hospital. The predicted readmission rate for each patient is calculated through the hierarchical model by applying the estimated regression coefficients to the patient characteristics observed and adding the hospital-specific intercept. In order to assess hospital performance in any specific year (e.g. the validation cohort), we re-estimate the model coefficients using that year's data.

More specifically, we estimate 2 types of regression models (Table 8, Table 13). First, we fit a generalized linear model (GLM) linking the outcome to the risk factors (McCullagh P 1989). Let Y_{ij} denote the outcome (equal to 1 if patient readmitted within 30 days, zero otherwise) for the j^{th} patient who underwent PCI at the i^{th} hospital; \mathbf{Z}_{ij} denotes a set of risk factors, identified via administrative data. Let I denote the total number of hospitals and n_i the number of index patient stays in hospital i . We assume the outcome is related linearly to the covariates via a known linked function, h , where

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

and $\mathbf{Z}_{ij} = (Z_{1ij}, Z_{2ij}, \dots, Z_{pij})$ 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 HGLM that links the risk factors to the same outcome and a hospital-specific random effect,

$$\text{HGLM} \quad h(Y_{ij}) = \alpha_i + \beta \mathbf{Z}_{ij} \quad (2)$$

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

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 (Gatsonia CA 1999). This model separates within-hospital variation from between-hospital variation. Both HGLMs and GLMs are estimated using the SAS software system (GLIMMIX and LOGISTIC procedures, respectfully).

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

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

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

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

2.11 Hospital Performance Reporting

Using the set of risk factors in the GLM, we fit the HGLM defined by Equations (2) - (3) and estimate the parameters, $\hat{\mu}$, $\{\hat{\alpha}_1, \hat{\alpha}_2, \dots, \hat{\alpha}_I\}$, $\hat{\beta}$, 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

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

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

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

If more (fewer) “predicted” cases than “expected” cases have the outcome in a hospital, then \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 (Section 2.11) is a complex function of parameter estimates, we use re-sampling and simulation techniques to derive an interval estimate. The bootstrapping simulation has the advantage of avoiding unnecessary distributional assumptions.

2.11.2 Algorithm

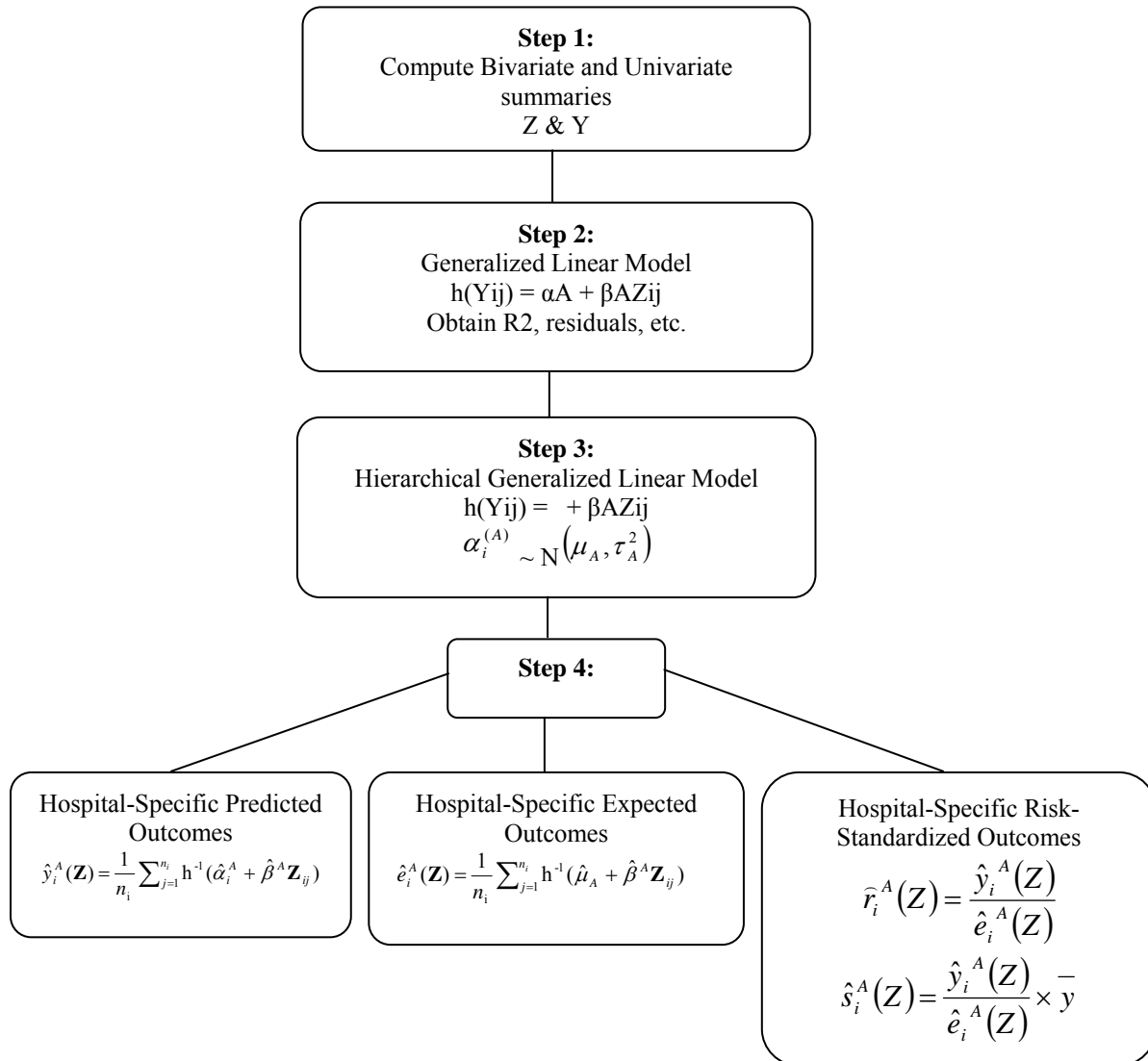
Let I denote the total number of hospitals in the sample. We repeat steps 1 – 4 below for $b = 1, 2, \dots, B$ times:

1. Sample I hospitals with replacement.
2. Fit the HGLM 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 $\hat{\sigma}^2(b)$.
 - c. The set of hospital-specific intercepts and corresponding variances, $\{\hat{\alpha}_i^{(b)}, \text{var}(\hat{\alpha}_i^{(b)}); i = 1, 2, \dots, I\}$.
3. We generate a hospital random effect by sampling from the distribution of the hospital-specific distribution obtained in Step 2c. We approximate the distribution for each random effect by a normal distribution. Thus, we draw $\alpha_i^{(b*)} \sim N(\hat{\alpha}_i^{(b)}, \text{var}(\hat{\alpha}_i^{(b)}))$ for the unique set of hospitals sampled in Step 1.

4. Within each unique hospital i sampled in Step 1, and for each case j in that hospital, we calculate $\hat{y}_{ij}^{(b)}$, $\hat{e}_{ij}^{(b)}$, and $\hat{s}_i(Z)^{(b)}$ 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) (Normand, Wang et al. 2007).

Figure 6 – Analysis Steps



3. RESULTS

3.1 Model Results

3.1.1 Development

The variable descriptions, standardized estimates, and standard errors for the GLM model are shown in Table 8. The standardized estimates are regression coefficients expressed in units of standard deviations and can range between -1 and 1, with ± 1 indicating a perfect linear relationship and 0 indicating no linear relationship.¹ The corresponding descriptions, estimates, and standard errors for the HGLM model are shown in Table 13 (HGLM).¹

3.1.2 Model Performance

We computed 6 summary statistics for assessing model performance (Harrell, 2001): over-fitting indices², percentage of variation explained by the risk factors, predictive ability, area under the receiver operating characteristic (ROC) curve, distribution of residuals, and model chi-square³ (see Table 10).

The development model has strong discrimination and fit. The readmission rate ranges from 4.1% in the lowest predicted decile to 25.1% in the highest predicted decile, a range of 21.0%. The area under the ROC curve is 0.665 (GLM).

The discrimination and the explained variation of the model are consistent with those of published AMI, HF, and Pneumonia. The ROC is higher than that of previously published models for readmission, likely reflecting the advantages of using registry as opposed to claims data for risk adjustment. Nevertheless, the ROC is substantially lower than that of the NQF

¹ Standardized estimates are like correlation coefficients. We compute them in order to compare the size of the coefficients by standardizing the coefficients to be unitless.

² Over-fitting refers to the phenomenon in which a model well describes the relationship between predictive variables and outcome in the development dataset, but fails to provide valid predictions in new patients.

³ 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)

approved PCI mortality measures. Readmissions are inherently more difficult to predict than mortality, with the risk of readmission more dependent on local practice patterns than patient characteristics. In addition, we did not consider covariates such as potential complications, certain patient demographics (e.g., race), and patients' admission path (e.g., outpatient, emergency department), and discharge destination (e.g. Discharged to home versus other facilities, both non-acute and acute care). These characteristics may be associated with readmission and thus could increase the model performance to predict patient readmission. However, these variables may be related to quality or supply factors that should not be included in an adjustment that seeks to control for patient clinical characteristics. As a result of these considerations the choice was made to focus on adjustment for clinical differences in the populations among hospitals. That is, we focused on patient characteristics present at the time of the procedure even though the time zero for the measure was discharge.

Table 8 – 30-Day Readmission Model (2007 Development Sample-GLM Results [ROC=0.665])*

Description	Estimate	S.E.	Wald Chi-Square	Pr > ChiSq	Standardized Estimates	OR (LOR, UOR)
Intercept	-3.84	0.15	689.5	0.00		
Age/10	0.23	0.01	246.4	0.00	0.08	1.26 (1.22, 1.29)
Female	0.26	0.02	184.4	0.00	0.07	1.29 (1.25, 1.34)
BMI/5	-0.13	0.01	84.8	0.00	-0.05	0.88 (0.86, 0.90)
CHF - Previous History	0.27	0.03	109.9	0.00	0.05	1.31 (1.25, 1.38)
Previous Valvular Surgery	0.19	0.06	9.4	0.00	0.01	1.21 (1.07, 1.37)
Cerebrovascular disease	0.19	0.02	66.3	0.00	0.04	1.21 (1.15, 1.26)
Peripheral Vascular Disease	0.20	0.02	67.5	0.00	0.04	1.22 (1.16, 1.28)
Chronic Lung disease	0.33	0.02	226.0	0.00	0.07	1.40 (1.34, 1.46)
Non-Insulin diabetes	0.12	0.02	26.7	0.00	0.03	1.12 (1.08, 1.18)
Insulin diabetes	0.33	0.03	127.1	0.00	0.05	1.39 (1.31, 1.47)
GFR: 0=Not measured	0.04	0.05	0.5	0.49	0.00	1.04 (0.94, 1.15)
GFR: 1="0<=GFR<30"	0.56	0.04	156.8	0.00	0.06	1.76 (1.61, 1.92)
GFR: 2="30<=GFR<60"	0.16	0.02	56.4	0.00	0.04	1.17 (1.12, 1.22)
GFR: 4="GFR>=90"	0.15	0.04	19.2	0.00	0.02	1.17 (1.09, 1.25)
Renal Failure - Dialysis	0.39	0.06	42.0	0.00	0.03	1.48 (1.32, 1.67)
Hypertension	0.08	0.03	9.7	0.00	0.02	1.08 (1.03, 1.14)
History of Tobacco Use	-0.05	0.01	11.0	0.00	-0.02	0.95 (0.93, 0.98)
Previous PCI	-0.08	0.02	18.2	0.00	-0.02	0.92 (0.89, 0.96)
CHF - Current Status	0.29	0.03	124.3	0.00	0.05	1.34 (1.27, 1.41)
No MI on admission	-0.13	0.03	23.8	0.00	-0.03	0.88 (0.83, 0.92)
MI after 24 hours on admission	0.10	0.04	7.2	0.01	0.01	1.11 (1.03, 1.19)
EFP: 1=Not measured	0.21	0.02	98.5	0.00	0.05	1.23 (1.18, 1.29)
EFP: 2="0<=EFP<30"	0.37	0.04	81.1	0.00	0.04	1.45 (1.34, 1.57)
EFP: 3="30<=EFP<45"	0.22	0.03	61.8	0.00	0.04	1.25 (1.18, 1.32)
PCI status: 2=Urgent	0.33	0.02	246.7	0.00	0.09	1.39 (1.33, 1.45)
PCI status: 3=Emergency	0.38	0.04	108.6	0.00	0.07	1.46 (1.36, 1.57)
PCI status: 4=Salvage	0.54	0.20	7.4	0.01	0.01	1.71 (1.16, 2.52)
pRCA/mLAD/pCIRC	0.04	0.02	4.4	0.04	0.01	1.04 (1.00, 1.09)
pLAD	0.12	0.03	21.8	0.00	0.02	1.13 (1.07, 1.19)
Left Main	0.15	0.06	7.2	0.01	0.01	1.16 (1.04, 1.30)
Highest Pre-Procedure TIMI Flow: None	0.08	0.03	5.8	0.02	0.01	1.09 (1.02, 1.16)

* N=128,745 in 766 hospitals; 11.1% readmission rate

3.1.3 Model Validation

We compared the model performance in the development sample with its performance in a similarly derived sample from patients discharged in 2006 who had undergone PCI. There were 117,375 cases discharged from the 618 hospitals in the 2006 validation dataset. This validation sample had a crude readmission rate of 10.7%.

The standardized estimates and standard errors for the 2006 validation dataset are shown in Table 9, and the performance metrics are shown in Table 10. The performance was not substantively different in this validation sample (ROC=0.663), as compared to the development sample (ROC=0.665). As the results in Table 10 show, the 2006 and 2007 models are similarly calibrated.

We also examined the temporal variation of the standardized estimates and frequencies of the variables in the models (Tables 11 and 12). The frequencies and regression coefficients are fairly consistent over the two years of data.

To assess the predictive ability of the model, we grouped patients into deciles of predicted 30-day readmission. We then compared predicted readmission with observed readmission for each decile in the derivation cohort (Figure 7). Overall there was excellent correlation between predicted and observed readmission.

Figure 7 – Observed Readmission by Predicted Readmission per Decile
($R^2=0.999$)

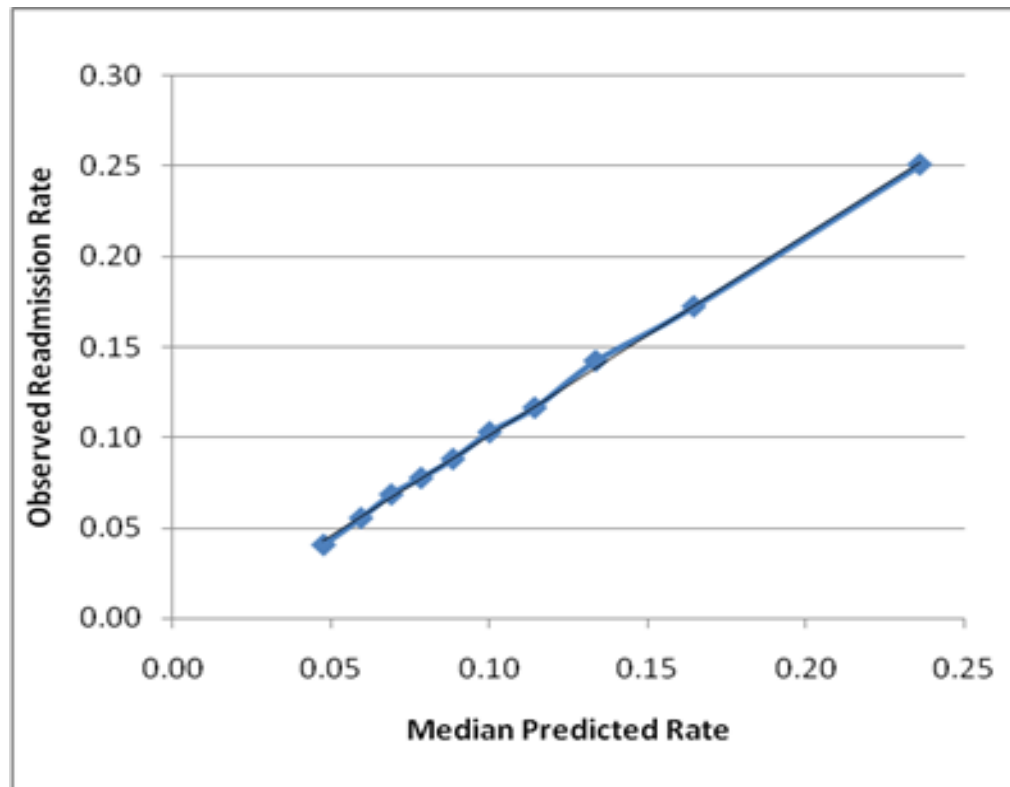


Table 9 – 30-Day Readmission * Model (2006 Validation Sample-GLM Results [ROC:0.663])**

Label	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq	Standardized Estimates	OR (LOR, UOR)
Intercept	-4.25	0.16	730.5	0.00		
Age/10	0.27	0.02	290.2	0.00	0.10	1.31 (1.27, 1.35)
Female	0.24	0.02	135.2	0.00	0.06	1.27 (1.22, 1.32)
BMI/5	-0.11	0.01	57.3	0.00	-0.04	0.89 (0.87, 0.92)
Heart Failure - previous history	0.31	0.03	127.5	0.00	0.06	1.36 (1.29, 1.43)
Previous valvular surgery	0.17	0.07	5.9	0.01	0.01	1.18 (1.03, 1.35)
Cerebrovascular disease	0.13	0.02	28.3	0.00	0.03	1.14 (1.09, 1.20)
Peripheral Vascular Disease	0.26	0.03	105.1	0.00	0.05	1.29 (1.23, 1.36)
Chronic Lung Disease	0.32	0.02	183.4	0.00	0.07	1.38 (1.31, 1.44)
Non-insulin diabetes	0.15	0.02	38.9	0.00	0.03	1.16 (1.11, 1.22)
Insulin diabetes	0.37	0.03	141.0	0.00	0.06	1.45 (1.36, 1.54)
GFR: 0=not measured	0.08	0.05	2.6	0.11	0.01	1.09 (0.98, 1.20)
GFR: 1="0<=GFR<30"	0.57	0.05	143.1	0.00	0.06	1.77 (1.61, 1.94)
GFR: 2="30<=GFR<60"	0.15	0.02	46.0	0.00	0.04	1.16 (1.11, 1.21)
GFR: 4="GFR>=90"	0.11	0.04	7.6	0.01	0.02	1.11 (1.03, 1.20)
Renal failure - dialysis	0.35	0.07	27.2	0.00	0.02	1.42 (1.25, 1.62)
Hypertension	0.02	0.03	0.7	0.39	0.00	1.02 (0.97, 1.08)
History of tobacco use	-0.06	0.02	17.9	0.00	-0.02	0.94 (0.91, 0.97)
Previous PCI	-0.10	0.02	23.4	0.00	-0.03	0.90 (0.87, 0.94)
Heart failure - current status	0.24	0.03	72.8	0.00	0.04	1.27 (1.20, 1.34)
No MI on admission	-0.03	0.03	0.7	0.40	-0.01	0.98 (0.92, 1.03)
MI after 24 hours on admission	0.14	0.04	11.7	0.00	0.02	1.15 (1.06, 1.25)
EFP: 1=not measured	0.16	0.02	48.3	0.00	0.04	1.17 (1.12, 1.22)
EFP: 2="0<=EFP<30"	0.41	0.04	88.4	0.00	0.04	1.51 (1.38, 1.64)
EFP: 3="30<=EFP<45"	0.17	0.03	31.7	0.00	0.03	1.18 (1.12, 1.26)
PCI status: 2=urgent	0.38	0.02	293.9	0.00	0.10	1.46 (1.40, 1.52)
PCI status: 3=emergency	0.46	0.04	135.3	0.00	0.08	1.58 (1.46, 1.71)
PCI status: 4=salvage	0.44	0.25	3.1	0.08	0.01	1.55 (0.95, 2.53)
pRCA/mLAD/pCIRC	0.09	0.02	18.1	0.00	0.02	1.10 (1.05, 1.14)
pLAD	0.11	0.03	15.4	0.00	0.02	1.11 (1.06, 1.18)
Left main	0.07	0.06	1.1	0.28	0.01	1.07 (0.95, 1.20)
Highest pre-procedure TIMI flow: none	0.08	0.04	4.4	0.04	0.01	1.08 (1.01, 1.17)

* Readmissions with revascularization but without myocardial infarction, heart failure, unstable angina, cardiac arrest or arrhythmia are not counted as readmissions

** N=117,375 in 618 hospitals; 10.7% readmission rate

Table 10 – 30-Day Readmission Model Performance: Results Based on the GLM

Indices	Development Sample	Validation Sample
Year	2007	2006
N	128745	117375
RR	11.1%	10.7%
Calibration (γ_0, γ_1) ¹	(0.00, 1.00)	(-0.06, 0.99)
Discrimination- Adjusted R-Square ²	0.07	0.06
Discrimination -Predictive Ability ³ (lowest decile %, highest decile %)	(4.05, 25.08)	(3.80, 23.80)
Discrimination – ROC	0.665	0.663
Residuals Lack of Fit (Pearson Residual Fall %)		
<-2	0.00	0.00
[-2, 0)	88.86	89.33
[0, 2)	2.21	1.85
[2+	8.93	8.82
Model χ^2 [Number of Covariates] ⁴	4448.36 [31]	3812.62 [31]

¹ 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., $\text{Logit}(P(Y=1|Z)) = \gamma_0 + \gamma_1 Z$. Estimated values of γ_0 far from 0 and estimated values of γ_1 far from 1 provide evidence of over-fitting.

² Max-rescaled R-Square

³ Observed Rates

⁴ Wald Chi-Square

Table 11 – 30-Day Readmission Model (GLM) Standardized Estimates by Year of Discharge (2006-2007)

Description	2006 (Validation) (N=117,375 in 618 hospitals; 10.7% RR*)	2007 (Development) (N=128,745 in 766 hospitals; 11.1% RR)
Age/10	0.10	0.08
Female	0.06	0.07
Body Mass Index/5	-0.04	-0.05
Heart Failure - previous history	0.06	0.05
Previous valvular surgery	0.01	0.01
Cerebrovascular Disease	0.03	0.04
Peripheral Vascular Disease	0.05	0.04
Chronic Lung disease	0.07	0.07
Non-insulin diabetes	0.03	0.03
Insulin diabetes	0.06	0.05
Glomerular Filtration Rate (GFR): 0=not measured	0.01	0.00
GFR: 1="0<=GFR<30"	0.06	0.06
GFR: 2="30<=GFR<60"	0.04	0.04
GFR: 4="GFR>=90"	0.02	0.02
Renal failure - dialysis	0.02	0.03
Hypertension	0.00	0.02
History of tobacco use	-0.02	-0.02
Previous PCI	-0.03	-0.02
Heart failure - current status	0.04	0.05
No MI on admission	-0.01	-0.03
MI after 24 hours on admission	0.02	0.01
Ejection Fraction Percentage (EFP): 1=not measured	0.04	0.05
EFP: 2="0<=EFP<30"	0.04	0.04
EFP: 3="30<=EFP<45"	0.03	0.04
PCI status: 2=urgent	0.10	0.09
PCI status: 3=emergency	0.08	0.07
PCI status: 4=salvage	0.01	0.01
pRCA/mLAD/pCIRC	0.02	0.01
pLAD	0.02	0.02
Left main	0.01	0.01
Highest pre-procedure TIMI flow: none	0.01	0.01

* Readmission rate

Table 12 – 30-Day Readmission Model (GLM) Risk Factor Frequency by Year of Discharge (2005-2007)

Description	2006 (Validation) N=117,375 in 618 Hospitals with a 10.7 RR* %	2007 (Development) N=128,745 in 766 Hospitals with a 11.1 RR %
Age/10	74.7 (6.5)	74.7 (6.6)
Female	41.8	41.2
BMI/5		
Unknown	0.1	0.1
Mean (SD)	28.5 (5.7)	28.6 (5.8)
Heart failure - previous history	13.8	13.8
Previous valvular surgery	1.6	1.7
Cerebrovascular Disease	16.0	16.0
Peripheral Vascular Disease	15.6	15.6
Chronic Lung Disease	18.6	18.6
Non-Insulin diabetes	22.4	22.6
Insulin diabetes	9.8	10.1
GFR: 0=Not measured	4.0	3.7
GFR: 1="0<=GFR<30"	4.0	4.3
GFR: 2="30<=GFR<60"	36.6	37.2
GFR: 4="GFR>=90"	8.3	8.3
Renal Failure - Dialysis	1.6	1.9
Hypertension	81.8	82.9
History of Tobacco Use	11.8	11.9
Previous PCI	35.9	37.2
Heart failure - current status	12.0	11.9
No MI on admission	75.4	73.5
MI after 24 hours on admission	5.7	6.0
EFP: 1=Not measured	28.3	28.5
EFP: 2="0<=EFP<30"	3.9	3.9
EFP: 3="30<=EFP<45"	11.9	11.9
PCI status: 2=Urgent	36.0	36.4
PCI status: 3=Emergency	11.1	12.2
PCI status: 4=Salvage	0.1	0.1
pRCA/mLAD/pCIRC	38.2	37.9
pLAD	17.6	17.3
Left main	2.4	2.4
Highest Pre-Procedure TIMI Flow: None	7.8	8.7

* Readmission rate

Table 13 – 30-Day Readmission* (2007 Development Sample – HGLM Results [ROC=0.677])^{# +}

Description	Estimate	Standard Error	T-Value	Pr > T-Value	Odds Ratio (95% CI)
Intercept	-3.84	0.15	-26.38	0.00	
Age/10	0.23	0.01	15.67	0.00	1.26 (1.22, 1.29)
Female	0.25	0.02	13.42	0.00	1.29 (1.24, 1.33)
BMI/5	-0.13	0.01	-9.27	0.00	0.88 (0.86, 0.90)
Heart failure - previous history	0.27	0.03	10.68	0.00	1.32 (1.25, 1.38)
Previous valvular surgery	0.20	0.06	3.28	0.00	1.23 (1.09, 1.38)
Cerebrovascular Disease	0.19	0.02	8.37	0.00	1.21 (1.16, 1.27)
Peripheral Vascular Disease	0.20	0.02	8.38	0.00	1.22 (1.16, 1.28)
Chronic Lung Disease	0.33	0.02	15.11	0.00	1.40 (1.34, 1.46)
Non-Insulin diabetes	0.11	0.02	5.11	0.00	1.12 (1.07, 1.17)
Insulin diabetes	0.32	0.03	11.18	0.00	1.38 (1.30, 1.46)
GFR: 0=Not measured	0.03	0.05	0.58	0.56	1.03 (0.93, 1.14)
GFR: 1="0<=GFR<30"	0.57	0.04	12.72	0.00	1.76 (1.62, 1.92)
GFR: 2="30<=GFR<60"	0.16	0.02	7.75	0.00	1.17 (1.13, 1.22)
GFR: 4="GFR>=90"	0.15	0.04	4.20	0.00	1.16 (1.08, 1.24)
Renal failure - dialysis	0.38	0.06	6.29	0.00	1.46 (1.40, 1.65)
Hypertension	0.08	0.03	3.08	0.00	1.08 (1.03, 1.14)
History of tobacco use	-0.05	0.01	-3.38	0.00	0.95 (0.93, 0.98)
Previous PCI	-0.08	0.02	-4.26	0.00	0.92 (0.89, 0.96)
Heart failure - current status	0.30	0.03	11.27	0.00	1.35 (1.28, 1.42)
No MI on admission	-0.13	0.03	-4.70	0.00	0.88 (0.83, 0.93)
MI after 24 hours on admission	0.10	0.04	2.73	0.01	1.11 (1.03, 1.19)
EFP: 1=Not measured	0.19	0.02	8.76	0.00	1.21 (1.16, 1.26)
EFP: 2="0<=EFP<30"	0.36	0.04	8.74	0.00	1.43 (1.32, 1.55)
EFP: 3="30<=EFP<45"	0.21	0.03	7.66	0.00	1.24 (1.17, 1.31)
PCI status: 2=Urgent	0.36	0.02	16.40	0.00	1.43 (1.37, 1.50)
PCI status: 3=Emergency	0.40	0.04	11.00	0.00	1.49 (1.39, 1.60)
PCI status: 4=Salvage	0.59	0.20	3.01	0.00	1.81 (1.23, 2.65)
pRCA/mLAD/pCIRC	0.04	0.02	2.12	0.03	1.04 (1.00, 1.09)
pLAD	0.12	0.03	4.72	0.00	1.13 (1.07, 1.19)
Left main	0.15	0.06	2.77	0.01	1.17 (1.05, 1.30)
Highest pre-procedure TIMI flow: none	0.09	0.03	2.64	0.01	1.09 (1.02, 1.17)

* Between hospital variance=0.03813. Standard error=0.005500.

[#] Readmissions with revascularization but without myocardial infarction, heart failure, unstable angina, cardiac arrest or arrhythmia are not counted as readmissions

⁺ N=128,745 in 766 hospitals; 11.1% readmission rate

3.1.4 30-Day Readmission Rate Distribution - With and Without Risk-Adjustment

Figure 8 and Figure 9 display the frequency distributions of the hospital-specific 30-day readmission rates, with and without risk-adjustment in the 2007 cohort. Figure 10 and Figure 11 display these results by hospital volume quartiles for the unadjusted and adjusted rates, respectively.

The observed readmission rate ranged from 0% to 100% across the 766 hospitals with a median (quartile range) of 10.8% (8.6%, 13.4%) (Figure 8), with low-volume hospitals demonstrating the greatest variation in crude rates (Figure 10). After adjusting for patient and clinical characteristics, the risk-standardized rates were found to be more normally distributed, both overall (Figure 9) and by hospital volume (Figure 11).

Figure 8 – Distribution of Unadjusted Hospital-level 30-Day Readmission Rates (2007 Development Sample; N=766 Hospitals)

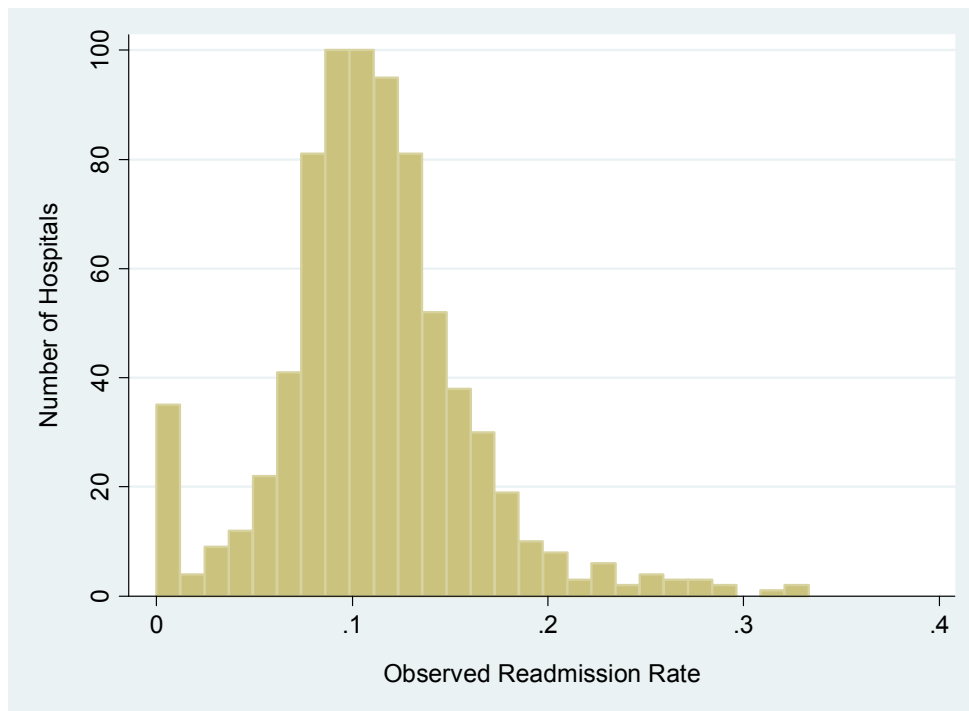


Figure 9 – Distribution of Risk-Standardized Hospital-level 30-Day Readmission Rates (2007 Development Sample; N=766 Hospitals) – HGLM

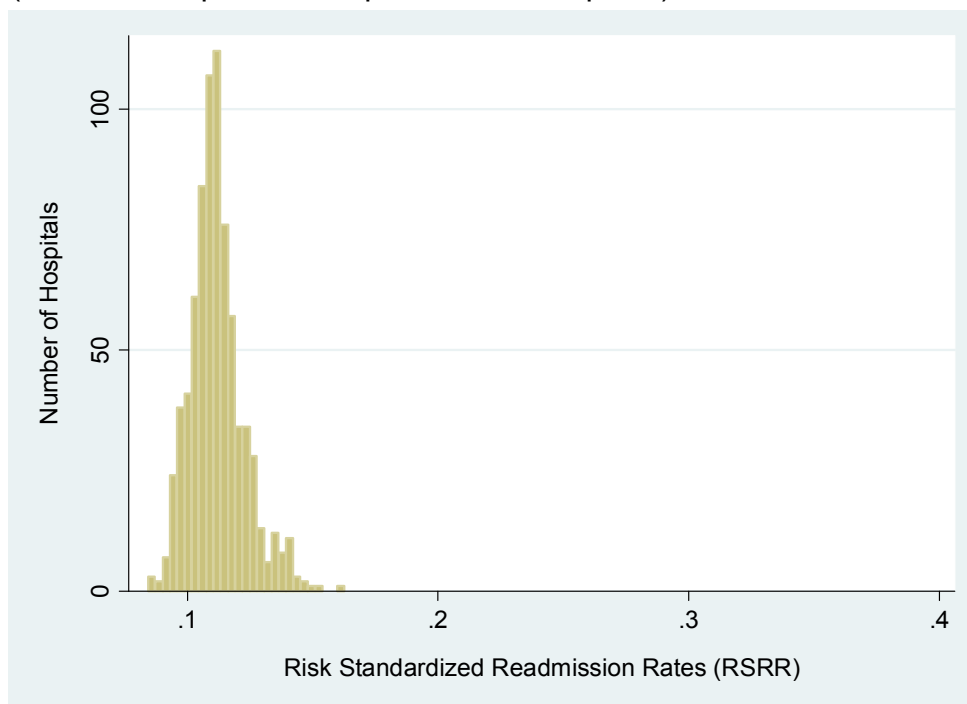


Figure 10 – Distribution of Unadjusted Hospital-level 30-Day Readmission Rates by Hospital Volume (2007 Development Sample; N=766 Hospitals)

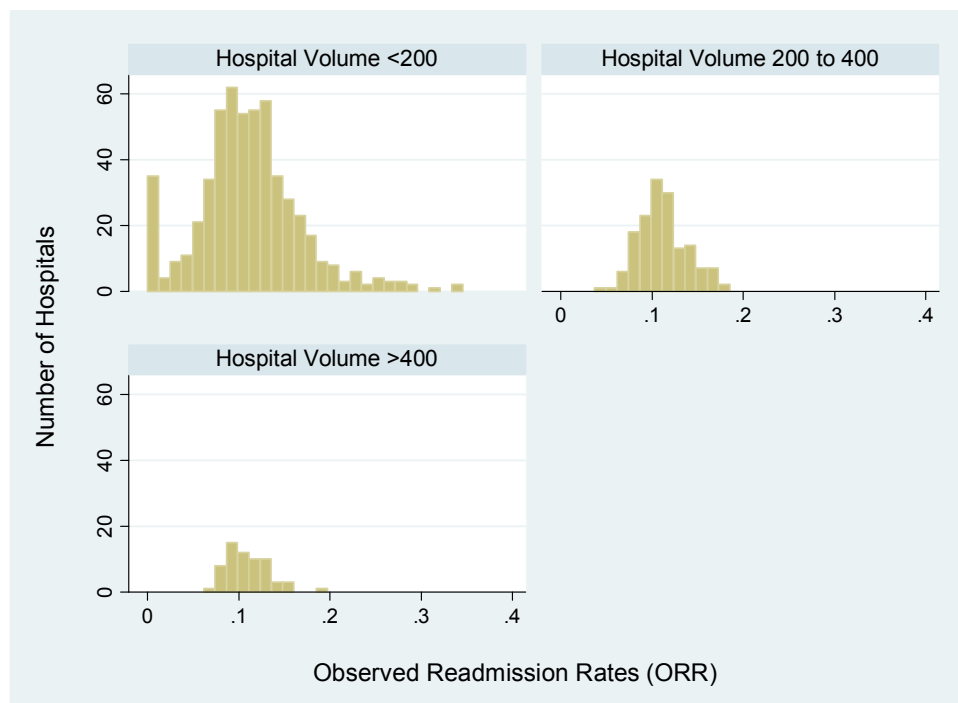
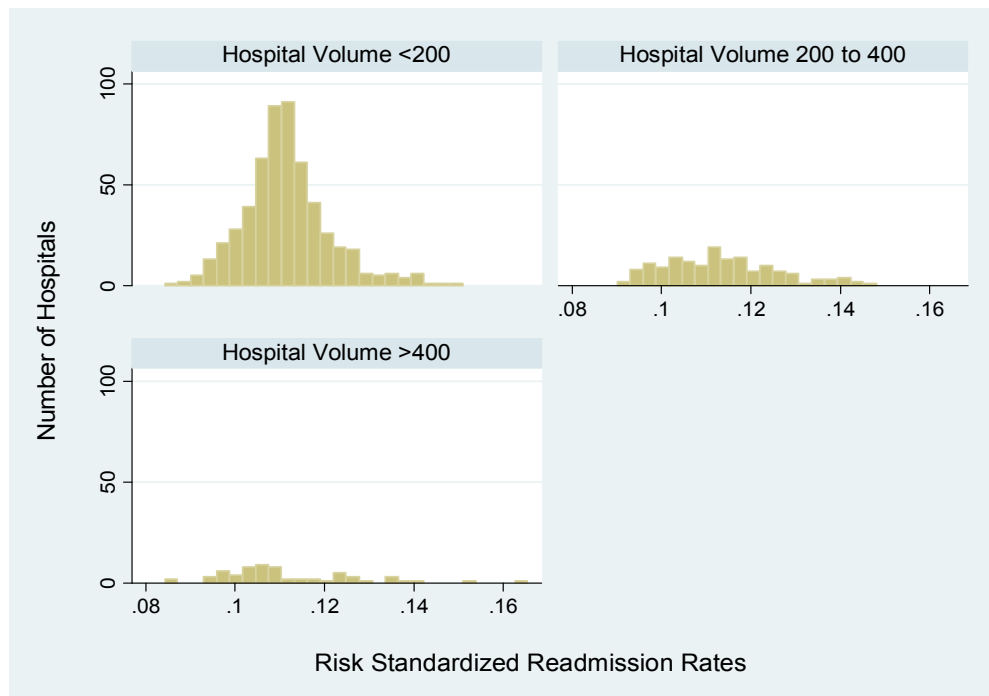


Figure 11 – Distribution of Risk-Standardized Hospital-level 30-Day Readmission Rates by Hospital Volume (2007 Development Sample; N=766)



4. POTENTIAL APPROACHES TO IMPLEMENTATION

While the model we developed has attributes that make it suitable for public reporting, additional steps will be necessary prior to implementation. We developed the model from a dataset that merged CathPCI Registry data with administrative claims data using a probabilistic match. The resulting dataset was adequate for developing a model of 30-day PCI readmission. However, implementing the measure will ideally require linking the NCDR data with administrative data sources based on a unique patient identifier common to both the NCDR and administrative data sets. This unique identifier is not yet in place for all patients undergoing PCI. However, processes necessary to routinely collect patient identifiers will have to be implemented prior to efforts to publicly report these measures. Additionally, although more than half of hospitals that perform PCI in the United States currently participate in the CathPCI Registry; public reporting will require collecting and merging data from all hospitals through CathPCI and/or other mechanisms prior to implementation.

As discussed, publicly reporting hospital risk standardized 30-day readmission rates requires that the data submitted by hospitals be complete, consistent, and accurate. Steps to ensure data quality could include monitoring data for variances in case mix (e.g., unexpectedly high proportion of salvage PCI or cardiogenic shock), chart audits, and possibly adjudicating cases that are vulnerable to systematic misclassification. This approach has been successfully implemented in the Massachusetts program for public reporting of PCI mortality, with significant rates of reclassification of cases initially classified as cardiogenic shock or salvage PCI, and elimination of some variables with poor reliability (Normand 2008).

5. MAIN FINDINGS / SUMMARY

We present a hierarchical logistic regression model for 30-day PCI readmission that is based on data from the NCDR CathPCI Registry and is suitable for public reporting. Our approach to risk adjustment is tailored to and appropriate for a publicly reported outcome measure. The study sample is appropriately defined, consisting of a PCI population that has distinct outcomes that will allow for valid comparisons of hospital outcomes. The 30-day outcome provides a standardized period of follow-up. The statistical approach takes into account the clustering of patients within hospitals and differences in sample size across hospitals. The models have good patient-level discrimination and explained variation. Finally, the overall approach is consistent with previously developed 30-day PCI mortality measures (Yale-CORE 2008).

In summary, we present a registry-based model of 30-day PCI readmission that is suitable for public reporting.

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7. APPENDIX

7.1 Appendix A- Top 50 ICD-9 Diagnosis Codes Associated with PCI Readmissions

Diagnosis Code	Count	Percent	Description
428	5791	12.10	Heart failure
414	4411	9.22	Other forms of chronic ischemic heart disease
786	4379	9.15	Symptoms involving respiratory system and other chest symptoms
410	3080	6.44	Acute myocardial infarction
427	2578	5.39	Cardiac dysrhythmias
486	1037	2.17	Pneumonia
584	986	2.06	Acute renal failure
440	952	1.99	Atherosclerosis
038	926	1.94	Septicemia
780	922	1.93	General Symptoms
578	894	1.87	Gastrointestinal hemorrhage
996	861	1.80	Complications peculiar to certain specified procedures
518	824	1.72	Other diseases of lung
998	805	1.68	Other complications of procedures not elsewhere classified
491	799	1.67	Chronic bronchitis
276	756	1.58	Disorders of fluid electrolyte and acid-base balance
997	692	1.45	Complications affecting specified body system not elsewhere classified
250	646	1.35	Diabetes mellitus
599	613	1.28	Other disorders of urethra and urinary tract
433	582	1.22	Occlusion and stenosis of precerebral arteries
458	577	1.21	Hypotension
434	529	1.11	Occlusion of cerebral arteries
530	475	0.99	Diseases of esophagus
562	419	0.88	Diverticula of intestine
535	405	0.85	Gastritis and duodenitis
008	366	0.76	Intestinal infections due to other organisms
415	357	0.75	Acute pulmonary heart disease
411	336	0.70	Other acute and subacute forms of ischemic heart disease
569	307	0.64	Other disorders of intestine
574	286	0.60	Cholelithiasis
285	281	0.59	Other and unspecified anemias
560	261	0.55	Intestinal obstruction without mention of hernia
531	260	0.54	Gastric ulcer
435	250	0.52	Transient cerebral ischemia
453	244	0.51	Other venous embolism and thrombosis
789	244	0.51	Other symptoms involving abdomen and pelvis
682	208	0.43	Other cellulitis and abscess
404	205	0.43	Hypertensive heart and kidney disease
403	194	0.41	Hypertensive kidney disease
537	184	0.38	Other disorders of stomach and duodenum
441	181	0.38	Aortic aneurysm and dissection

7.1 Appendix A- Top 50 ICD-9 Diagnosis Codes Associated with PCI Readmissions (*cont.*)

Diagnosis Code	Count	Percent	Description
507	180	0.38	Pneumonitis due to solids and liquids
577	176	0.37	Diseases of pancreas
558	173	0.36	Other and unspecified noninfectious gastroenteritis and colitis
532	168	0.35	Duodenal ulcer
820	167	0.35	Fracture of neck of femur
402	162	0.34	Hypertensive heart disease
401	160	0.33	Essential hypertension
162	159	0.33	Malignant neoplasm of trachea bronchus and lung
787	155	0.32	Symptoms involving digestive system

7.2 Appendix B- Top 50 ICD-9 Procedure Codes Associated with PCI Readmissions

Procedure Code	Count	Percent	Description
3722	3578	13.04	Left heart cardiac catheterization
9904	1714	6.25	Transfusion of packed cells
3995	1705	6.21	Hemodialysis
0066	1336	4.87	Percutaneous transluminal coronary angioplasty [ptca] or coronary atherectomy
4516	1049	3.82	Esophagogastroduodenoscopy [egd] with closed biopsy
3950	1031	3.76	Angioplasty or atherectomy of non-coronary vessel
4513	983	3.58	Other endoscopy of small intestine
3893	904	3.29	Venous catheterization, not elsewhere classified
8872	625	2.28	Diagnostic ultrasound of heart
9671	507	1.85	Continuous mechanical ventilation for less than 96 consecutive hours
3794	505	1.84	Implantation or replacement of automatic cardioverter/defibrillator, total system [aicd]
8856	483	1.76	Coronary arteriography using two catheters
3772	419	1.53	Initial insertion of transvenous leads [electrodes] into atrium and ventricle
3491	359	1.31	Thoracentesis
3812	341	1.24	Endarterectomy, other vessels of head and neck
4523	287	1.05	Colonoscopy
4443	274	1.00	Endoscopic control of gastric or duodenal bleeding
9390	268	0.98	Continuous positive airway pressure [cpap]
9929	268	0.98	Injection or infusion of other therapeutic or prophylactic substance
0051	263	0.96	Implantation of cardiac resynchronization defibrillator, total system [crt-d]
3952	204	0.74	Other repair of aneurysm
387	198	0.72	Interruption of vena cava
4525	188	0.69	Closed [endoscopic] biopsy of large intestine
9672	186	0.68	Continuous mechanical ventilation for 96 consecutive hours or more
8622	185	0.67	Excisional debridement of wound, infection, or burn
9604	180	0.66	Insertion of endotracheal tube
3783	176	0.64	Initial insertion of dual-chamber device
3723	174	0.63	Combined right and left heart cardiac catheterization
3761	170	0.62	Implant of pulsation balloon
3895	165	0.60	Venous catheterization for renal dialysis
5794	164	0.60	Insertion of indwelling urinary catheter
0061	161	0.59	Percutaneous angioplasty or atherectomy of precerebral (extracranial) vessel(s)
5123	158	0.58	Laparoscopic cholecystectomy
8944	157	0.57	Other cardiovascular stress test

7.2 Appendix B- Top 50 ICD-9 Procedure Codes Associated with PCI Readmissions (*cont.*)

Procedure Code	Count	Percent	Description
3734	137	0.50	Excision or destruction of other lesion or tissue of heart, other approach
8703	126	0.46	Computerized axial tomography of head
8604	117	0.43	Other incision with drainage of skin and subcutaneous tissue
3971	111	0.40	Endovascular implantation of graft in abdominal aorta
3324	108	0.39	Closed [endoscopic] biopsy of bronchus
4542	103	0.38	Endoscopic polypectomy of large intestine
8741	103	0.38	Computerized axial tomography of thorax
8954	102	0.37	Electrographic monitoring
9962	99	0.36	Other electric countershock of heart
9919	94	0.34	Injection of anticoagulant
9907	87	0.32	Transfusion of other serum
4573	83	0.30	Right hemicolectomy
3726	82	0.30	Cardiac electrophysiologic stimulation and recording studies
9921	82	0.30	Injection of antibiotic
8949	80	0.29	Automatic implantable cardioverter/defibrillator (aicd) check