Hospital-level 30-Day All-Cause Risk-Standardized Readmission Rate Following Elective Primary Total Hip Arthroplasty (THA) And/Or Total Knee Arthroplasty (TKA)

Measure Methodology Report

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

Laura M. Grosso, PhD, MPH
Jeptha P. Curtis, MD
Zhenqiu Lin, PhD
Lori L. Geary, MPH
Smitha Vellanky, MSc
Carol Oladele, PhD
Lesli S. Ott, MA, MA
Craig Parzynski, MS
Susannah Bernheim, MD, MHS
Lisa G. Suter, MD
Elizabeth E. Drye, MD, SM
Harlan M. Krumholz, MD, SM

Contract # HHSM-500-2008-0025I/HHSM-500-T0001,
Modification No. 000007, Option Year 2

Prepared For:

Centers for Medicare & Medicaid Services (CMS)

Submitted June 25, 2012

ACKNOWLEDGEMENTS

We would like to acknowledge the ongoing support from our working group. These individuals gave generously of their time, providing guidance on key clinical and methodological decisions. Without their expertise, this project would not have been possible. Working group members include:

Daniel J. Berry, MD
Professor of Orthopedics, Mayo Clinic College of Medicine
Chair, Department of Orthopædic Surgery, Mayo Clinic

Kevin J. Bozic, MD, MBA
Associate Professor and Vice Chair, Department of Orthopaedic Surgery at the University of California, San Francisco
Chair, Health Systems Committee, AAOS

Robert Bucholz, MD
Professor, Orthopædic Surgery, University of Texas Southwestern Medical Center
Past President, American Academy of Orthopædic Surgeons (AAOS)

Lisa Gale Suter, MD
Assistant Professor, Yale University School of Medicine, Section of Rheumatology

Charles M. Turkelson, PhD
Director of Research and Scientific Affairs, AAOS

Lawrence Weis, MD
Assistant Professor, Yale Orthopædics and Rehabilitation, Yale University School of Medicine, Orthopædics (West Haven Veterans Association Hospital)

We would also like to thank the Technical Expert Panel members, who provided great support and insight on key measure decisions. These members include:

Mark L. Francis, MD
Professor of Medicine and Biomedical Sciences, Chief, Division of Rheumatology, Department of Internal Medicine, Texas Tech University Health Sciences CenterTexas Tech University, Health Sciences Center

Cynthia Jacelon, PhD, RN, CRRN
Associate Professor, School of Nursing, University of Massachusetts
Association of Rehabilitation Nurses

Norman Johanson, MD
Chairman, Orthopedic Surgery, Drexel University College of Medicine

C. Kent Kwoh, MD
Professor of Medicine, Associate Chief and Director of Clinical Research, Division of Rheumatology and Clinical Immunology University of Pittsburgh

Courtland G. Lewis, MD
American Association of Orthopaedic Surgeons

Jay Lieberman, MD
Professor and Chairman, Department of Orthopedic Surgery, University of Connecticut Health Center; Director, New England Musculoskeletal Institute

Peter Lindenauer, MD, MSc
Hospitalist and Health Services Researcher, Baystate Medical Center; Professor of Medicine, Tufts University

Russell Robbins, MD, MBA
Principal, Mercer's Total Health Management

Barbara Schaffer
THA Patient

Nelson SooHoo, MD, MPH
Professor, University of California at Los Angeles

Steven H. Stern, MD
Vice President, Cardiology & Orthopedics/ Neuroscience, United Healthcare

Richard E. White, Jr., MD
American Association of Hip and Knee Surgeons

In addition, we would like to acknowledge and thank Kanchana Bhat from YNHHSC/CORE, Angela Merrill, Sandi Nelson, Marian Wrobel, and Eric Schone from Mathematica Policy Research, Inc., Sharon-Lise Normand from Harvard Medical School, and Lein Han and Michael Rapp at the Centers for Medicare & Medicaid Services for their contributions to this work.

We would also like to acknowledge the very thoughtful and instructive feedback on the measure during the public comment period.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

1.1 Purpose and Organization of This Report

This report describes the hospital-level risk-standardized elective primary total hip arthroplasty and/or total knee arthroplasty (THA/TKA) readmission measure as it is currently specified for the Center for Medicare & Medicaid Services' (CMS) dry-run period in 2012. The body of the report presents the measure specifications, measure methodology and results. Appendix A details the initial measure development and validation process.

1.2 Background

In 2009 the CMS contracted with Yale New Haven Health Services Corporation/Center for Outcomes Research and Evaluation (YNHHSC/CORE) to develop hospital outcomes measures that reflect the quality of care for patients undergoing elective primary total hip and/or total knee arthroplasty procedures (THA and TKA respectively). YNHHSC/CORE developed two measures: (1) a hospital-level, risk-standardized complication rate (RSCR) following elective primary THA and/or TKA procedures (presented in a separate technical report entitled Hospital-Level Risk-Standardized Complication Rate Following Elective Primary Total Hip Arthroplasty and/or Total Knee Arthroplasty located at http://www.qualitynet.org > Hospitals-Inpatient > Claims-Based Measures > New Hospital Wide and Hip/Knee Measures In Testing) and (2) a hospital-level 30-day all-cause risk-standardized readmission rate (RSRR) following elective primary THA and/or TKA procedures (presented in this report).

The goal of the measures is to improve the quality of care delivered to patients undergoing elective primary THA and/or TKA procedures. They are complementary measures that assess different domains of quality. The complications measure will inform quality improvement efforts targeted toward minimizing medical and surgical complications during surgery and the postoperative period. The readmission measure captures an additional domain of care provided in the transition to outpatient settings. The premise is that improved quality of care, including coordination and communication among providers and with patients and their caregivers, can favorably influence performance on these measures. Both measures were endorsed by the NQF in 2012.

After YNHHSC/CORE developed both measures, a medical-record validation of the complications in the risk-standardized complications measure was conducted because administrative databases may be subject to coding errors and variation in coding practices within and across care settings. Based on findings from the validation study and NQF review, YNHHSC/CORE made minor modifications to the cohort exclusions for both measures. The changes pertaining to this measure are detailed in Appendix A, Section II. b. iii.

1.3 Importance of a Readmission Measure for Elective Primary THA/TKA

THA and TKA are commonly performed procedures that improve quality of life. In 2003 there were 202,500 THAs and 402,100 TKAs performed[1] and the number of procedures performed has increased steadily over the past decade.[2,3] Although these procedures dramatically improve quality of life, they are costly. In 2005 annual hospital charges totaled $3.95 billion and $7.42 billion for primary THA and TKA, respectively.[2] These costs are projected to increase by 340% to $17.4 billion for THA and by 450% to $40.8 billion for TKA by 2015.[2] Medicare is the single largest payer for these procedures, covering approximately two-thirds of all THAs and TKAs performed in the US.[3] Combined, THA and TKA procedures account for the largest procedural cost in the Medicare budget.[4]

Hospital readmission is an outcome that is influenced by quality of care and is an important outcome for patients. Hospital processes that reflect the quality of inpatient and outpatient care such as discharge planning, medication reconciliation, and coordination of outpatient care have been shown to reduce readmission rates.[5] Although readmission rates are also influenced by hospital system characteristics, such as the bed capacity of the local health care system,[6] these hospital characteristics should not influence quality of care. Therefore, this measure does not risk adjust for such hospital characteristics.

Measuring and reporting elective primary THA/TKA readmission rates will inform health care providers about opportunities to improve care, strengthen incentives for quality improvement, and promote improvements in the quality of care received by Medicare patients and the outcomes they experience. The measure will also provide patients with information that could guide their choices regarding where they seek care for these elective procedures. Furthermore, the measure will increase transparency for consumers and has the potential to lower health care costs by reducing the risk of readmissions.

Analyses using 2008-2010 Medicare Part A inpatient claims indicate that the median THA/TKA 30-day RSRR was 5.7%, and the results demonstrated that the rates varied across hospitals (5^{th} percentile, 4.6%; 95^{th} percentile, 7.0%), indicating there is room for quality improvement.

2. CURRENT MEASURE SPECIFICATIONS

2.1 Overview

This hospital-level risk-standardized readmission measure for patients undergoing elective primary THA and/or TKA identifies "index" admissions for inclusion in the measure using Medicare Part A inpatient claims for fee-for-service (FFS) Medicare beneficiaries hospitalized in calendar years 2008-2010. An "index" admission is any eligible admission to an acute care hospital for an elective primary THA and/or TKA included in the measure. The date of discharge of the index hospitalization is the starting point for all follow-up, and the hospital that ultimately discharges the patient to a non-acute care setting is the one held accountable for the readmission.

The measure calculates readmission rates using a hierarchical logistic regression model to account for the clustering of patients within hospitals while risk-adjusting for differences in patient case-mix. The measure calculates the hospital RSRR by producing a ratio of the number of "predicted" to the number of "expected" readmissions for each hospital and then multiplying the ratio by the national unadjusted readmission rate.

YNHHSC/CORE developed this measure in accordance with national guidelines for publicly reported outcomes measures including the NQF[7], CMS' Measure Management System, and guidance articulated in the American Heart Association scientific statement, "Standards for Statistical Models Used for Public Reporting of Health Outcomes".[8] Expert and stakeholder input on the measure were obtained through three mechanisms: first, through regular discussions with a working group of clinical and methodological experts; second, through a series of three conference calls with a national Technical Expert Panel (TEP); and third, through a public comment period.

Early in the development phase, YNHHSC/CORE assembled an advisory working group comprised of orthopedic surgeons and experts in orthopedic quality measurement. Regular conference calls were held throughout the development process and YNHHSC/CORE solicited detailed feedback and guidance on key clinical and methodological decisions pertaining to measure development. The working group provided a forum for focused expert review and discussion of technical issues during measure development prior to consideration by the broader TEP.

In alignment with CMS' Measure Management System, YNHHSC/CORE also released a public call for nominations and convened a national TEP. Potential members were also solicited via e-mail in consultation with the working group and CMS. The role of the TEP was to provide feedback on key methodological decisions made in consultation with the working group. The TEP was comprised of individuals with diverse perspectives and backgrounds and included clinicians,

consumers, hospitals, purchasers, and experts in quality improvement. Finally, YNHHSC/CORE solicited public comment on the proposed measure through CMS' Measure Management System Public Comment website (https://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/MMS/CallforPublicComment.html). Public comments were summarized and publicly posted for 30 days after the close of the public comment period. The resulting content was taken into consideration during the final stages of measure development.

A detailed description of the development of the original measure specifications, including the rationales for the cohort identification, selection of the variables for risk-adjustment, and statistical modeling is provided in Appendix A.

2.2 Data Sources

The measure uses 2008-2010 claims data from the Medicare inpatient, outpatient, and carrier (physician) Standard Analytic Files for the results presented in this report. (This is the same data that is included in the dry run.) The measure identifies index hospitalizations and readmissions in Part A inpatient data and identifies comorbidities for risk adjustment in Part A inpatient and outpatient and Part B claims data in the 12 months prior to admission. The measure uses the Medicare Enrollment Database to determine FFS enrollment and post-discharge mortality status, and medical record data was used to validate the complications identified in administrative claims data for the complementary complications measure.

Part A inpatient data - contains final action claims data submitted by inpatient hospital providers for Medicare FFS beneficiaries for reimbursement of facility costs. Information in this file includes ICD-9 diagnosis codes, ICD-9 procedure codes, dates of service, hospital provider ID, and beneficiary demographic information.

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

Part B data - contains final action claims data for the physician services (regardless of setting) and other outpatient care, services, and supplies for Medicare FFS beneficiaries. For purposes of this project, Part B services included only face-to-face encounters between a care provider and patient. Therefore, the measure does not include information for services such as laboratory tests, medical supplies, or other ambulatory services.

Medicare Enrollment Database - contains Medicare beneficiary demographic, benefit/coverage, and vital status information.

2.3 Cohort Definition

The measure combines patients undergoing elective primary THA and/or TKA procedures because: both procedures are performed in clinically similar patient cohorts and for similar indications (osteoarthritis); hospitals typically develop protocols for lower extremity total joint arthroplasty, rather than for THA or TKA individually; the same surgeons frequently perform both procedures; and outcomes are similar. During measure development YNHHSC/CORE conducted analyses that indicated the types of complications, rates for complications and readmission, and length of stay were similar in both patient cohorts (analyses are in Table A.1, Appendix A, Section II. b.). Furthermore, combining procedures provides greater power to detect hospital-level variation in readmission rates.

In 2010-2011, YNHHSC/CORE conducted a medical record validation study of the ICD-9 codes used to identify the complications (except death) in the complementary risk-standardized complications measure. We used a sample of administrative claims for elective primary THA and/or TKA procedures both with and without indicated complications. The primary goal of the validation study was to determine the overall agreement between patients identified as having a complication (or no complication) in the claims-based measure and those who had a complication (or no complication) also documented in the medical record. After a detailed review of all disagreements, we made minor modifications to the codes defining the measure cohorts for both measures (complications and readmission). The current readmission measure cohort exclusions take these findings into consideration, as well as feedback on both measures from public comment during the NQF endorsement process. Details regarding the changes made to the original cohort are provided in Appendix E of the complementary THA/TKA complications measure technical report located at http://www.qualitynet.org > Hospitals-Inpatient > Claims-Based Measures > New Hospital Wide and Hip/Knee Measures In Testing.

.

2.3.1 Inclusion Criteria

Patients eligible for inclusion in the measure are those aged 65 years and older electively admitted to non-federal acute care hospitals, as indicated by an ICD-9-CM procedure code for primary THA and/or TKA.

Eligible index admissions are identified using the following ICD-9 procedure codes in Medicare Part A inpatient claims data:

- 81.51 Total Hip Arthroplasty
- 81.54 Total Knee Arthroplasty

2.3.2 Exclusion Criteria

To identify a homogeneous cohort of patients undergoing elective primary THA and/or TKA procedures, the measure excludes patients who had a principal discharge diagnosis on the index admission indicative of a non-elective arthroplasty (e.g., hip fracture, mechanical complication). The measure also excludes patients who had a procedure code for an arthroplasty procedure that is not an elective primary arthroplasty (e.g., partial hip arthroplasty, revision procedures) or represents a different procedure (e.g., hip resurfacing, removal of implanted device).

In order to identify a cohort of elective THA and/or TKA procedures, the measure excludes admissions for patients:

1. With a femur, hip or pelvic fracture coded in the principal discharge diagnosis field for the index admission
   Rationale: THA procedures are not elective in these patients, and these patients represent a higher risk category for mortality, complication, and readmission.

2. Undergoing partial hip arthroplasty (PHA) procedures (with a concurrent THA/TKA)
   Rationale: Partial arthroplasties are primarily done for hip fractures, and are typically performed on patients who are older, frailer, and have more comorbid conditions.

3. Undergoing revision procedures (with a concurrent THA/TKA)
   Rationale: Revision procedures may be performed at a disproportionately small number of hospitals and represent a higher risk category for mortality, complication, and readmission.

4. Undergoing resurfacing procedures (with a concurrent THA/TKA)
   Rationale: Resurfacing procedures are a different type of procedure involving only the joint's articular surface. Resurfacing procedures are typically performed on younger, healthier patients.

5. With a mechanical complication coded in the principal discharge diagnosis field for the index admission
   Rationale: A complication coded as the principal discharge diagnosis suggests the procedure was more likely the result of a previous procedure and indicates the complication was present on admission. These patients may require more technically complex arthroplasty procedures and may be at increased risk for complications, particularly mechanical complications.

6. With a malignant neoplasm of the pelvis, sacrum, coccyx, lower limbs, or bone/bone marrow or a disseminated malignant neoplasm coded in the principal discharge diagnosis field for the index admission
   Rationale: Patients with these malignant neoplasms are at increased risk for readmission, and the procedure may not be elective.

7. With a procedure code for removal of implanted devices / prostheses
   Rationale: Elective procedures performed in these patients may be more complicated.

After excluding the above admissions to select elective primary THA/TKA procedures, the measure also excludes admissions for patients:

8. Without at least 12 months pre-index admission enrollment in Medicare FFS
   Rationale: Appropriate risk adjustment requires uniform data availability of pre-operative comorbidity.

9. Without at least 30 days post-discharge enrollment in Medicare FFS
   Rationale: The 30-day readmission outcome cannot be assessed for the standardized time period.

10. Who were transferred in to the index hospital
    Rationale: If the patient is transferred from another acute care facility to the hospital where the index procedure occurs, it is likely that the procedure is not elective or that the admission is associated with an acute condition.

11. Who were admitted for the index procedure and subsequently transferred to another acute care facility
    Rationale: Attribution of readmission to the index hospital would not be possible in these cases, since the index hospital performed the procedure but another hospital discharged the patient to the non-acute care setting.

12. Who leave the hospital against medical advice (AMA)
    Rationale: Hospitals and physicians do not have the opportunity to provide the highest quality care for these patients.

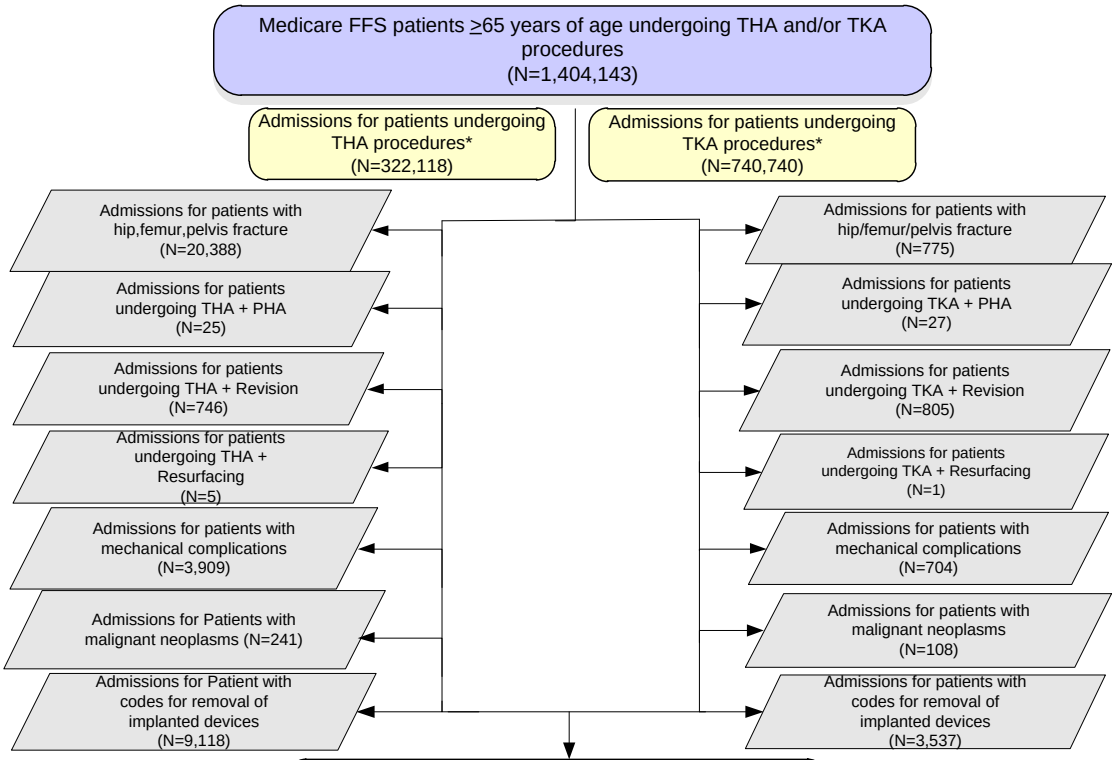
13. With more than two THA/TKA procedures codes during the index hospitalization
    Rationale: Although clinically possible, it is highly unlikely that patients would receive more than two elective THA/TKA procedures in one hospitalization, and this may reflect a coding error.

14. Who die during the index admission

Rationale: Patients who die during the initial hospitalization are not eligible for readmission.

The flowchart depicting cohort selection is presented in Figure 1. Appendix C lists the ICD-9 codes for the following exclusion categories: femur, hip and pelvic fractures, revision procedures, partial hip arthroplasty procedures, resurfacing procedures, mechanical complications, removal of implanted device/prosthesis, and malignant neoplasms.

Figure 1. Measure Cohort (2008-2010 Medicare FFS Patients)



Final Measure Cohort (N=897,321)	
Procedure	N (%)
1 THA procedure	254,366 (28.4)
1 TKA Procedure	616,217 (68.7)
THA + THA	821 (0.1)
TKA + TKA	25,799 (2.9)
THA + TKA	118 (0.0)

*THA and TKA are presented separately for illustrative purposes and are not mutually exclusive

2.4 Outcome Definition

The outcome for this measure is readmission within 30 days. The measure defines a readmission as a subsequent acute care hospital inpatient admission within 30 days of the discharge date of index admission. The intent is to include all unplanned readmissions. An index admission is any eligible hospitalization to an acute care hospital assessed in the measure for the readmission outcome.

As this is a dichotomous (yes/no) readmission outcome, each index admission is either coded as having a readmission within 30 days or not, and therefore any index admission with multiple readmissions within 30 days of discharge will only contribute one outcome event (i.e., yes, readmission occurred) to the model. Additional otherwise qualifying THA and/or TKA admissions that occurred within 30 days of discharge date of an earlier index admission are not considered potential index admissions. Any THA and/or TKA admission is either an index admission or a potential readmission, but not both.

2.4.1 Planned Readmissions

Some patients are admitted within 30 days of the index hospitalization to undergo another elective primary THA/TKA procedure (criteria for identifying elective primary procedures for inclusion in the measure cohort are detailed in Section 2.3). If a patient undergoes a second elective primary THA/TKA within 30 days of the discharge date for the index admission, and the admission is associated with a primary discharge diagnosis of osteoarthritis, rheumatoid arthritis, osteonecrosis, or arthropathy (excluding septic arthropathy), the readmission is considered "planned" and is not counted as a readmission in the measure. Appendix B lists the ICD-9 codes used to identify these discharge diagnoses.

2.4.2 30-Day Timeframe

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

2.4.3 All-cause Readmission

The measure assesses all-cause readmission (excluding planned readmissions), rather than readmission for specific procedural complications, for several reasons. First, from the patient perspective, readmission for any reason is likely to be an undesirable outcome of care after elective surgery. Second, readmissions not directly related to the procedure may still be a result of the care received during the index hospitalization. For example, a patient who underwent a THA/TKA who develops a hospital-acquired infection may ultimately be readmitted for sepsis. It would be inappropriate to treat this readmission as unrelated to the care the patient received for the procedure. Another patient might experience a procedure-related complication following his THA or TKA, which may go untreated and result in renal failure. The resulting readmission for renal failure could have been prevented with higher quality of care during the admission for the THA/TKA that could have reduced the risk for the complication. Furthermore, the range of potentially avoidable readmissions also includes those not directly related to the procedures such as those resulting from poor communication or inadequate follow-up. As such, creating a comprehensive list of potential complications related to THA/TKA 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. Thus, the goal of this measure is not to reduce readmissions to zero but to instead promote quality improvement efforts by assessing individual hospital performance relative to the national average.

2.4.4 Outcome Attribution For Multiple THA/TKA Procedures

Any readmissions that occur following a second elective primary THA/TKA (that meets the measure eligibility criteria) are attributed to the hospital performing the second (most recent) THA/TKA, even if the readmission is within 30 days following discharge for the first THA/TKA.

2.5 Overview of Risk Adjustment

The goal of risk adjustment is to account for patient age and comorbid conditions that are clinically relevant and have strong relationships with the outcome while illuminating important quality differences. The measure adjusts for case-mix differences based on the clinical status of the patient at the time of admission. Conditions that may represent adverse outcomes due to care received during the index admission are not considered for inclusion in the risk-adjustment. Although they may increase the risk of readmission, including them as covariates in the risk-adjustment could attenuate the measure's ability to characterize the quality of care delivered by hospitals. Appendix D lists the conditions not adjusted for if

they only appear in the index admission and not in the 12 months prior to admission.

Comorbidities for inclusion in the risk adjustment model are identified in administrative claims during the 12 months prior to and including the index admission. To assemble the more than 15,000 ICD-9 codes into clinically coherent variables for risk adjustment, the measure employs the publicly available CMS hierarchical condition categories (CCs) to group codes into CCs[9], and select comorbidities on the basis of clinical relevance and statistical significance. A detailed description of the risk adjustment methodology is provided in Appendix A, Section II. f.

Additionally, the measure does not adjust for patients' admission source or their discharge disposition (e.g. skilled nursing facility) because these factors are associated with the structure of the health care system, not solely patients' clinical risk factors. Regional differences in resource availability and practice patterns may exert an undue influence on model results. Moreover, the accuracy of these admission and discharge disposition codes is not known. The measure does not adjust for socioeconomic status (SES), race or ethnicity. Variation in quality associated with these characteristics may be indicative of disparities in the quality of the care provided to vulnerable populations, and adjusting for these factors would obscure these disparities. The measure does not adjust for hospital characteristics either (e.g., teaching status) since this would hold different types of hospitals to different quality standards and because such characteristics may exist on a causal pathway to the outcome, rather than act as confounders. This approach is consistent with NQF guidelines (http://www.qualityforum.org/docs/measure_evaluation_criteria.aspx).

2.6 Model Performance Testing

Two summary statistics were computed to assess model performance in each year of data: discrimination in terms of predictive ability and discrimination in terms of C statistic (area under the receiver operating curve [ROC]). Further performance testing results are provided in Appendix A.

Discrimination in predictive ability measures the model's ability to distinguish high-risk subjects from low-risk subjects. Good model discrimination is indicated by a wide range between the lowest decile and highest decile.

The C statistic is a measure of the extent a statistical model is able to distinguish between a patient with and without an outcome. A C statistic of 0.50 indicates random prediction, implying all patient risk factors are useless. A C statistic of 1.0 indicates perfect prediction, implying patients' outcomes can be predicted completely by their risk factors, and physicians and hospitals play no role in patients' outcomes. Although a higher C statistic is desirable, we would not want

to maximize model discrimination by adjusting for hospital and physician characteristics that may influence the outcome.

To assess model performance across years, we computed model performance statistics for each calendar year of data (2008, 2009, and 2010) and for the three-year combined period (2008-2010). Logistic regression models were used during this step as we are interested in the model's capability of predicting the outcome using selected risk adjusters prior to assessing hospital specific effects.

2.7 Statistical Approach to Measure Calculation

The measure estimates hospital-level 30-day all-cause RSRRs using a hierarchical logistic regression model. In brief, the approach simultaneously models two levels (patient and hospital) to account for the variance in patient outcomes within and between hospitals. The patient level models the log-odds of a hospital readmission within 30days of discharge adjusting for age, sex, selected clinical covariates, and a hospital-specific intercept. The second level models the hospital-specific intercepts as arising from a normal distribution. The hospital-specific intercept represents the underlying risk of a readmission at that hospital, after accounting for patient risk. If there were no differences among hospitals, then after adjusting for patient risk, the hospital intercepts should be identical across all hospitals.

The RSRR is calculated as the ratio of the number of "predicted" to the number of "expected" readmissions, multiplied by the national unadjusted readmission rate. For each hospital, the numerator of the ratio is the number of readmissions within 30 days predicted on the basis of the hospital's performance with its observed case-mix, and the denominator is the number of readmissions expected on the basis of the nation's performance with that hospital's case-mix. This approach is analogous to a ratio of "observed" to "expected" used in other types of statistical analyses. It conceptually allows for a comparison of a particular hospital's performance given its case-mix to an average hospital's performance with the same case-mix. Thus a lower ratio indicates lower-than-expected readmission or better quality and a higher ratio indicates higher-than-expected readmission or worse quality.

After regressing the risk factors and the hospital specific intercept on the risk of readmission, the predicted number of readmissions within 30 days (the numerator) is calculated by summing the estimated regression coefficients multiplied by the patient characteristics, adding the estimated hospital-specific intercept, transforming this value to the probability scale, and then summing over all patients attributed to the hospital to get the predicted value. The expected number of readmissions within 30 days (the denominator) is obtained by summing the estimated regression coefficients multiplied by the patient characteristics observed in the hospital, adding the estimated average hospital

intercept, transforming to the probability scale and then summing over all patients in the hospital to get the expected value.

Please refer to Appendix A, Section II. g. for technical details.

2.8 Hospital Performance Reporting

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

3. RESULTS

3.1 Frequency of Model Variables

We examined the temporal variation in both overall readmission and frequency of clinical and demographic variables. Between 2008 and 2010, the crude readmission rate remained stable at just under 6%. During this time period, no risk factor frequency changed by more than 1.5 absolute percentage points between 2008 and 2010 (Table 1). The largest relative changes were seen in the percentage of patients with renal failure (CC 131), which increased from 6.1% in 2008 to 7.5% in 2010, and the percentage of patients with morbid obesity (ICD-9 code 278.01), which increased from 3.5% in 2008 to 4.2% in 2010. These changes are consistent with published reports of increased comorbidities.[10] The percentage of patients having two procedures (versus one) decreased from 3.2% in 2008 to 2.7% in 2010.

Table 1. Frequency of Model Variables (2008-2010)

Variable	2008 Freq (%)	2009 Freq (%)	2010 Freq (%)	2008-2010 Freq (%)
Number of Admissions	292,257	299,532	305,532	897,321
Number of Hospitals	3,308	3,297	3,325	3,497
Number of Readmissions	17,104	16,846	17,040	50,990
Crude Readmission Rate	5.9%	5.6%	5.6%	5.7%
Demographic				
Age-65 (years above 65, continuous)[1]	10.2	10.1	10.0	10.1
Male	35.9	36.1	36.1	36.0
THA/TKA Procedure				
THA procedure	28.0	28.7	28.7	28.5
Number of procedures (two vs. one)	3.2	3.0	2.7	3.0
Comorbid Conditions				
Skeletal deformities (ICD-9 code 755.63)	0.1	0.1	0.2	0.1
Post traumatic osteoarthritis (ICD-9 codes 716.15, 716.16)	0.5	0.5	0.4	0.4
Morbid obesity (ICD-9 code 278.01)	3.5	3.8	4.2	3.8
History of Infection (CC 1, 3-6)	17.8	18.0	17.9	17.9
Metastatic cancer and acute leukemia (CC 7)	0.6	0.5	0.5	0.5
Cancer (CC 8-12)	18.7	18.7	18.6	18.6
Diabetes and DM complications (CC 15-20, 119, 120)	27.3	27.9	28.4	27.9
Protein-calorie malnutrition (CC 21)	0.6	0.6	0.7	0.6
Disorders of fluid/electrolyte/acid-base (CC 22, 23)	11.8	12.2	12.2	12.1
Rheumatoid arthritis and inflammatory connective tissue disease (CC 38)	8.6	8.4	8.7	8.6
Severe hematological disorders (CC 44)	0.7	0.7	0.7	0.7
Dementia and senility (CC 49, 50)	4.2	4.3	4.2	4.2
Major psychiatric disorders (CC 54-56)	3.7	3.8	4.1	3.9
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177-178)	1.6	1.6	1.6	1.6
Polyneuropathy (CC 71)	5.6	5.8	6.0	5.8
Congestive heart failure (CC 80)	9.6	9.3	9.2	9.3
Chronic atherosclerosis (CC 83-84)	30.6	30.0	29.3	30.0
Hypertension (CC 89, 91)	82.6	82.8	83.2	82.9
Arrhythmias (CC 92, 93)	22.2	22.7	23.2	22.7
Stroke (CC 95, 96)	2.4	2.3	2.2	2.3
Vascular or circulatory disease (CC 104-106)	22.4	22.8	22.8	22.7
COPD (CC 108)	14.5	14.4	14.0	14.3
Pneumonia (CC 111-113)	4.8	4.4	4.3	4.5
End-stage renal disease or dialysis (CC 129, 130)	0.1	0.1	0.1	0.1
Renal failure (CC 131)	6.1	6.7	7.5	6.8
Decubitus ulcer or chronic skin ulcer (CC 148, 149)	2.6	2.7	2.6	2.6
Cellulitis, local skin infection (CC 152)	7.8	7.7	7.8	7.7
Other injuries (CC162)	26.5	26.9	27.3	26.9
Major symptoms, abnormalities (CC 166)	52.4	52.1	51.8	52.1

[1] Mean number of years over age 65

3.2 Model Parameters and Performance

Table 2 shows the risk-adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for the model variables by individual year and for the combined 2008-2010 calendar year dataset. Overall, the variable effect sizes were relatively constant across years.

Table 3 conveys the model performance statistics. Good discrimination for this model is indicated by a wide range between the lowest decile and highest decile (range is 3% - 13% in all years of data). The C statistic ranges from 0.64 in 2008 to 0.65 in 2009 and 2010, indicating good discriminant ability.

Table 2. Model Variable Adjusted ORs and 95% CIs (2008-2010 – Hierarchical Logistic Regression Model)

Variable	2008 OR (95% CI)	2009 OR (95% CI)	2010 OR (95% CI)	2008-2010 OR (95% CI)
Demographic				
Age-65 (years above 65, continuous)	1.03 (1.03,1.04)	1.04 (1.03,1.04)	1.03 (1.03,1.04)	1.04 (1.03,1.04)
Male	1.14 (1.10,1.17)	1.15 (1.11,1.19)	1.12 (1.09,1.16)	1.14 (1.12,1.16)
THA/TKA Procedure				
THA procedure	1.13 (1.09,1.17)	1.13 (1.10,1.17)	1.11 (1.07,1.15)	1.12 (1.10,1.15)
Number of procedures (two vs. one)	1.25 (1.14,1.36)	1.37 (1.26,1.50)	1.41 (1.29,1.55)	1.33 (1.27,1.40)
Comorbid Conditions				
Skeletal deformities (ICD-9 code 755.63)	1.09 (0.74,1.63)	1.28 (0.88,1.85)	0.93 (0.62,1.39)	1.10 (0.88,1.37)
Post traumatic osteoarthritis (ICD-9 codes 716.15, 716.16)	0.93 (0.74,1.17)	0.88 (0.69,1.11)	1.00 (0.79,1.26)	0.94 (0.82,1.07)
Morbid obesity (ICD-9 code 278.01)	1.28 (1.18,1.38)	1.31 (1.22,1.42)	1.31 (1.22,1.41)	1.30 (1.24,1.36)
History of Infection (CC 1, 3-6)	1.11 (1.07,1.15)	1.12 (1.07,1.16)	1.10 (1.06,1.14)	1.11 (1.08,1.13)
Metastatic cancer and acute leukemia (CC 7)	1.17 (0.98,1.40)	1.15 (0.96,1.39)	1.22 (1.02,1.46)	1.19 (1.07,1.32)
Cancer (CC 8-12)	0.96 (0.92,0.99)	0.98 (0.95,1.02)	1.00 (0.96,1.04)	0.98 (0.96,1.00)
Diabetes and DM complications (CC 15-20, 119, 120)	1.13 (1.09,1.17)	1.15 (1.12,1.19)	1.12 (1.08,1.16)	1.13 (1.11,1.15)
Protein-calorie malnutrition (CC 21)	1.19(1.02,1.39)	1.34 (1.16,1.55)	1.41 (1.23,1.59)	1.32 (1.21,1.43)
Disorders of fluid/electrolyte/acid-base (CC 22, 23)	1.14 (1.09,1.19)	1.15 (1.10,1.20)	1.15 (1.10,1.20)	1.15 (1.12,1.17)
Rheumatoid arthritis and inflammatory connective tissue disease (CC 38)	1.10 (1.04,1.16)	1.14 (1.08,1.20)	1.15 (1.10,1.21)	1.13 (1.10,1.17)
Severe hematological disorders (CC 44)	1.49 (1.30,1.71)	1.37 (1.19,1.57)	1.38 (1.21,1.59)	1.41 (1.30,1.53)
Dementia and senility (CC 49, 50)	1.26 (1.18,1.34)	1.18 (1.10,1.26)	1.19 (1.12,1.27)	1.21 (1.16,1.25)
Major psychiatric disorders (CC 54-56)	1.33 (1.24,1.43)	1.33 (1.25,1.43)	1.29 (1.20,1.37)	1.32 (1.26,1.37)
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177-178)	1.13 (1.02,1.26)	1.19 (1.07,1.32)	0.98 (0.88,1.09)	1.10 (1.03,1.17)
Polyneuropathy (CC 71)	1.18 (1.11,1.25)	1.12 (1.06,1.19)	1.13 (1.06,1.19)	1.14 (1.10,1.18)
Congestive heart failure (CC 80)	1.25 (1.20,1.31)	1.28 (1.22,1.34)	1.26 (1.20,1.31)	1.26 (1.23,1.30)
Chronic atherosclerosis (CC 83-84)	1.27 (1.23,1.31)	1.24 (1.20,1.28)	1.24 (1.19,1.28)	1.25 (1.22,1.27)
Hypertension (CC 89, 91)	1.19 (1.13,1.24)	1.19 (1.13,1.25)	1.22 (1.16,1.28)	1.19 (1.16,1.23)
Arrhythmias (CC 92, 93)	1.18 (1.14,1.23)	1.16 (1.12,1.20)	1.14 (1.10,1.18)	1.16 (1.14,1.19)
Stroke (CC 95, 96)	1.05 (0.97,1.15)	1.07 (0.98,1.17)	1.10 (1.01,1.20)	1.07 (1.02,1.13)
Vascular or circulatory disease (CC 104-106)	1.10 (1.06,1.14)	1.14 (1.10,1.18)	1.18 (1.14,1.22)	1.14 (1.12,1.16)
COPD (CC 108)	1.29 (1.24,1.34)	1.29 (1.24,1.34)	1.35 (1.30,1.39)	1.31 (1.28,1.34)
Pneumonia (CC 111-113)	1.13 (1.06,1.20)	1.15 (1.08,1.22)	1.14 (1.07,1.21)	1.14 (1.10,1.18)
End-stage renal disease or dialysis (CC 129, 130)	2.11 (1.65,2.70)	1.50 (1.14,1.98)	1.53 (1.18,1.98)	1.70 (1.46,1.97)
Renal failure (CC 131)	1.23 (1.16,1.30)	1.26 (1.19,1.32)	1.32 (1.26,1.39)	1.27 (1.23,1.31)
Decubitus ulcer or chronic skin ulcer (CC 148, 149)	1.17 (1.08,1.27)	1.10 (1.02,1.20)	1.21 (1.12,1.31)	1.16 (1.11,1.22)
Cellulitis, local skin infection (CC 152)	1.16 (1.11,1.23)	1.08 (1.03,1.14)	1.11 (1.05,1.16)	1.12 (1.09,1.15)
Other injuries (CC162)	1.15 (1.11,1.19)	1.09 (1.05,1.13)	1.08 (1.05,1.12)	1.11 (1.09,1.13)
Major symptoms, abnormalities (CC 166)	1.14 (1.10,1.18)	1.21 (1.17,1.25)	1.17 (1.13,1.21)	1.17 (1.15,1.20)

Table 3. Model Performance (Logistic Regression Model)

Indices	2008	2009	2010	2008-2010
Discrimination -Predictive Ability (lowest decile %, highest decile %)	(3%, 13%)	(3%, 13%)	(3%, 13%)	(3%, 13%)
Discrimination – Area Under Receiver Operator Curve (C-statistic)	0.64	0.65	0.65	0.64

3.3 Distribution of Hospital Volumes and RSRRs

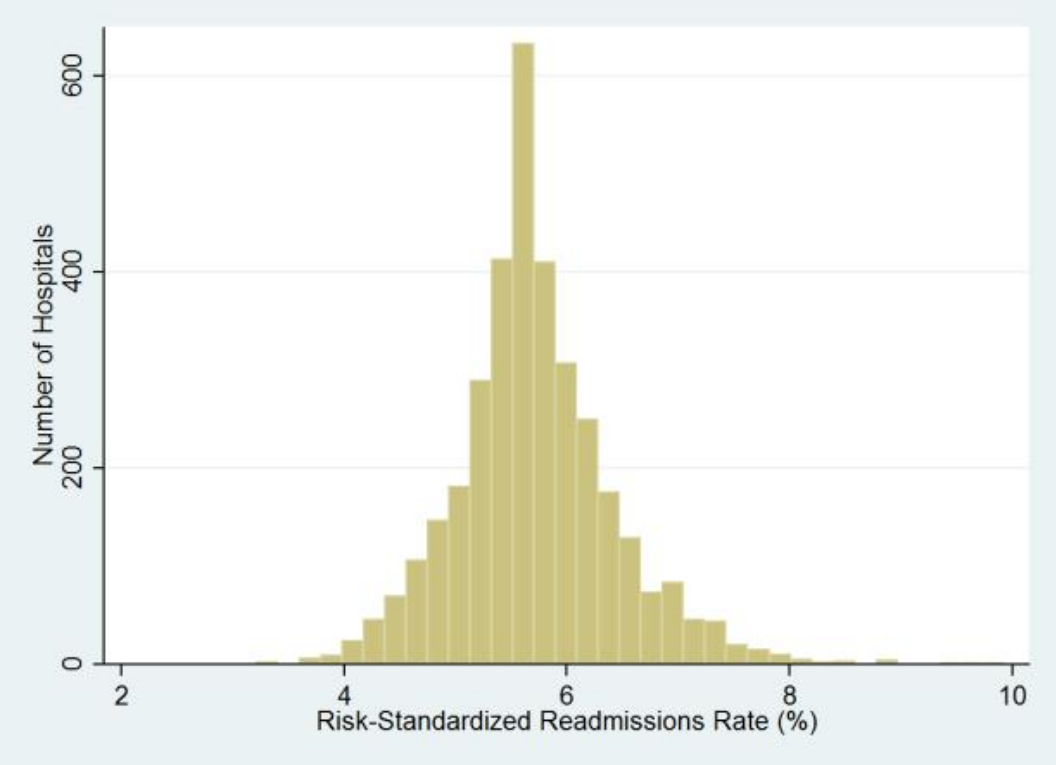
Table 4 shows the distributions of hospital volumes and hospital RSRRs, as well as the between-hospital variance, by individual year and for the combined 2008-2010 calendar year dataset. Between 2008 and 2010, mean elective primary THA/TKA volume increased from 88 to 92 admissions per hospital. The mean RSRR was stable across the three year time period. The mean hospital RSRR in the combined three-year dataset was 5.7% (range: 3.2% to 9.9%). The median RSRR was 5.7%. Between-hospital variance in the combined dataset was 0.05 (SE: 0.004). If there were no systematic differences between hospitals, the between hospital variance would be 0.

Figure 2 shows the overall distribution of the hospital RSRRs for the combined 2008-2010 calendar year dataset. The odds of all-cause readmission if treated at a hospital one standard deviation above the national average were 1.6 times higher than the odds of all-cause readmission if treated at a hospital one standard deviation below the national average.

Table 4. Distribution of Hospital Volumes and RSRRs

Characteristic	2008	2009	2010	2008-2010
Number of Hospitals	3,308	3,297	3,325	3,497
Hospital Volume				
Mean (SD)	88 (117)	91 (120)	92 (122)	257 (351)
Range (min. – max.)	(1-1,881)	(1-1,993)	(1-2,091)	(1-5,965)
25th percentile	15	16	16	39
50th percentile	47	49	49	132
75th percentile	116	119	122	338
RSRR (%)				
Mean (SD)	5.88 (0.59)	5.64 (0.49)	5.60 (0.52)	5.72 (0.70)
Range (min. – max.)	(3.64-9.31)	(3.79-9.46)	(3.67-8.37)	(3.22-9.93)
25th percentile	5.57	5.38	5.32	5.33
50th percentile	5.82	5.60	5.55	5.65
75th percentile	6.16	5.87	5.83	6.08
Between Hospital Variance (SE)	0.06 (0.01)	0.05 (0.01)	0.06 (0.01)	0.05 (0.004)

Figure 2. Distribution of Hospital-Specific Risk-Standardized Readmission Rates (2008-2010 Cohort; N=3,497 Hospitals) – Hierarchical Logistic Regression Model



4. MAIN FINDINGS / SUMMARY

This NQF-endorsed quality outcomes measure has the potential to significantly improve the quality of care delivered to patients undergoing elective primary THA and/or TKA procedures. It will inform healthcare providers about opportunities to improve care, and strengthen incentives for quality improvement, particularly for care at the time of transitions (e.g., discharge to home or a rehabilitation facility). Improvements in inpatient care and care transitions for this common, costly procedure are likely to reduce readmissions. The mean hospital RSRR was nearly 6%, and there was considerable variation in the RSRRs across hospitals, supporting the existence of differences in care quality.

This measure is consistent with the consensus standards for publicly reported outcomes measures, and can be implemented using available data. This measure was developed with input from experts with clinical and methodological expertise relevant to orthopedic quality measurement. The cohort for inclusion in the measure is homogeneous, comprised of patients undergoing elective primary THA and/or TKA and will allow for valid comparisons of hospital quality across institutions. We excluded covariates that are not appropriate for inclusion in a quality measure, such as race, SES, and hospital-level factors (e.g., hospital bed size and volume of arthroplasty cases). The hierarchical modeling accounts for hospital case-mix, the clustering of patients within hospitals, and differences in sample size across hospitals, thereby making the measure suitable for public reporting.

5. REFERENCES

1. Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. *J Bone Joint Surg Am.* Apr 2007;89(4):780-785.
2. Kurtz SM, Ong KL, Schmier J, et al. Future clinical and economic impact of revision total hip and knee arthroplasty. *J Bone Joint Surg Am.* Oct 2007;89 Suppl 3:144-151.
3. Ong KL, Mowat FS, Chan N, Lau E, Halpern MT, Kurtz SM. Economic burden of revision hip and knee arthroplasty in Medicare enrollees. *Clin Orthop Relat Res.* May 2006;446:22-28.
4. Bozic KJ, Rubash HE, Sculco TP, Berry DJ. An analysis of medicare payment policy for total joint arthroplasty. *J Arthroplasty.* Sep 2008;23(6 Suppl 1):133-138.
5. Nelson EA, Maruish ME, Axler JL. Effects of Discharge Planning and Compliance With Outpatient Appointments on Readmission Rates. *Psychiatr Serv.* July 1 2000;51(7):885-889.
6. Fisher ES, Wennberg JE, Stukel TA, Sharp SM. Hospital Readmission Rates for Cohorts of Medicare Beneficiaries in Boston and New Haven. *New England Journal of Medicine.* 1994;331(15):989-995.
7. National Quality Forum. National voluntary consensus standards for patient outcomes, first report for phases 1 and 2: A consensus report http://www.nysna.org/images/pdfs/practice/nqf_ana_outcomes_draft10.pdf. Accessed August 19, 2010.
8. Krumholz HM, Brindis RG, Brush JE, et al. Standards for Statistical Models Used for Public Reporting of Health Outcomes: An American Heart Association Scientific Statement From the Quality of Care and Outcomes Research Interdisciplinary Writing Group: Cosponsored by the Council on Epidemiology and Prevention and the Stroke Council Endorsed by the American College of Cardiology Foundation. *Circulation.* January 24, 2006 2006;113(3):456-462.
9. Pope G, Ellis R, Ash A, et al. Principal Inpatient Diagnostic Cost Group Models for Medicare Risk Adjustment. *Health Care Financing Review.* 2000;21(3):26.
10. Wong CY, Chaudhry SI, Desai MM, Krumholz HM. Trends in Comorbidity, Disability, and Polypharmacy in Heart Failure. *The American Journal of Medicine.* 2011;124(2):136-143.
11. McCallagh PNJ. *Generalized Linear Models*. London: Chapman and Hall; 1989.
12. Daniels M, Gatsonis C. Hierarchical Generalized Linear Models in the Analysis of Variations in Health Care Utilization. *Journal of the American Statistical Association.* 1999;94(445):14.
13. Normand S, Wang Y, Krumholz H. Assessing surrogacy of data sources for institutional comparisons. *Health Services and Outcomes Research Methodology.* 2007;7:79-96.
14. Harrell F, Shih Y. Using full probablility models to compute probabiliites of actual interest to decision makers. *Int J Technol Assess Health Care.* Winter 2001;17(1):10.

6. APPENDIX

Appendix A: Technical Measure Development and Validation Process

I. INTRODUCTION TO APPENDIX A

The purpose of this appendix is to provide the detailed methodology used to develop and validate the initial logistic regression model and calculate the RSRRs.

The logistic regression model presented in this appendix report was developed in 2009-2010 using 2008 data from Medicare administrative claims. The original cohort exclusions were then revised in 2011, based on feedback received during NQF review and on findings from a medical-record validation study of the complementary complications measure that used a sample of administrative elective primary THA and/or TKA claims both with and without complications. We conducted the validation study in 2010-2011 under contract with CMS. These changes are reflected in the current measure specifications described in the main report.

Specific topics discussed in this appendix include the original cohort definition for inclusion in the measure (Section II. b.), the risk adjustment methodology (Section II. e - f), and the methods to test model reliability (Section III. f. ii.) and validity (Section III. f. iii.). Each section details the decisions made, the rationale for those decisions, and any subsequent changes incorporated into the current measure (described in the main body of the report).

II. METHODS FOR MEASURE DEVELOPMENT

a. Data Sources (Measure Development)

The data sources used to develop the logistic regression model are detailed in the main report (Section 2.2). For measure development, using Part A administrative claims data, the measure identified hospitalizations for patients aged 65 years and older who underwent an elective primary THA and/or TKA in 2008. Comorbidities were identified via Part A inpatient and outpatient and Part B outpatient claims in the 12 months prior to and including the index admission. Enrollment and post-discharge mortality status were obtained from Medicare's Enrollment Database which contains beneficiary demographic, benefit/coverage, and vital status information.

b. Cohort Definition (Measure Development)

We considered whether to develop separate measures for patients undergoing THA and TKA procedures or to combine patients undergoing either procedure into a single hospital quality measure. To inform that decision, we consulted with the working group and conducted analyses to examine the average length of stay, and mortality, complication, and readmission rates for each procedure.

Based on those analyses (Table A.1), and in consultation with the working group, we combined these patient cohorts for the readmission measure for several reasons including:

- A large proportion of THA and TKA procedures are elective and performed in similar patient cohorts for similar indications (e.g., osteoarthritis)
- The same surgeons frequently perform both procedures
- Both procedures have similar lengths of stay
- The rates and types of complications are similar
- The mortality and readmission rates are similar
- Hospitals develop protocols/programs for lower extremity total joint arthroplasty, rather than for THA and TKA separately
- Combining admissions for both procedures will provide greater power to detect hospital-level variation to enable quality improvement

Table A.1 Procedure Characteristics and Unadjusted Mortality, Readmission, and Complication Rates for THA and TKA (Medicare Inpatient Part A, 2008)

		Total Hip Replacement* (excludes partial hip replacement and hip fractures)	Total Knee Replacement**
Procedure-related characteristics			
Number of Patients Receiving Procedure		97,130	240,517
Mean Length of Stay (SD)		3.8 (2.3)	3.6 (1.7)
Mean Patient Age (SD)		75.2 (6.6)	74.2 (6.1)
Number of Hospitals Performing Procedure		3083	3307
Median Number of Procedures Performed at Each Hospital (Q1-Q3)		16 (6 - 41)	40 (13 - 257)
Mortality		**% (5th-95th)**	**% (5th-95th)**
In-hospital Mortality	Patient level	0.2	0.1
	Hospital level: median	0 (0 - 0.9)	0 (0 - 0.6)
30-day Mortality	Patient level	0.5	0.3
	Hospital level: median	0 (0 - 2.9)	0 (0 - 1.7)
90-day Mortality	Patient level	0.9	0.5
	Hospital level: median	0 (0 - 5.6)	0 (0 - 3.0)
Readmission		**% (5th-95th)**	**% (5th-95th)**
30-day All-cause Readmission	Patient level	6.9	5.9
	Hospital level: median	5 (0 - 25)	5 (0 - 18)
90-day All-cause Readmission	Patient level	12.2	10.7
	Hospital level: median	11 (0 - 38)	10 (0 - 27)
Complications		**% (30-day / 90-day)**	**% (30-day / 90-**
Dislocation		0.8 / 1.1	0.1 / 0.1
DVT		0.1 /0.2	0.2 / 0.2
Hematoma		1.9 / 2.0	1.2 / 1.3
Periprosthetic Joint Infection		0.5 / 0.7	0.4 / 0.6
Postoperative infection		0.8 / 1.0	0.7 / 0.8
Pulmonary Embolism		0.5 / 0.7	0.8 / 1.0
Mechanical complication of internal orthopedic device, implant and graft		2.7 / 3.3	0.3 / 0.4
Venous thrombosis		0.1 / 0.2	0.1 / 0.1
Wound Infection		0.7 / 0.9	0.7 / 0.8
All complications combined		5.8 / 7.0	3.4 / 4.1
* Includes ICD-9 code 81.51 ** Incudes ICD-9 code 81.54			

i. Inclusion Criteria (Measure Development)

Patients eligible for inclusion in the measure were those aged 65 and older electively admitted to non-federal acute care hospitals with an ICD-9 procedure code for THA and/or TKA in 2008. The flow chart depicting cohort selection for the measure as originally specified is presented in Figure A.1.

Eligible index admissions are identified using the following ICD-9-CM

- 81.51 Total Hip Arthroplasty
- 81.54 Total Knee Arthroplasty

ii. Exclusion Criteria (Measure Development)

To identify a homogeneous cohort of patients undergoing elective primary THA and/or TKA procedures, we excluded patients who on the index admission had a principal discharge diagnosis indicative of a non-elective arthroplasty (e.g., hip fracture, mechanical complication). We also excluded patients who had a procedure code for an arthroplasty procedure that was not an elective primary arthroplasty (e.g., partial hip arthroplasty, revision procedures) or represented a different procedure (e.g., hip resurfacing).

The original measure specifications excluded admissions for patients:

1. With hip fractures coded in the principal discharge diagnosis field on the index admission
   Rationale: Patients with hip fractures have higher mortality, complication, and readmission rates and the procedures are not elective.

2. Undergoing partial hip arthroplasty (PHA) procedures (with a concurrent THA/TKA)
   Rationale: Partial arthroplasties are primarily done for hip fractures and are typically performed on patients who are older, frailer, and have more comorbid conditions.

3. Undergoing revision procedures (with a concurrent THA/TKA)
   Rationale: Revision procedures may be performed at a disproportionately small number of hospitals and are associated with higher mortality, complication, and readmission rates.

4. Undergoing resurfacing procedures (with a concurrent THA/TKA)
   Rationale: Resurfacing procedures are a different type of procedure where only the joint's articular surface is replaced. A THA involves surgical removal of the neck of the femur (thighbone) and insertion of a stem deep inside the bone to connect with the pelvic socket and liner. These procedures are typically performed on younger, healthier patients.

5. Without at least 30-days post-discharge enrollment in Medicare FFS.
   Rationale: The 30-day readmission outcome cannot be assessed for the standardized time period.

6. Who were transferred in to the index hospital
   Rationale: If the patient is transferred from another acute care facility to the hospital where the index procedure occurs, it is likely that the procedure is not elective or that the admission is associated with an acute condition.

7. Who were admitted for the index procedure and subsequently transferred to another acute care facility
   Rationale: Attribution of readmission to the index hospital would not be possible in these cases, since the index hospital performed the procedure but another hospital discharged the patient to the non-acute care setting.

8. Who leave the hospital against medical advice (AMA)
   Rationale: Hospitals and physicians do not have the opportunity to provide the highest quality care for these patients.

9. With more than two THA/TKA procedures codes during the index hospitalization
   Rationale: It is unlikely that patients would receive more than two THA/TKA procedures in one hospitalization, and this may reflect a coding error.

10. Who die during the index admission
    Rationale: Patients who die during the initial hospitalization are not eligible for readmission.

If a patient has more than one admission within 30 days of discharge from the index hospitalization, only one is counted as a readmission, as we are interested in a dichotomous (yes/no) readmission outcome, rather than the number of readmissions. Additional otherwise qualifying THA and/or TKA admissions that occurred within 30 days of discharge date of an earlier index admission are not considered as index admissions. They are considered as potential readmissions. Any THA and/or TKA admission is either an index admission or a potential readmission, but not both.

Appendix C lists the ICD-9 codes for the following exclusion categories: femur, hip and pelvic fractures, revision procedures, partial hip arthroplasty procedures, resurfacing procedures. Appendix C also includes the ICD-9 codes (shaded rows) for the additional exclusions from the current measure cohort noted below.

iii. Changes to the Original Cohort Exclusions

Based on feedback we received during the NQF public comment period and findings from the medical record validation study of the

complementary complications measure, we excluded additional patients from the readmission measure cohort. These changes are reflected in the current measure specifications presented in the report (Section 2.3.2). We excluded patients who had an ICD-9 code for one of the following conditions in the principal discharge diagnosis field during the index admission (please see shaded rows in Appendix C):

- mechanical complication;
- femur and pelvic fractures; and
- malignant neoplasm of the pelvic bones, sacrum, coccyx, lower limbs, bone and bone marrow, and disseminated malignant neoplasms.

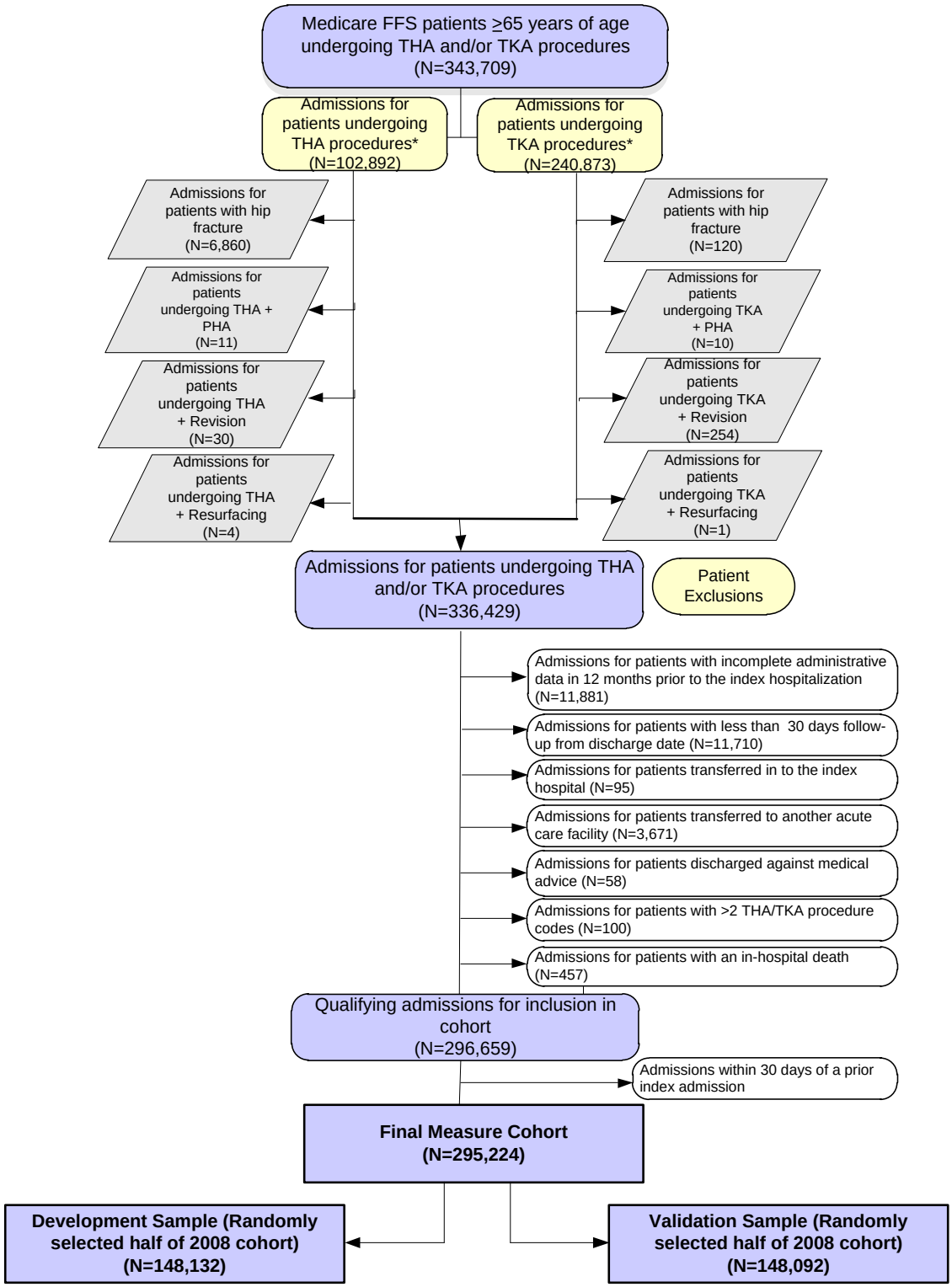
We also excluded patients who had an ICD-9 code for one of the following procedures in a secondary diagnosis field during the index admission (please see shaded rows in Appendix C):

- removal of implanted device from femur, patella, tibia, fibula; and
- arthrotomy for removal of prosthesis (femur and knee, and non-specified site).

c. Outcome Definition (Measure Development)

The outcome for this measure is 30-day all-cause readmission, defined as a subsequent acute care hospitalization within 30 days of the discharge date for the index admission. Please refer to the main report Section 2.4 for outcome details.

Figure A.1 Cohort for Measure Development (2008 Medicare FFS Patients)



*THA and TKA are presented separately for illustrative purposes and are not mutually exclusive

d. Development and Validation Overview (Measure Development)

We randomly selected 50% of the THA and/or TKA admissions in 2008 that met all inclusion and exclusion criteria and created a model "development sample" which we used to select risk-adjustment variables and build the logistic regression model. The performance of the model was then evaluated using patients contained in the other half of the 2008 administrative dataset. To assess stability of the model over time, we also evaluated the model using eligible THA and/or TKA hospitalizations from 2007.

e. Approach to Risk Adjustment (Measure Development)

The goal of risk adjustment is to account for patient age and comorbid conditions at the time of admission that are clinically relevant and have strong relationships with the outcome while illuminating important quality differences. Conditions that may represent adverse outcomes due to care received during the index admission are not considered for inclusion in the risk-adjusted model. Although they may increase the risk of readmission, including them as covariates in a risk-adjusted model could attenuate the measure's ability to characterize the quality of care delivered by hospitals. Appendix D lists the conditions not adjusted for if they are coded only during the index admission and not in the 12 months prior to admission.

f. Candidate and Final Variables for Inclusion in Risk-Adjustment (Measure Development)

i. Candidate Variable Selection

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

For model development, YNHHSC/CORE clinicians reviewed the 189 CCs, which are clinically relevant diagnostic groups of the more than 15,000 ICD-9 codes.[9] They used the April 2010 version of the ICD-9 to CC assignment map, which is maintained by CMS and posted at http://qualitynet.org/.

To select candidate variables, clinicians reviewed all 189 CCs and excluded those that were not relevant to the Medicare population

(Appendix E) or that were not clinically relevant to the readmission outcome (e.g., attention deficit disorder, female infertility, cataract). Clinically relevant CCs were selected as candidate variables. CCs with high clinical relevance to the outcome were broken out and certain conditions within that CC were examined separately when clinically indicated. For example, obesity and morbid obesity are known risk factors for readmission following THA/TKA. We examined the effect on the outcome for these conditions after separating them from the CC. Based on these analyses and expert feedback, morbid obesity was separated from CC 24 (obesity and other endocrine/metabolic/nutritional disorders) and included in the risk adjusted model independently. Other CCs were combined into clinically coherent groups. Other candidate variables included age, sex, type of procedure (THA, TKA, or both), and number of procedures (1 versus 2) and are listed in Table A.2.

Table A.2 THA/TKA Readmission Measure Candidate Model Variables

Category	Variable	ICD-9 Code(s) or CC(s)
Demographic	Age-65 (years above 65, continuous)	
	Sex	
Procedure	Type of procedure	ICD-9-CM 81.51 (THA) ICD-9-CM 81.54 (TKA)
	Number of procedures (two versus one)	
Comorbidities	Skeletal deformities	ICD-9-CM 755.63
	Post traumatic osteoarthritis	ICD-9-CM 716.15, 716.16
	Morbid obesity	ICD-9-CM 278.01
	History of Infection	CC 1, 3-6
	Septicemia/shock	CC 2
	Metastatic cancer and acute leukemia	CC 7
	Cancer	CC 8-12
	Other neoplasms	CC 13
	Benign neoplasms of skin, breast, eye	CC 14
	Diabetes and DM complications	CC 15-20, 119, 120
	Protein-calorie malnutrition	CC 21
	Disorders of Fluid/Electrolyte/Acid-Base	CC 22, 23
	Obesity/disorders of thyroid, cholesterol, lipids	CC 24
	Liver and biliary disease	CC 25-30
	Intestinal Obstruction/Perforation	CC 31
	Pancreatic Disease	CC 32
	Inflammatory Bowel Disease	CC 33
	Peptic Ulcer, Hemorrhage, Other Specified Gastrointestinal Disorders	CC 34
	Appendicitis	CC 35
	Other Gastrointestinal Disorders	CC 36
	Bone/Joint/Muscle Infections/Necrosis	CC 37
	Rheumatoid Arthritis and Inflammatory Connective	CC 38

Category	Variable	ICD-9 Code(s) or CC(s)
	Tissue Disease	
	Disorders of the Vertebrae and Spinal Discs	CC 39
	Osteoarthritis of Hip and Knee	CC 40
	Osteoporosis and Other Bone/Cartilage Disorders	CC 41
	Congenital/Developmental Skeletal and Connective Tissue Disorders	CC 42
	Other Musculoskeletal and Connective Tissue Disorders	CC 43
	Severe Hematological Disorders	CC 44
	Disorders of Immunity	CC 45
	Coagulation Defects and Other Specified Hematological Disorders	CC 46
	Iron Deficiency and Other/Unspecified Anemias and Blood Disease	CC 47
	Delirium and Encephalopathy	CC 48
	Dementia and senility	CC 49, 50
	Drug/alcohol abuse/dependence/psychosis	CC 51-53
	Major psychiatric Disorders	CC 54-56
	Personality Disorders	CC 57
	Depression	CC 58
	Anxiety Disorders	CC 59
	Other psychiatric disorders	CC 60
	Mental retardation or developmental disability	CC 61-65
	Hemiplegia, paraplegia, paralysis, functional disability	CC 67-69, 100-102, 177-178
	Muscular Dystrophy	CC 70
	Polyneuropathy	CC 71
	Multiple Sclerosis	CC 72
	Parkinson's and Huntington's Diseases	CC 73
	Seizure Disorders and Convulsions	CC 74
	Coma, Brain Compression/Anoxic Damage	CC 75
	Mononeuropathy, Other Neurological Conditions/Injuries	CC 76
	Respirator Dependence/Tracheostomy Status	CC 77
	Respiratory Arrest	CC 78
	Cardio-Respiratory Failure and Shock	CC 79
	Congestive Heart Failure	CC 80
	Acute Coronary Syndrome	CC 81-82
	Chronic Atherosclerosis	CC 83-84
	Heart Infection/Inflammation, Except Rheumatic	CC 85
	Valvular and Rheumatic Heart Disease	CC 86
	Congenital cardiac/circulatory defect	CC 87-88
	Hypertension	CC 89, 91
	Hypertensive heart disease	CC 90
	Arrhythmias	CC 92, 93
	Other and Unspecified Heart Disease	CC 94
	Stroke	CC 95, 96
	Cerebrovascular disease	CC 97-99, 103
	Vascular or circulatory disease	CC 104-106

Category	Variable	ICD-9 Code(s) or CC(s)
	Cystic fibrosis	CC 107
	COPD	CC 108
	Fibrosis of lung or other chronic lung disorder	CC 109
	Asthma	CC 110
	Pneumonia	CC 111-113
	Pleural effusion/pneumothorax	CC 114
	Other lung disorder	CC 115
	Legally Blind	CC 116
	Major eye infections/inflammations	CC 117
	Retinal detachments	CC 118
	Retinal Disorders, Except Detachment and Vascular Retinopathies	CC 121
	Glaucoma	CC 122
	Other Eye Disorders	CC 124
	Significant Ear, Nose, and Throat Disorders	CC 125
	Hearing Loss	CC 126
	Other Ear, Nose, Throat, and Mouth Disorders	CC 127
	Kidney Transplant Status	CC 128
	End-stage renal disease or dialysis	CC 130
	Renal Failure	CC 131
	Nephritis	CC 132
	Urinary Obstruction and Retention	CC 133
	Incontinence	CC 134
	Urinary Tract Infection	CC 135
	Other urinary tract disorders	CC 136
	Pelvic Inflammatory disease	CC 138
	Other female genital disorders	CC 139
	Male genital disorders	CC 140
	Decubitus ulcer or chronic skin ulcer	CC 148, 149
	Extensive burns	CC 150, 151
	Cellulitis, Local Skin Infection	CC 152
	Other Dermatological Disorders	CC 153
	Trauma	CC 154-156, 158-161
	Vertebral Fractures	CC 157
	Other Injuries	CC 162
	Poisonings and Allergic Reactions	CC 163
	Major Complications of Medical Care and Trauma	CC 164
	Other Complications of Medical Care	CC 165
	Major Symptoms, Abnormalities	CC 166
	Minor Symptoms, Signs, Findings	CC 167
	Major Organ Transplant Status	CC 174
	Other organ transplant/replacement	CC 175

ii. Final Variable Selection

To inform final variable selection, a modified approach to stepwise logistic regression was performed. The development sample was used to create

500 “bootstrap” samples. For each sample, we ran a logistic stepwise regression that included all candidate variables. The results were summarized to show the percentage of times that each of the candidate variables was significantly associated with readmission ($p<0.001$) in each of the 500 repeated samples (e.g., 70 percent would mean that the candidate variable was selected as significant at $p<0.001$ in 70 percent of the estimations). We also assessed the direction and magnitude of the regression coefficients.

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

Markers for end of life/frailty:

- decubitus ulcer (CC 148)
- dementia and senility (CC 49 and CC 50, respectively)
- metastatic cancer and acute leukemia (CC 7)
- protein-calorie malnutrition (CC 21)
- hemiplegia/paraplegia/paralysis/functional disability (CCs 67-69, 100-102, 177-178)
- stroke (CCs 95-96)

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

- cancer (CCs 8-12)

Final model variables are listed in Table A.3.

Table A.3 THA/TKA Readmission Measure Final Model Variables

Category	Variable	ICD-9 Code(s) or CC(s)
Demographic	Age-65 (years above 65, continuous)	
	Sex	
Procedure	Type of procedure	ICD-9-CM 81.51 (THA)
	Number of procedures (2 vs. 1)	
Comorbidities	Skeletal deformities	ICD-9-CM 755.63
	Post traumatic osteoarthritis	ICD-9-CM 716.15, 716.16
	Morbid obesity	ICD-9-CM 278.01
	History of Infection	CC 1, 3-6
	Metastatic cancer and acute leukemia	CC 7
	Cancer	CC 8-12
	Diabetes and DM complications	CC 15-20, 119, 120
	Protein-calorie malnutrition	CC 21
	Disorders of Fluid/Electrolyte/Acid-Base	CC 22, 23
	Rheumatoid Arthritis and Inflammatory Connective Tissue Disease	CC 38
	Severe Hematological Disorders	CC 44
	Dementia and senility	CC 49. 50
	Major psychiatric disorders	CC 54-56
	Hemiplegia, paraplegia, paralysis, functional disability	CC 67-69, 100-102, 177-178
	Polyneuropathy	CC 71
	Congestive Heart Failure	CC 80
	Chronic Atherosclerosis	CC 83-84
	Hypertension	CC 89, 91
	Arrhythmias	CC 92, 93
	Stroke	CC 95, 96
	Vascular or circulatory disease	CC 104-106
	COPD	CC 108
	Pneumonia	CC 111-113
	End-stage renal disease or dialysis	CC 130
	Renal Failure	CC 131
	Decubitus ulcer or chronic skin ulcer	CC 148, 149
	Cellulitis, Local Skin Infection	CC 152
	Other injuries	CC 162
	Major Symptoms, Abnormalities	CC 166

g. Statistical Approach to Risk Adjustment (Measure Development)

Two models were fitted, a logistic regression model linking the outcome to the patient-level risk factors and a hierarchical logistic regression to account for the natural clustering of the patients within hospitals. The logistic regression modeled the log-odds of readmission within 30 days of discharge from an index admission as a function of only patient demographic and clinical characteristics. The

demographic and clinical characteristics. The hierarchical logistic regression modeled the log-odds of having a complication as a function of not only patient demographic and clinical characteristics but also 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 then calculated the risk-standardized complication rates as the ratio of the number of "predicted" to the number of "expected" admissions with a complication, multiplied by the national unadjusted complications rate. For each hospital, the numerator of the ratio is the number of admissions with a complication predicted on the basis of the hospital's performance with its observed case-mix, and the denominator is the number of admissions with a complication expected on the basis of the nation's performance with that hospital's case-mix. This approach is analogous to a ratio of "observed" to "expected" used in other types of statistical analyses. It conceptually allows for a comparison of a particular hospital's performance given its case-mix to an average hospital's performance with the same case-mix. Thus a lower ratio indicates a lower-than-expected complication rate or better quality and a higher ratio indicates a higher-than-expected complication rate or worse quality.

After regressing the risk factors and the hospital specific intercept on the risk of a complication, the predicted number of admissions with a complication (the numerator) is calculated by summing the estimated regression coefficients multiplied by the patient characteristics, adding the estimated hospital specific intercept, transforming this value to the probability scale, and then summing over all patients attributed to the hospital to get the predicted value. The expected number of admissions with a complication (the denominator) is obtained by summing the estimated regression coefficients multiplied by the patient characteristics observed in the hospital, adding the estimated average hospital intercept, transforming to the probability scale and then summing over all patients in the hospital to get the expected value.

More specifically, the logistic regression model links the outcome to the patient-level risk factors.[20] Let Y_{ij} denote the outcome (equal to 1 if the patient dies or has a complication, zero otherwise) for the j^{th} patient who had a THA/TKA procedure at the i^{th} hospital; $\mathbf{Z}_{ij}$ denotes a set of risk factors based on the 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

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

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

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

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

$\alpha_i = \mu + \omega_i; \quad \omega_i \sim N(0, \tau^2)$ (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.[21] This model separates within-hospital variation from between-hospital variation. Both the logistic regression model and the hierarchical logistic regression model were estimated using the SAS software system (PROC LOGISTIC and PROC GLIMMIX procedures respectively.)

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

h. Hospital Performance Reporting

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

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

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

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

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

i. Creating Interval Estimates

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

ii. Algorithm

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

1. Sample *I* hospitals with replacement.

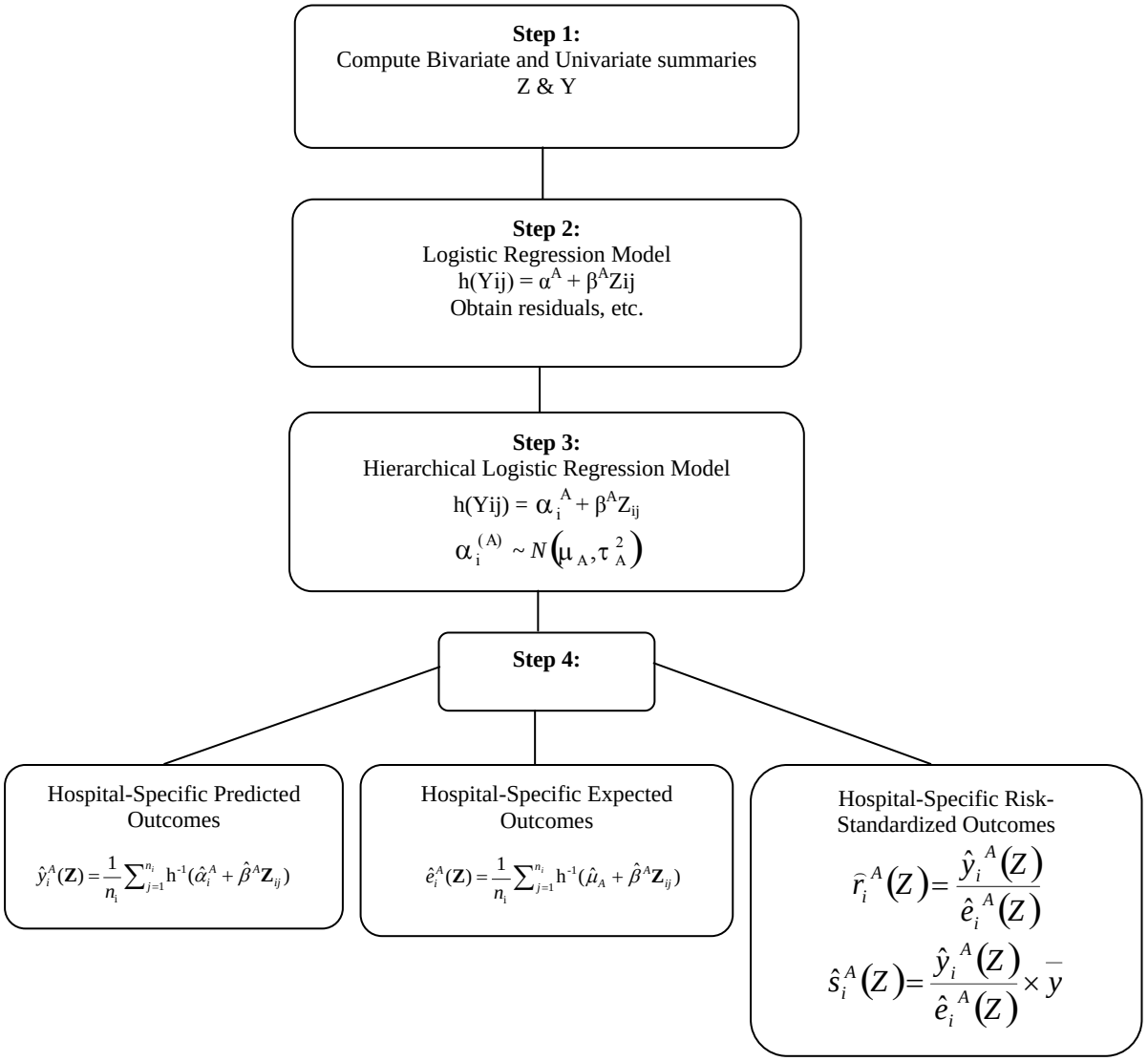
2. Fit the hierarchical logistic regression model using all patients within each sampled hospital. We use as starting values the parameter estimates obtained by fitting the model to all hospitals. If some hospitals are selected more than once in a bootstrapped sample, we treat them as distinct so that we have *I* random effects to estimate the variance components. At the conclusion of Step 2, we have:
   a. $\hat{\beta}^{(b)}$ (the estimated regression coefficients of the risk factors).
   b. The parameters governing the random effects, hospital adjusted outcomes, distribution, $\hat{\mu}^{(b)}$ and $\hat{\tau}^{2(b)}$.
   c. The set of hospital-specific intercepts and corresponding variances, $\{\hat{\alpha}_i^{(b)}, \hat{\text{var}}(\alpha_i^{(b)}); i = 1,2,\ldots,I\}$.

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

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

Ninety-five percent interval estimates (or alternative interval estimates) for the hospital-standardized outcome can be computed by identifying the 2.5th and 97.5th percentiles of randomly half of the B estimates (or the percentiles corresponding to the alternative desired intervals). [22]

Figure A.4 Analysis Steps



III. MODEL DEVELOPMENT/VALIDATION RESULTS

a. Model Development and Validation Samples

The risk-adjustment model development sample included 148,132 admissions at 3,223 hospitals in 2008.

The 2008 model validation sample included 148,092 admissions at 3,213 hospitals and the 2007 model validation sample included 300,338 admissions at 3,295 hospitals.

b. Risk-Factor Results in Development and Validation Samples

Table A.4 conveys the parameter estimates, standard errors, odds ratios (OR), and 95% confidence intervals for the model risk factors in the 2008 development and validation samples. Odds ratios are similar in both samples.

Table A.4 Logistic Regression Model Results for 2008 Development Sample (ROC = 0.65) and 2008 Validation Sample (ROC = 0.64)

	2008 Development Sample (N=148,132 at 3,223 hospitals)				2008 Validation Sample (N=148,092 at 3,213 hospitals)			
	Estimate	Standard Error	Odds Ratio	95% Confidence Interval for OR	Estimate	Standard Error	Odds Ratio	95% Confidence Interval for OR
Intercept	-3.86	0.04			-3.85	0.04		
Demographics								
Age-65 (years above 65, continuous)	0.03	0.00	1.03	(1.03 – 1.04)	0.03	0.00	1.03	(1.03 – 1.04)
Male	0.10	0.02	1.10	(1.05 – 1.16)	0.11	0.02	1.11	(1.07 – 1.17)
THA/TKA Procedure								
THA procedure	0.12	0.02	1.13	(1.07 – 1.18)	0.16	0.02	1.17	(1.12 – 1.22)
Number of procedures (two vs. one)	0.17	0.06	1.18	(1.05 – 1.33)	0.27	0.06	1.31	(1.16 – 1.47)
Comorbid Conditions								
Skeletal deformities (ICD-9 code 755.63)	0.02	0.29	1.02	(0.58 – 1.80)	0.09	0.28	1.10	(0.63 – 1.91)
Post traumatic osteoarthritis (ICD-9 codes 716.15, 716.16)	0.01	0.14	1.01	(0.76 – 1.34)	-0.17	0.16	0.85	(0.62 – 1.15)
Morbid obesity (ICD-9 code 278.01)	0.24	0.06	1.28	(1.14 – 1.42)	0.26	0.06	1.27	(1.13 – 1.41)
History of infection (CC 1, 3-6)	0.11	0.03	1.11	(1.06 – 1.17)	0.11	0.03	1.11	(1.06 – 1.18)
Metastatic cancer and acute leukemia (CC 7)	0.17	0.12	1.19	(0.94 – 1.51)	0.22	0.12	1.25	(0.99 – 1.58)
Cancer (CC 8-12)	-0.01	0.03	0.99	(0.93 – 1.04)	-0.07	0.03	0.94	(0.89 – 0.99)
Diabetes and DM complications (CC 15-20, 119, 120)	0.17	0.02	1.18	(1.13 – 1.24)	0.09	0.02	1.09	(1.04- 1.15)
Protein-calorie malnutrition (CC 21)	0.19	0.10	1.21	(0.99 – 1.48)	0.13	0.11	1.14	(0.92 – 1.41)
Disorders of fluid/electrolyte/acid-base (CC 22, 23)	0.14	0.03	1.51	(1.08 – 1.22)	0.14	0.03	1.15	(1.08 – 1.23)
Rheumatoid arthritis and inflammatory connective Tissue disease (CC 38)	0.07	0.04	1.07	(1.00 – 1.16)	0.11	0.04	1.12	(1.04 – 1.20)
Severe hematological disorders (CC 44)	0.37	0.10	1.45	(1.20 – 1.75)	0.43	0.10	1.54	(1.28 – 1.86)
Dementia and senility (CC 49, 50)	0.27	0.04	1.31	(1.20 – 1.42)	0.14	0.05	1.15	(1.05 – 1.26)
Major psychiatric disorders (CC 54-56)	0.33	0.05	1.39	(1.26 – 1.53)	0.25	0.05	1.28	(1.16 – 1.41)
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177-178)	0.10	0.07	1.10	(0.95 – 1.28)	0.16	0.07	1.17	(1.01 – 1.35)
Polyneuropathy (CC 71)	0.15	0.04	1.16	(1.07 – 1.26)	0.15	0.04	1.16	(1.07 – 1.26)
Congestive heart failure (CC 80)	0.20	0.03	1.23	(1.15 – 1.31)	0.22	0.03	1.25	(1. 17 – 1.33)
Chronic atherosclerosis (CC 83-84)	0.21	0.02	1.24	(1.18 – 1.30)	0.24	0.02	1.27	(1.21 – 1.33)
Hypertension (CC 89, 91)	0.17	0.03	1.19	(1.11 – 1.27)	0.19	0.03	1.21	(1.13 – 1.29)
Arrhythmias (CC 92, 93)	0.15	0.03	1.17	(1.11 – 1.22)	0.16	0.03	1.17	(1.12 – 1.23)
Stroke (CC 95, 96)	0.01	0.06	1.01	(0.90 – 1.14)	0.09	0.06	1.10	(0.97 – 1.24)
Vascular or circulatory disease (CC 104-106)	0.13	0.03	1.14	(1.08 – 1.19)	0.08	0.03	1.09	(1.04 – 1.14)
COPD (CC 108)	0.25	0.03	1.28	(1.22 – 1.36)	0.26	0.03	1.29	(1.22 – 1.37)
Pneumonia (CC 111-113)	0.22	0.04	1.25	(1.15 – 1.35)	0.18	0.04	1.20	(1.11 – 1.30)
End-stage renal disease or dialysis (CC 129, 130)	0.59	0.18	1.80	(1.27 – 2.55)	0.88	0.17	2.41	(1.73 – 3.34)
Renal failure (CC 131)	0.18	0.04	1.19	(1.11 – 1.29)	0.21	0.04	1.23	(1.14 – 1.33)
Decubitus ulcer or chronic skin ulcer (CC 148, 149)	0.13	0.06	1.14	(1.02 – 1.27)	0.15	0.06	1.17	(1.05 – 1.30)
Cellulitis, local skin infection (CC 152)	0.19	0.04	1.20	(1.12 – 1.29)	0.10	0.04	1.11	(1.03 – 1.19)
Other injuries (CC162)	0.13	0.02	1.14	(1.09 – 1.20)	0.17	0.02	1.18	(1.13 – 1.24)
Major symptoms, abnormalities (CC 166)	0.14	0.02	1.15	(1.10 – 1.21)	0.14	0.02	1.15	(1.10 – 1.21)

c Risk-Adjustment Model Performance and Validation

Using the development sample, we computed five summary statistics for assessing the risk-adjustment model performance[14]: over-fitting indices, predictive ability, area under the receiver operating characteristic (ROC) curve (C statistic), distribution of residuals, and model Chi Square. We then compared the model performance in the development sample with its performance in the 2008 and 2007 model validation samples. Table A.5 conveys the logistic regression model performance for all samples.

Over-fitting refers to the phenomenon in which a model describes the relationship between predictive variables and outcome well in one group of patients, but fails to provide valid predictions in another distinct group of patients. Estimated values of γ_0 far from 0 and estimated values of γ_1 far from 1 provide evidence of over-fitting (See footnote for Table A.5 for calculation steps). In the development and validation samples, γ_0 is close to zero and the γ_1 is close to one, providing no evidence of over-fitting (Table A.5).

Discrimination in predictive ability measures the ability to distinguish high-risk subjects from low-risk subjects. Good model discrimination is indicated by a wide range between the lowest decile and highest decile, which the models show (Table A.5).

The C statistic is a measure of how accurately a statistical model is able to distinguish between a patient with and without an outcome. For binary outcomes the C statistic is identical to the receiver operator curve (ROC). A C statistic of 0.50 indicates random prediction, implying all patient risk factors are useless. A c statistic of 1.0 indicates perfect prediction, implying patients' outcomes can be predicted completely by their risk factors, and physicians and hospitals play no role in patients' outcomes. While higher C statistic is desirable, we do not want to maximize it by adjusting for hospital and physician characteristics that may influence the outcome. The C statistic for the 2008 development model is 0.65 and 0.64 for the 2008 validation model. The C statistic for the 2007 validation model is 0.64, indicating good discriminant ability.

Overall, the model showed good performance consistent across all samples.

Table A.5 Model Performance for Logistic Regression Model

Indices	2008 Development Sample	2008 Validation Sample	2007 Validation Sample
Year	2008 (50%)	2008 (50%)	2007 (100%)
Number of Admissions	148,132	148,092	300,338
Number of Hospitals	3,223	3,213	3,295
Number of Readmissions	9,121	9,131	19,129
Calibration ($\gamma 0$, $\gamma 1$)[1]	(0, 1)	(-0.06, 0.98)	(-0.11, 0.94)
Discrimination -Predictive Ability (lowest decile %, highest decile %)	(2.4%, 13.4%)	(2.6%, 13.2%)	(2.8%, 13.4%)
Discrimination – Area Under Receiver Operator Curve	0.65	0.64	0.64
Residuals Lack of Fit (Pearson Residual Fall %)			
<-2	0	0	0
[-2, 0)	93.8	93.8	93.6
[0, 2)	0.1	0.1	0.1
[2+	6.0	6.0	6.2
Model Wald χ^2 [Number of Covariates]	2492 [33]	2406 [33]	4596 [33]

d. Hierarchical Logistic Regression Model Results

Table A.6 conveys the hierarchical logistic regression model results for the full 2008 dataset.

[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., 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.

Table A.6 Hierarchical Logistic Regression Model Results for Full 2008 Sample

Description	Estimate	Standard Error	T-Value	Pr > T-Value	Odds Ratio	95% Confidence Interval for OR
Intercept	-3.88	0.04	-94.45	<.0001		
Demographics						
Age-65 (years above 65, continuous)	0.03	0.00	19.44	<.0001	1.04	(1.03 – 1.04)
Male	0.11	0.02	4.85	<.0001	1.12	(1.07 – 1.17)
THA/TKA Procedure						
THA procedure	0.12	0.02	4.96	<.0001	1.12	(1.07 – 1.18)
Number of procedures (two vs. one)	0.17	0.06	2.73	0.006	1.18	(1.05 – 1.33)
Comorbid Conditions						
Skeletal deformities (ICD-9 code 755.63)	0.05	0.28	0.18	0.855	1.05	(0.61 – 1.83)
Post traumatic osteoarthritis (ICD-9 codes 716.15, 716.16)	-0.01	0.14	-0.04	0.967	0.99	(0.75 – 1.31)
Morbid obesity (ICD-9 code 278.01)	0.24	0.05	4.33	<.0001	1.27	(1.14 – 1.41)
History of infection (CC 1, 3-6)	0.10	0.03	3.77	0.000	1.11	(1.05 – 1.16)
Metastatic cancer and acute leukemia (CC 7)	0.19	0.12	1.62	0.105	1.21	(0.96 – 1.53)
Cancer (CC 8-12)	-0.01	0.03	-0.46	0.649	0.99	(0.94 – 1.04)
Diabetes and DM complications (CC 15-20, 119, 120)	0.16	0.02	6.88	<.0001	1.18	(1.12 – 1.23)
Protein-calorie malnutrition (CC 21)	0.20	0.10	1.98	0.047	1.22	(1.00 – 1.49)
Disorders of fluid/electrolyte/acid-base (CC 22, 23)	0.14	0.03	4.48	<.0001	1.15	(1.08 – 1.22)
Rheumatoid arthritis and inflammatory connective Tissue disease (CC 38)	0.07	0.04	2.06	0.039	1.08	(1.00 – 1.16)
Severe hematological disorders (CC 44)	0.38	0.09	4.05	<.0001	1.46	(1.22 – 1.76)
Dementia and senility (CC 49, 50)	0.27	0.04	6.29	<.0001	1.31	(1.20 – 1.43)
Major psychiatric disorders (CC 54-56)	0.33	0.05	7.02	<.0001	1.39	(1.27 – 1.52)
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177-178)	0.10	0.07	134	0.182	1.10	(0.96 – 1.27)
Polyneuropathy (CC 71)	0.16	0.04	3.83	0.001	1.17	(1.08 – 1.27)
Congestive heart failure (CC 80)	0.20	0.03	6.31	<.0001	1.22	(1.15 – 1.30)
Chronic atherosclerosis (CC 83-84)	0.21	0.02	9.03	<.0001	1.24	(1.18 – 1.30)
Hypertension (CC 89, 91)	0.16	0.03	5.15	<.0001	1.18	(1.11 – 1.26)
Arrhythmias (CC 92, 93)	0.16	0.02	6.27	<.0001	1.17	(1.11 – 1.23)
Stroke (CC 95, 96)	0.02	0.06	0.40	0.689	1.02	(0.91 – 1.15)
Vascular or circulatory disease (CC 104-106)	0.12	0.02	4.82	<.0001	1.13	(1.07 – 1.18)
COPD (CC 108)	0.24	0.03	8.92	<.0001	1.28	(1.21 – 1.35)
Pneumonia (CC 111-113)	0.22	0.04	5.65	<.0001	1.25	(1.16 – 1.35)
End-stage renal disease or dialysis (CC 129, 130)	0.58	0.18	3.28	0.001	1.78	(1.26 – 2.52)
Renal failure (CC 131)	0.18	0.04	4.68	<.0001	1.20	(1.11 – 1.29)
Decubitus ulcer or chronic skin ulcer (CC 148, 149)	0.12	0.05	2.28	0.023	1.13	(1.02 – 1.26)
Cellulitis, local skin infection (CC 152)	0.19	0.04	4.53	<.0001	1.21	(1.13 – 1.30)
Other injuries (CC162)	0.13	0.02	5.68	<.0001	1.14	(1.09 – 1.20)
Major symptoms, abnormalities (CC 166)	0.14	0.02	5.95	<.0001	1.15	(1.10 – 1.20)

e. Unadjusted and Adjusted Readmission Rate Distributions (Model Development)

Figures A.3 and A.4 display the frequency distributions of the hospital-specific readmission rates, with and without risk adjustment and standardization for the full 2008 cohort. The unadjusted mean readmission rate was 6.78% and ranges from 0% to 100% (Figure A.3). The median unadjusted readmission rate was 5.52%.

After adjusting for patient and clinical characteristics, accounting for the clustering of patients within hospitals, and including a hospital-specific effect, the risk-standardized rates are more normally distributed (Figure A.4) with a mean of 6.30%, ranging from 3.06% to 50.94%. The median adjusted readmission rate was 6.06%.

Figure A.3 Distribution of Unadjusted Hospital Readmission Rates (full 2008 Sample; N=3,310 Hospitals)

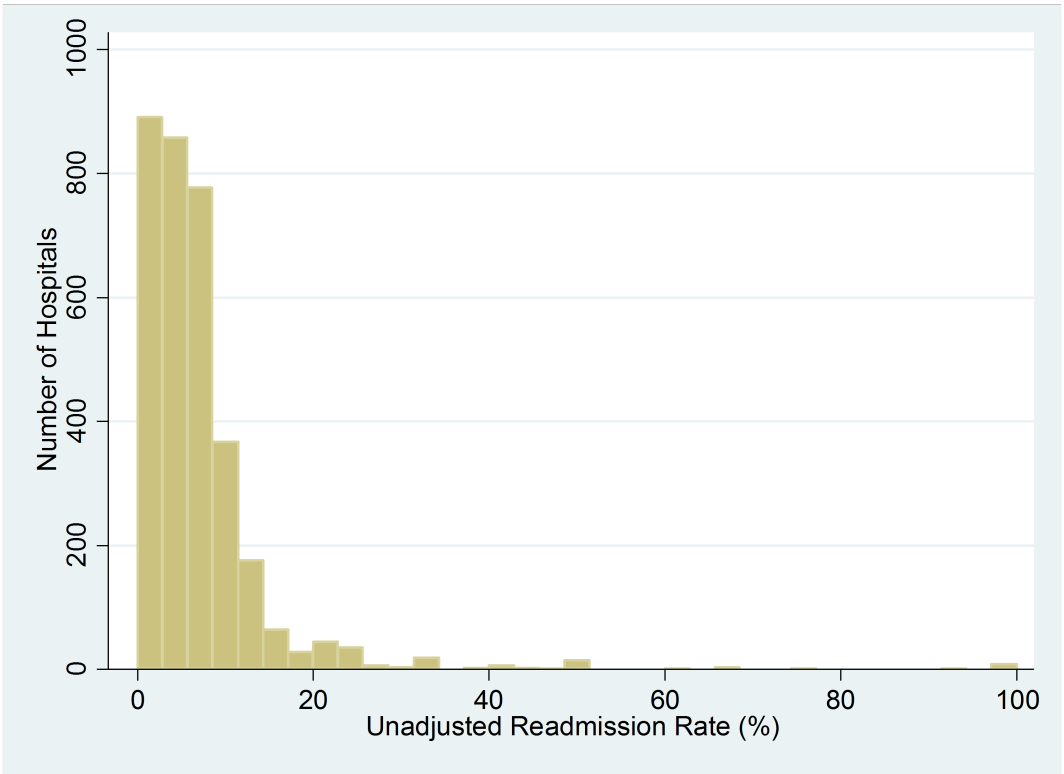
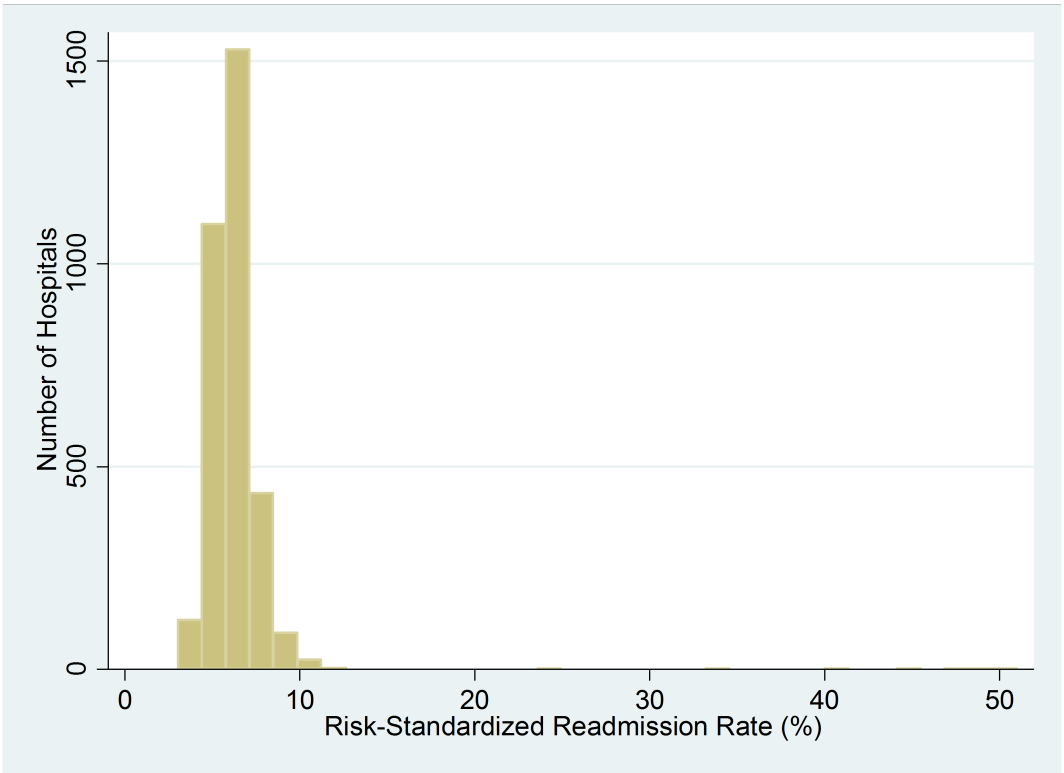


Figure A.4 Distribution of Hospital Risk-Standardized Readmission Rates (full 2008 Sample; N=3,310 Hospitals) – Hierarchical Logistic Regression Model



f. Measure Testing

i. Reliability of the Data Elements

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

In addition, CMS has in place several hospital auditing programs used to assess overall claims code accuracy, ensure appropriate billing, and for

overpayment recoupment. CMS routinely conducts data analysis to identify potential problem areas and detect fraud, and audits important data fields used in our measures, including diagnosis and procedure codes, and other elements that are consequential to payment.

The data elements we use are stable over time. We used data from 2007 and 2008 to assess the stability of the data elements over time: 148,132 admissions from 3,223 hospitals in 2008 development sample, 148,092 admissions from 3,213 hospitals in 2008 validation sample and 300,338 admissions from 3,295 hospitals in 2007 validation sample. Table A.7 conveys the model risk factor frequencies in these samples. There were no notable changes in risk factor frequencies.

Table A.8 shows the adjusted odds ratios for the logistic regression (patient-level) model variables in the 2007 and 2008 data samples. There are no notable differences in the odds ratios across the samples. The consistency in the rates of the risk adjustment variables, and their relationship to the outcome across two years of data all demonstrate the reliability of the measure data elements.

Table A.7 Risk Factor Frequency by Year of Discharge (Logistic Regression Model)

Description	2008 Development Sample	2008 Validation Sample	2007 Validation Sample
Male	35.8	35.6	35.5
THA procedure	28.8	28.7	28.6
Number of procedures (one vs. two)	3.3	3.3	3.6
Skeletal deformities	0.1	0.1	0.1
Post traumatic osteoarthritis	0.5	0.6	0.5
Morbid obesity	3.4	3.4	2.9
Metastatic cancer and acute leukemia	0.6	0.6	0.7
Cancer	12.8	12.8	12.8
Respiratory/Heart/Digestive/Urinary/Other Neoplasms	17.9	18.0	17.8
Diabetes and DM complications	27.3	27.4	26.8
Protein-calorie malnutrition	0.6	0.7	0.5
Bone/Joint/Muscle Infections/Necrosis	3.0	2.8	3.1
Rheumatoid Arthritis and Inflammatory Connective Tissue Disease	8.5	8.6	8.3
Osteoarthritis of Hip or Knee	95.3	95.4	95.3
Osteoporosis and Other Bone/Cartilage Disorders	24.8	25.1	24.2
Dementia and senility	4.4	4.4	4.2
Major psychiatric disorders	3.7	3.8	3.6
Hemiplegia, paraplegia, paralysis, functional disability	1.5	1.6	1.5
Cardio-Respiratory Failure and Shock	2.1	2.1	2.0
Chronic Atherosclerosis	30.7	30.7	31.1
Stroke	2.5	2.4	2.5
Vascular or circulatory disease	22.5	22.6	22.1
COPD	14.7	14.7	15.2
Pneumonia	5.4	5.5	5.5
Pleural effusion/pneumothorax	1.5	1.5	1.5
End-stage renal disease or dialysis	0.1	0.2	0.2
Renal Failure	6.0	6.2	5.5
Decubitus ulcer or chronic skin ulcer	0.4	0.5	0.4
Trauma	5.1	5.1	5.0
Vertebral Fractures	1.3	1.4	1.3
Other injuries	27.6	27.7	27.7
Major Complications of Medical Care and Trauma	3.9	3.9	3.9

Table A.8 Standardized Estimates by Year of Discharge (Logistic Regression Model)

Description	2008 (100%)			2007 (100%)		
	Standardized Estimates	OR	95% CI for OR	Standardized Estimates	OR	95% CI for Odds Ratio
Demographics						
Age-65 (years above 65, continuous)	0.11	1.03	(1.03 - 1.04)	0.11	1.03	(1.03 – 1.04)
Male	0.03	1.11	(1.07 - 1.15)	0.02	1.09	(1.06 – 1.13)
THA/TKA Procedure						
THA procedure	0.03	1.15	(1.11 - 1.19)	0.02	1.10	(1.07 – 1.14)
Number of procedures (two vs. one)	0.02	1.24	(1.14 - 1.35)	0.02	1.22	(1.13 – 1.32)
Comorbid Conditions						
Skeletal deformities (ICD-9 code 755.63)	0.00	1.05	(0.71 - 1.57)	-0.00	0.98	(0.66 – 1.46)
Post traumatic osteoarthritis (ICD-9 codes 716.15, 716.16)	-0.00	0.93	(0.75 - 1.14)	0.01	1.14	(0.94 – 1.39)
Morbid obesity (ICD-9 code 278.01)	0.02	1.29	(1.19 - 1.39)	0.03	1.41	(1.30 – 1.52)
History of Infection (CC 1, 3-6)	0.02	1.11	(1.07 - 1.16)	0.02	1.10	(1.06 – 1.14)
Metastatic cancer and acute leukemia (CC 7)	0.01	1.22	(1.03 - 1.44)	0.01	1.38	(1.18 – 1.60)
Cancer (CC 8-12)	-0.01	0.96	(0.92 - 1.00)	-0.00	0.98	(0.95 – 1.02)
Diabetes and DM complications (CC 15-20, 119, 120)	0.03	1.14	(1.10 - 1.18)	0.03	1.14	(1.10 – 1.18)
Protein-calorie malnutrition (CC 21)	0.01	1.18	(1.01 - 1.36)	0.01	1.38	(1.19 – 1.59)
Disorders of Fluid/Electrolyte/Acid-Base (CC 22, 23)	0.03	1.15	(1.10- 1.20)	0.02	1.13	(1.09 – 1.18)
Rheumatoid Arthritis and Inflammatory Connective Tissue Disease (CC 38)	0.01	1.10	(1.04 - 1.15)	0.01	1.12	(1.07 – 1.18)
Severe Hematological Disorders (CC 44)	0.02	1.50	(1.31 - 1.71)	0.02	1.46	(1.28 – 1.67)
Dementia and senility (CC 49, 50)	0.02	1.23	(1.16 - 1.31)	0.02	1.18	(1.11 – 1.26)
Major psychiatric disorders (CC 54-56)	0.03	1.33	(1.25 - 1.43)	0.03	1.31	(1.22 – 1.40)
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177-178)	0.01	1.14	(1.02 - 1.26)	0.01	1.17	(1.06 – 1.29)
Polyneuropathy (CC 71)	0.02	1.16	(1.09 - 1.23)	0.02	1.14	(1.07 – 1.21)
Congestive Heart Failure (CC 80)	0.03	1.24	(1.18 - 1.29)	0.03	1.23	(1.17 – 1.28)
Chronic Atherosclerosis (CC 83-84)	0.06	1.26	(1.21 - 1.30)	0.05	1.22	(1.18 – 1.26)
Hypertension (CC 89, 91)	0.04	1.20	(1.15 - 1.26)	0.03	1.16	(1.11 – 1.21)
Arrhythmias (CC 92, 93)	0.04	1.17	(1.13 - 1.21)	0.03	1.14	(1.10 – 1.18)
Stroke (CC 95, 96)	0.00	1.05	(0.97 - 1.15)	0.02	1.19	(1.10 – 1.29)
Vascular or circulatory disease (CC 104-106)	0.02	1.11	(1.07 - 1.15)	0.02	1.09	(1.06 – 1.13)
COPD (CC 108)	0.05	1.29	(1.24 - 1.34)	0.05	1.27	(1.23 – 1.32)
Pneumonia (CC 111-113)	0.03	1.22	(1.16 - 1.29)	0.02	1.18	(1.12 – 1.25)
End-stage renal disease or dialysis (CC 129, 130)	0.02	2.08	(1.64 - 2.65)	0.01	1.31	(1.01 – 1.71)
Renal Failure (CC 131)	0.03	1.21	(1.15 - 1.28)	0.03	1.30	(1.23 – 1.37)
Decubitus ulcer or chronic skin ulcer (CC 148, 149)	0.01	1.15	(1.07 - 1.24)	0.01	1.17	(1.09 – 1.26)
Cellulitis, Local Skin Infection (CC 152)	0.02	1.16	(1.10 - 1.22)	0.02	1.11	(1.05 – 1.17)
Other injuries (CC162)	0.04	1.16	(1.12 - 1.20)	0.03	1.12	(1.09 – 1.16)
Major Symptoms, Abnormalities (CC 166)	0.04	1.15	(1.11 - 1.19)	0.05	1.18	(1.14 – 1.22)

ii. Reliability of the Risk-Adjustment Model

As stated previously we evaluated model performance in the development sample and validation samples. The results of these analyses were consistent in all samples indicating good reliability (See Section III. c. for detailed results). Additionally, no notable differences were observed in risk factor ORs across the years of data (Table A.8), indicating reliable model estimation.

iii. Validity

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

In 2010, YNHHSC/CORE conducted a national, multi-site validation study for a procedure-based complications measure, it was developed in 2009 (Hospital Risk-Standardized Complication Rate Following Implantation of Implantable Cardioverter Defibrillator (ICD)). That study demonstrated strong agreement between complications coded in claims and those documented in the medical record, suggesting that claims data variables are valid and therefore can be used reliably for developing new claims-based outcome measures.

In 2010 – 2011, YNHHSC/CORE also conducted a medical record validation study of the complementary complications measure (hospital-level, risk-standardized complication rate following elective primary THA and/or TKA procedures). The goal of that study was to determine the overall agreement between arthroplasty patients identified as having a complication (or no complication) in the claims-based measure and those who had a complication (or no complication) also documented in the medical record. Overall measure agreement was 93% (598/644 patients) before any changes were made to the model specifications. After the measure specifications were changed based upon both the results of this validation study, the measure agreement between claims data and the medical record was 99% (635/644). The full report from that validation study is in Appendix E of the complementary hospital-level risk-

standardized complications measure technical report located at http://www.qualitynet.org > Hospitals-Inpatient > Claims-Based Measures > New Hospital Wide and Hip/Knee Measures In Testing.

Appendix B: ICD-9-CM Codes for Osteoarthritis, Rheumatoid Arthritis, Osteonecrosis, and Arthropathy

Rheumatoid Arthritis	
714.0	Rheumatoid arthritis
714	Rheumatoid arthritis and other inflammatory polyarthropathies
714.1	Felty's syndrome
714.2	Other rheumatoid arthritis with visceral or systemic involvement
714.3	Juvenile chronic polyarthritis
714.30	Chronic or unspecified polyarticular juvenile rheumatoid arthritis
714.31	Acute polyarticular juvenile rheumatoid arthritis
714.32	Pauciarticular juvenile rheumatoid arthritis
714.33	Monoarticular juvenile rheumatoid arthritis
714.4	Chronic postrheumatic arthropathy
714.8	Other specified inflammatory polyarthropathies
714.89	Other specified inflammatory polyarthropathies
714.9	Unspecified inflammatory polyarthropathy

Osteoarthritis	
715	Osteoarthrosis and allied disorders
715.0	Osteoarthrosis generalized
715.00	Osteoarthrosis generalized involving unspecified site
715.09	Osteoarthrosis generalized involving multiple sites
715.1	Osteoarthrosis localized primary
715.10	Osteoarthrosis localized primary involving unspecified site
715.15	Osteoarthrosis localized primary involving pelvic region and thigh
715.16	Osteoarthrosis localized primary involving lower leg
715.18	Osteoarthrosis localized primary involving other specified sites
715.2	Osteoarthrosis localized secondary
715.20	Osteoarthrosis localized secondary involving unspecified site
715.25	Osteoarthrosis localized secondary involving pelvic region and thigh
715.26	Osteoarthrosis localized secondary involving lower leg
715.28	Osteoarthrosis localized secondary involving other specified sites
715.3	Osteoarthrosis localized not specified whether primary or secondary
715.30	Osteoarthrosis localized not specified whether primary or secondary involving unspecified site
715.35	Osteoarthrosis localized not specified whether primary or secondary involving pelvic region and thigh
715.36	Osteoarthrosis localized not specified whether primary or secondary involving lower leg
715.38	Osteoarthrosis localized not specified whether primary or secondary involving other specified sites
715.8	Osteoarthrosis involving or with mention of more than one site but not specified as generalized
715.80	Osteoarthrosis involving or with more than one site but not specified as generalized and involving unspecified site
715.89	Osteoarthrosis involving or with multiple sites but not specified as generalized
715.9	Osteoarthrosis unspecified whether generalized or localized
715.90	Osteoarthrosis unspecified whether generalized or localized involving unspecified site
715.95	Osteoarthrosis unspecified whether generalized or localized involving pelvic region and thigh
715.96	Osteoarthrosis unspecified whether generalized or localized involving lower leg
715.98	Osteoarthrosis unspecified whether generalized or localized involving other specified sites

Arthropathy	
716.5	Unspecified polyarthropathy or polyarthritis
716.50	Unspecified polyarthropathy or polyarthritis site unspecified
716.55	Unspecified polyarthropathy or polyarthritis involving pelvic region and thigh
716.56	Unspecified polyarthropathy or polyarthritis involving lower leg
716.58	Unspecified polyarthropathy or polyarthritis involving other specified sites
716.59	Unspecified polyarthropathy or polyarthritis involving multiple sites
716.8	Other specified arthropathy
716.80	Other specified arthropathy no site specified
716.85	Other specified arthropathy involving pelvic region and thigh
716.86	Other specified arthropathy involving lower leg
716.88	Other specified arthropathy involving other specified sites
716.89	Other specified arthropathy involving multiple sites
716.9	Unspecified arthropathy
716.90	Unspecified arthropathy site unspecified
716.95	Unspecified arthropathy involving pelvic region and thigh
716.96	Unspecified arthropathy involving lower leg
716.98	Unspecified arthropathy involving other specified sites
716.99	Unspecified arthropathy involving multiple sites

Osteonecrosis	
733.42	Aseptic necrosis of head and neck of femur
733.43	Aseptic necrosis of medial femoral condyle

Appendix C: ICD-9-CM Codes for Femur, Hip, and Pelvic Fractures, Revision Procedures, Partial Hip Arthroplasty, Resurfacing Procedures, Mechanical Complications, Removal of Implanted Device, and Malignant Neoplams[1]

Femur, Hip, and Pelvic Fracture Codes	
733.10	Pathological fracture unspecified site
733.14	Pathological fracture of neck of femur
733.15	Pathological fracture of other specified part of femur
733.19	Pathological fracture of other specified site
733.8	Malunion and nonunion of fracture
733.81	Malunion of fracture
733.82	Nonunion of fracture
733.95	Stress fracture of other bone
733.96	Stress fracture of femoral neck
733.97	Stress fracture of shaft of femur
808.0	Closed fracture of acetabulum
808.1	Open fracture of acetabulum
808.2	Closed fracture of pubis
808.3	Open fracture of pubis
808.41	Closed fracture of ilium
808.42	Closed fracture of ischium
808.43	Multiple closed pelvic fractures w/ disruption of pelvic circle
808.49	Closed fracture of other specified part of pelvis
808.50	Open fracture of other specified part of pelvis
808.51	Open fracture of ilium
808.52	Open fracture of ischium
808.53	Multiple open pelvic fractures w/ disruption of pelvic circle
808.8	Unspecified closed fracture of pelvis
820	Fracture of neck of femur
820.0	Transcervical fracture closed
820.00	Fracture of unspecified intracapsular section of neck of femur closed
820.01	Fracture of epiphysis (separation) (upper) of neck of femur closed
820.02	Fracture of midcervical section of femur closed
820.03	Fracture of base of neck of femur closed
820.09	Other transcervical fracture of femur closed
820.1	Transcervical fracture open
820.10	Fracture of unspecified intracapsular section of neck of femur open
820.11	Fracture of epiphysis (separation) (upper) of neck of femur open
820.12	Fracture of midcervical section of femur open
820.13	Fracture of base of neck of femur open
820.19	Other transcervical fracture of femur open
820.2	Pertrochanteric fracture of femur closed
820.20	Fracture of unspecified trochanteric section of femur closed
820.21	Fracture of intertrochanteric section of femur closed
820.22	Fracture of subtrochanteric section of femur closed
820.3	Pertrochanteric fracture of femur open
820.30	Fracture of unspecified trochanteric section of femur open
820.31	Fracture of intertrochanteric section of femur open

[1] Shaded rows refer to ICD-9 codes that were added as exclusions based on NQF review of the measure and on the medical record validation study.

Femur, Hip, and Pelvic Fracture Codes	
820.32	Fracture of subtrochanteric section of femur open
820.8	Fracture of unspecified part of neck of femur closed
820.9	Fracture of unspecified part of neck of femur open
821	Fracture of other and unspecified parts of femur
821.0	Fracture of shaft or unspecified part of femur closed
821.00	Fracture of unspecified part of femur closed
821.01	Fracture of shaft of femur closed
821.1	Fracture of shaft or unspecified part of femur open
821.10	Fracture of unspecified part of femur open
821.11	Fracture of shaft of femur open
821.2	Fracture of lower end of femur closed
821.20	Fracture of lower end of femur unspecified part closed
821.21	Fracture of femoral condyle closed
821.22	Fracture of lower epiphysis of femur closed
821.23	Supracondylar fracture of femur closed
821.29	Other fracture of lower end of femur closed
821.3	Fracture of lower end of femur open
821.30	Fracture of lower end of femur unspecified part open
821.31	Fracture of femoral condyle open
821.32	Fracture of lower epiphysis of femur open
821.33	Supracondylar fracture of femur open
821.39	Other fracture of lower end of femur open

THA and TKA Revision Codes	
81.53	Revise Hip Replacement, NOS
81.55	Revision of Knee replacement, NOS
81.59	Revision of joint replacement of lower extremity, not elsewhere classified
00.70	REV Hip Repl-acetab/fem OCT05
00.71	REV Hip Repl-acetab comp OCT05
00.72	REV Hip Repl-fem comp OCT05
00.73	REV Hip Repl-liner/head OCT05
00.80	Replacement of femoral, tibial, and patellar components (all components)
00.81	Replacement of tibial baseplate and tibial insert (liner)
00.82	Revision of knee replacement, femoral component
00.83	Revision of knee replacement, patellar component
00.84	Revision of total knee replacement, tibial insert (liner)

Partial Hip Replacement	
81.52	Partial Hip Replacement

THA Resurfacing Procedure Codes	
00.85	Resurfacing hip, total, acetabulum and femoral head, hip resurfacing arthroplasty, total
00.86	Resurfacing hip, partial, femoral head, hip resurfacing arthroplasty, NOS, hip resurfacing arthroplasty, partial, femoral head
00.87	Resurfacing hip, partial, acetabulum, hip resurfacing arthroplasty, partial, acetabulum

[1] Shaded rows refer to ICD-9 codes that were added as exclusions based on NQF review of the measure and on the medical record validation study.

Mechanical Complications Codes	
996.4	Mechanical complication of internal orthopedic device implant and graft
996.40	Unspecified mechanical complication of internal orthopedic device, implant and graft
996.41	Mechanical loosening of prosthetic joint
996.42	Dislocation of prosthetic joint
996.43	Broken prosthetic joint implant
996.44	Peri prosthetic fracture around prosthetic joint
996.45	Peri prosthetic osteolysis
996.46	Articular bearing surface wear of prosthetic joint
996.47	Other mechanical complication of prosthetic joint implant
996.49	Other mechanical complication of other internal orthopedic device, implant, and graft
996.77	Other complications due to internal joint prosthesis
996.78	Other complications due to other internal orthopedic device implant and graft

Removal of Implanted Devices/Prosthesis Codes	
78.65	Removal of implanted devices from femur
78.66	Removal of implanted devices from bone; patella
78.67	Removal of implanted devices from bone; tibia and fibula
80.05	Arthrotomy for removal of prosthesis - femur
80.06	Arthrotomy for removal of prosthesis without replacement, knee
80.09	Arthrotomy For Removal Of Prosthesis Without Replacement, Other Specified Sites

Malignant Neoplasms Codes	
170.6	Malignant neoplasm of pelvic bones sacrum and coccyx
170.7	Malignant neoplasm of long bones of lower limb
170.9	Malignant neoplasm of bone and articular cartilage site unspecified
195.3	Malignant neoplasm of pelvis
195.5	Malignant neoplasm of lower limb
198.5	Secondary malignant neoplasm of bone and bone marrow
199.0	Disseminated malignant neoplasm

[1] Shaded rows refer to ICD-9 codes that were added as exclusions based on NQF review of the measure and on the medical record validation study.

Appendix D: Conditions Not Adjusted For If Coded Only During Index Admission As They May Represent Adverse Outcomes of Care Received

CC	Description
2	Septicemia/Shock
6	Other Infectious Diseases
17	Diabetes with Acute Complications
23	Disorders of Fluid/Electrolyte/Acid-Base
24	Other Endocrine/Metabolic/Nutritional Disorders
28	Acute Liver Failure/Disease
31	Intestinal Obstruction/Perforation
34	Peptic Ulcer, Hemorrhage, Other Specified Gastrointestinal Disorders
36	Other Gastrointestinal Disorders
37	Bone/Joint/Muscle Infections/Necrosis
43	Other Musculoskeletal and Connective Tissue Disorders
46	Coagulation Defects and Other Specified Hematological Disorders
47	Iron Deficiency and Other/Unspecified Anemias and Blood Disease
48	Delirium and Encephalopathy
51	Drug/Alcohol Psychosis
75	Coma, Brain Compression/Anoxic Damage
76	Mononeuropathy, Other Neurological Conditions/Injuries
77	Respirator Dependence/Tracheostomy Status
78	Respiratory Arrest
79	Cardio-respiratory failure and shock
80	Congestive heart failure
81	Acute myocardial infarction
85	Heart Infection/Inflammation, Except Rheumatic
92	Specified Heart Arrhythmias
93	Other Heart Rhythm and Conduction Disorders
95	Cerebral Hemorrhage
96	Ischemic or Unspecified Stroke
97	Precerebral Arterial Occlusion and Transient Cerebral Ischemia
100	Hemiplegia/Hemiparesis
101	Cerebral Palsy and Other Paralytic Syndromes
102	Speech, Language, Cognitive, Perceptual
104	Vascular Disease with Complications
105	Vascular Disease
106	Other Circulatory Disease
111	Aspiration and Specified Bacterial Pneumonias
112	Pneumococcal Pneumonia, Emphysema, Lung Abscess
113	Viral and Unspecified Pneumonia, Pleurisy
114	Pleural Effusion/Pneumothorax
130	Dialysis Status
131	Renal failure
132	Nephritis
133	Urinary Obstruction and Retention
135	Urinary Tract Infection
148	Decubitus Ulcer of Skin

CC	Description
152	Cellulitis, Local Skin Infection
154	Severe Head Injury
155	Major Head Injury
156	Concussion or Unspecified Head Injury
158	Hip Fracture/Dislocation
159	Major Fracture, Except of Skull, Vertebrae, or Hip
160	Internal Injuries
161	Traumatic Amputation
162	Other Injuries
163	Poisonings and Allergic Reactions
164	Major Complications of Medical Care and Trauma
165	Other Complications of Medical Care
175	Other Organ Transplant/Replacement
177	Amputation Status, Lower Limb/Amputation
178	Amputation Status, Upper Limb

Appendix E: CCs Not Considered for Risk Adjustment

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