NATIONAL QUALITY FORUM

Measure Evaluation 4.1
December 2009

This form contains the measure information submitted by stewards. Blank fields indicate no information was provided. Attachments also may have been submitted and are provided to reviewers. The subcriteria and most of the footnotes from the evaluation criteria are provided in Word comments within the form and will appear if your cursor is over the highlighted area. Hyperlinks to the evaluation criteria and ratings are provided in each section.

TAP/Workgroup (if utilized)**:** Complete all yellow highlighted areas of the form. Evaluate the extent to which each subcriterion is met. Based on your evaluation, summarize the strengths and weaknesses in each section.

Note: *If there is no TAP or workgroup, the SC also evaluates the subcriteria (yellow highlighted areas).*

Steering Committee: Complete all pink highlighted areas of the form. Review the workgroup/TAP assessment of the subcriteria, noting any areas of disagreement; then evaluate the extent to which each major criterion is met; and finally, indicate your recommendation for the endorsement. Provide the rationale for your ratings.

Evaluation ratings of the extent to which the criteria are met
C = Completely (unquestionably demonstrated to meet the criterion)
P = Partially (demonstrated to partially meet the criterion)
M = Minimally (addressed BUT demonstrated to only minimally meet the criterion)
N = Not at all (NOT addressed; OR incorrectly addressed; OR demonstrated to NOT meet the criterion)
NA = Not applicable (only an option for a few subcriteria as indicated)

(for NQF staff use) **NQF Review #:** 1551 **NQF Project:** Surgery Endorsement Maintenance 2010
MEASURE DESCRIPTIVE INFORMATION
De.1 **Measure Title:** Hospital-level 30-day all-cause risk-standardized readmission rate (RSRR) following elective primary total hip arthroplasty (THA) and total knee arthroplasty (TKA)
De.2 **Brief description of measure***:* This measure estimates hospital 30-day RSRRs following elective primary THA and TKA in patients 65 years and older. The measure uses Medicare claims data to develop a hospital-level RSRR for THA and TKA and will include patients readmitted for any reason within 30 days of discharge date of the index admission. Some patients are admitted within 30 days of the index hospitalization to undergo another elective THA/TKA procedure. These are considered planned readmissions and are NOT counted in the measure as readmissions.
1.1-2 **Type of Measure:** Outcome De.3 **If included in a composite or paired with another measure, please identify composite or paired measure** This measure is paired with a complications measure for THA and TKA.
De.4 **National Priority Partners Priority Area:** Care coordination, Safety De.5 **IOM Quality Domain**: Effectiveness, Patient-centered, Efficiency, Safety De.6 **Consumer Care Need:** Getting better, Living with illness

CONDITIONS FOR CONSIDERATION BY NQF	
Four conditions must be met before proposed measures may be considered and evaluated for suitability as voluntary consensus standards:	NQF Staff
A. The measure is in the public domain or an intellectual property (measure steward agreement) is signed. *Public domain only applies to governmental organizations. All non-government organizations must sign a measure steward agreement even if measures are made publicly and freely available.* A.1 **Do you attest that the measure steward holds intellectual property rights to the measure and the right to use aspects of the measure owned by another entity (e.g., risk model, code set)?** Yes A.2 **Indicate if Proprietary Measure** (*as defined in measure steward agreement*)**:**	**A** Y☐ N☐

A.3 Measure Steward Agreement: Government entity and in the public domain - no agreement necessary **A.4 Measure Steward Agreement attached:**	
B. The measure owner/steward verifies there is an identified responsible entity and process to maintain and update the measure on a schedule that is commensurate with the rate of clinical innovation, but at least every 3 years. Yes, information provided in contact section	**B** Y☐ N☐
C. The intended use of the measure includes both public reporting and quality improvement. ►**Purpose:** Public Reporting, Quality Improvement with Benchmarking (external benchmarking to multiple organizations)	**C** Y☐ N☐
D. The requested measure submission information is complete. Generally, measures should be fully developed and tested so that all the evaluation criteria have been addressed and information needed to evaluate the measure is provided. Measures that have not been tested are only potentially eligible for a time-limited endorsement and in that case, measure owners must verify that testing will be completed within 12 months of endorsement. **D.1Testing:** Yes, fully developed and tested **D.2 Have NQF-endorsed measures been reviewed to identify if there are similar or related measures?** Yes	**D** Y☐ N☐
(for NQF staff use) **Have all conditions for consideration been met?** **Staff Notes to Steward** (*if submission returned*)**:**	**Met** Y☐ N☐
Staff Notes to Reviewers (*issues or questions regarding any criteria*)**:**	
Staff Reviewer Name(s):	

TAP/Workgroup Reviewer Name:	
Steering Committee Reviewer Name:	
1. IMPORTANCE TO MEASURE AND REPORT	
Extent to which the specific measure focus is important to making significant gains in health care quality (safety, timeliness, effectiveness, efficiency, equity, patient-centeredness) and improving health outcomes for a specific high impact aspect of healthcare where there is variation in or overall poor performance. ***Measures must be judged to be important to measure and report*** *in order to be evaluated against the remaining criteria.* (evaluation criteria) **1a. High Impact**	**Eval Rating**
(for NQF staff use) **Specific NPP goal**:	
1a.1 Demonstrated High Impact Aspect of Healthcare: Affects large numbers, Frequently performed procedure, High resource use, Other **1a.2** High cost **1a.3 Summary of Evidence of High Impact:** Primary elective THA and TKA are beneficial procedures that greatly improve the quality of life for patients who choose to undergo these procedures (Hawker et al., 1998). However, these high volume procedures are expensive and are associated with significant readmission rates. High Readmission Rate We conducted analyses using 2008 Medicare Part A inpatient claims data and found a median 30-day risk-standardized hospital readmission rate of 6.1%. This rate is high considering these are elective procedures typically performed on younger, healthier patients, as compared to other Medicare patients. High Volume THA and TKA are priority areas for outcomes measure development, as they are commonly performed procedures in the US. In 2003 there were 202,500 primary hip arthroplasties and 402,100 primary total knee arthroplasties performed (Kurtz et al., 2007). The number of procedures performed has increased steadily	**1a** C☐ P☐ M☐ N☐

over the past decade (Kurtz et al., 2007; Ong et al., 2006).

High Cost
Although these procedures can dramatically improve patient health-related 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 (Kurtz et al., 2007). 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 (Kurtz et al., 2007). Medicare is the single largest payer for these procedures, covering approximately two-thirds of all THAs and TKAs performed in the US (Ong et al., 2006). THA and TKA procedures combined account for the largest procedural cost in the Medicare budget (Bozic et al., 2008).

1a.4 Citations for Evidence of High Impact: Bozic KJ, Rubash HE, Sculco TP, Berry DJ. An analysis of medicare payment policy for total joint arthroplasty. Journal of Arthroplasty. 2008;23(6 Suppl 1):133-138.

Hawker GJ, Wright J, Coyte P, Paul J, Dittus R, Croxford B, et al. Health-related quality of life after knee replacement. J Bone Joint Surg Am. 1998; 80:163-73.

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.

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.

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.

1b. Opportunity for Improvement

1b.1 Benefits (improvements in quality) envisioned by use of this measure: THA and TKA are priority areas for outcomes measure development, as they are costly and commonly performed procedures. Hospital readmission is an outcome that is likely attributable to care processes and is an important outcome for patients. Measuring and reporting readmission rates will inform health care providers about opportunities to improve care, strengthen incentives for quality improvement, and ultimately improve the quality of care received by Medicare patients. The measure will also provide patients with information that could guide their choices. Furthermore, the measure will increase transparency for consumers and has the potential to lower health care costs associated with readmissions.

1b.2 Summary of data demonstrating performance gap (variation or overall poor performance) across providers:
Readmission rates are high, given these are elective procedures and there is marked variation in rates across hospitals. The unadjusted mean readmission rate was 6.78% and ranged from 0% to 100% across 3,310 hospitals in 2008. Even after adjustment for patient and clinical characteristics, the mean readmission rate was 6.30%, ranging from 3.06% to 50.94%. Because these are elective procedures that are performed on relatively healthy patients, readmission rates are expected to be lower in these patients as compared to patients admitted for an emergent procedure.

The literature indicates there is considerable variation in practice patterns, patient outcomes, and adherence to payer-defined practice guidelines for both THA and TKA (Bozic et al 2008; Ong et al 2008). Our analyses are consistent with this evidence. In 2008, 30-day adjusted readmission rates ranged from 3.06% to 50.94%. This variation likely indicates differences in the quality of care received across hospitals. These findings suggest that many readmissions could potentially be prevented.

1b.3 Citations for data on performance gap:
Bozic KJ, Chiu V. Quality Measurement and Public Reporting in Total Joint Replacement. The Journal of Replacement. 2008; 23:146-149.

Ong K, Lau E, Manley M, Kurtz S. Effect of procedure duration on total hip arthroplasty and total knee arthroplasty survivorship in the United States Medicare population. J Arthroplasty. 2008; 23(6): 127-132.

1b.4 Summary of Data on disparities by population group:

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N ☐

We conducted analyses to explore disparities by SES. We used Medicaid eligibility status identified in the Medicare claims enrollment database (EDB) as a proxy for SES. This approach is consistent with prior research as well as NQF recommendations (http://www.nysna.org/images/pdfs/practice/nqf_ana_outcomes_draft10.pdf). Patients were categorized into two groups, based on their eligibility status for Medicaid (yes/no). The Medicaid eligible population represents lower SES status. Analyses demonstrated that although SES is a significant predictor of readmission at the patient level, it does not affect overall hospital performance in the risk-adjusted readmission model. Consistent with NQF guidelines, this measure does not risk-adjust for SES factors.

1b.5 Citations for data on Disparities:
N/A

1c. Outcome or Evidence to Support Measure Focus

1c.1 Relationship to Outcomes (*For non-outcome measures, briefly describe the relationship to desired outcome. For outcomes, describe why it is relevant to the target population*)**:** This measure will calculate 30-day all-cause hospital-level readmission rates after elective primary THA and/or TKA. The goal is to reduce readmission rates post hospitalization for elective THA/TKA. It addresses an outcome for a commonly performed, high cost procedure performed for a priority condition (osteoarthritis) and may lead to reduced morbidity and mortality.

1c.2-3. Type of Evidence: Expert opinion, Systematic synthesis of research

1c.4 Summary of Evidence (*as described in the criteria; for outcomes, summarize any evidence that healthcare services/care processes influence the outcome*)**:**
Readmission is an outcome that reflects the quality of healthcare for patients undergoing a primary elective THA and/or TKA procedure. However, evidence regarding the relationship between healthcare processes (including inpatient and post-discharge care) and readmissions for this population is sparse. A systematic review of the literature did not identify any existing statistical models to compare hospital-level readmission for patients admitted for an elective THA or TKA. However, a working group and technical expert panel (TEP) of orthopedists, rheumatologists, consumer and purchaser perspective, disparities experts, and quality improvement experts were consulted in confirming that readmission is an outcome likely attributable to care processes see section 2c for details) and that hospital-level readmission rates could be improved.

Research has shown that readmission rates are influenced by the quality of inpatient and outpatient care, as well as hospital system characteristics, such as the bed capacity of the local health care system (Fisher et al. 1994). In addition, specific hospital processes such as discharge planning, medication reconciliation, and coordination of outpatient care have been shown to affect readmission rates (Nelson et al. 2000).

1c.5 Rating of strength/quality of evidence (*also provide narrative description of the rating and by whom***):**
N/A

1c.6 Method for rating evidence: N/A

1c.7 Summary of Controversy/Contradictory Evidence: All-cause readmission

This measure calculates 30-day all cause readmission rate. An alternative approach would be to calculate readmissions for procedure-specific complications (e.g. mechanical complications, revision, wound infection, surgical site bleeding). In consultation with an expert panel, we decided on all-cause readmission (except for planned readmissions), rather than procedure-specific readmission for several reasons. First, from the patient perspective, readmission for any reason is likely to be an undesirable outcome of care. Second, readmissions not associated with a procedure-specific diagnosis may still be related to inpatient care and patients' transitions to non-acute setting. Examples include errors in medication reconciliation, inadequate follow-up, and failure to ensure that patients discharged home have adequate support. Third, a readmission measure will complement the complications measure for patients undergoing TKA/THA that is submitted to NQF. Using all-cause readmission will, however, undoubtedly include a mix of unavoidable and avoidable readmissions. However, the goal of the measure is not to reduce readmissions to zero, but to decrease the readmission rates across hospitals. Readmissions within 30 days after discharge from an elective procedure are likely attributable to the care received during the index admission.

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N ☐

Planned Readmissions

Some patients are admitted within 30 days of the index hospitalization to undergo another THA/TKA procedure. Some of these are considered planned readmissions and we do NOT count them as readmissions in the measure. If a patient undergoes a second primary THA/TKA and is admitted to the hospital 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, and arthropathy (excluding septic arthropathy), the readmission is likely planned and is not counted as a readmission in the measure.

Use of Hierarchical Generalized Linear Modeling
Hierarchical modeling for hospital outcomes measurement is the appropriate statistical approach for hospital outcomes measures given the structure of the data and the underlying assumption of such measures, which is that hospital quality of care influences 30-day readmission rates. However, CMS frequently receives comments and questions about this approach, so we are concisely reiterating the rationale for and merits of using hierarchical logistic regression. Patients are clustered within hospitals and, as such, have a shared exposure to the hospital quality and processes. The use of hierarchical modeling accounts for the clustering of patients within hospitals. Second, hierarchical models distinguish within-hospital variation and between-hospital variation to estimate the hospital's contribution to the risk of readmission. This allows for an estimation of the hospital's influence on patient outcomes. Finally, within hierarchical models we can account for both differences in case mix and sample size to fairly profile hospital performance. If we did not use hierarchical modeling we could overestimate variation and potentially misclassify hospitals' performance. Accurately estimating variation is an important objective for models used in public reporting and potentially used in value-based purchasing programs.

1c.8 Citations for Evidence (*other than guidelines*): Fisher ES, Wennberg JE, Stukel TA, Sharp SM. Hospital readmission rates for cohorts of Medicare beneficiaries in Boston and New Haven. N Engl J Med. 1994;331(15):989-995.

Nelson EA, Maruish ME, Axler JL. Effects of discharge planning and compliance with outpatient appointments on readmission rates. Psychiatr Serv. 2000;51(7):885-889.

1c.9 Quote the Specific guideline recommendation (*including guideline number and/or page number*):
Not applicable-we didn't cite any clinical practice guidelines because this is an outcomes measure, not a process of care measure.

1c.10 Clinical Practice Guideline Citation: N/A
1c.11 National Guideline Clearinghouse or other URL: N/A

1c.12 Rating of strength of recommendation (*also provide narrative description of the rating and by whom*):
N/A

1c.13 Method for rating strength of recommendation (*If different from USPSTF system, also describe rating and how it relates to USPSTF)*:
N/A

1c.14 Rationale for using this guideline over others:
N/A

TAP/Workgroup: What are the strengths and weaknesses in relation to the subcriteria for *Importance to Measure and Report?*	**1**
Steering Committee: Was the threshold criterion, *Importance to Measure and Report*, met? **Rationale:**	**1** **Y☐** **N☐**
2. SCIENTIFIC ACCEPTABILITY OF MEASURE PROPERTIES	

Extent to which the measure, as specified, produces consistent (reliable) and credible (valid) results about the quality of care when implemented. (evaluation criteria)	Eval Rating

2a. MEASURE SPECIFICATIONS

S.1 Do you have a web page where current detailed measure specifications can be obtained?
S.2 If yes, provide web page URL:

2a. Precisely Specified

2a.1 Numerator Statement (*Brief, text description of the numerator - what is being measured about the target population, e.g. target condition, event, or outcome***):**
This outcome measure does not have a traditional numerator and denominator like a core process measure (e.g., percentage of adult patients with diabetes aged 18-75 years receiving one or more hemoglobin A1c tests per year); thus, we are using this field to define readmissions.

The outcome for this measure is a readmission to any acute care hospital, for any reason occurring within 30 days of the discharge date of the index hospitalization. We do not count planned readmissions in the outcome (see numerator details).

2a.2 Numerator Time Window (*The time period in which cases are eligible for inclusion in the numerator***):**
30 days from discharge date of index hospitalization

2a.3 Numerator Details (*All information required to collect/calculate the numerator, including all codes, logic, and definitions***):**
A readmission to any acute care hospital for any reason within 30 days of the discharge date of index hospitalization.

Planned (elective) readmissions: We do not count readmissions in the measure that are associated with a subsequent "planned" THA/TKA procedure within 30-days of discharge from index hospitalization. Some patients may elect to stage their orthopedic replacement procedures across hospitalizations (for example, a patient may have the left and right knees replaced within one or two weeks of each other, potentially across multiple hospitalizations). In consultation with an expert panel we define planned readmissions as a second admission with an ICD-9 procedure code for THA or TKA AND a principal discharge diagnosis of osteoarthritis, rheumatoid arthritis, osteonecrosis, or arthropathy (excluding septic arthropathy).

The criteria for identifying a subsequent planned THA and/or TKA is as follows:
1. Admission with at least one of the following ICD-9 procedure codes within 30 days of discharge date of index hospitalization:
- 81.51 – Primary total hip replacement
- 81.54 – Primary total knee replacement, AND

2. A principal diagnosis code of one the following ICD-9 codes for osteoarthritis, rheumatoid arthritis, osteonecrosis, or arthropathy:
- 714, 714.0, 714.1, 714.2, 714.3, 714.30, 714.31, 714.32, 714.33, 714.4, 714.8, 714.89, 714.9, 715, 715.0, 715.00, 715.09, 715.1, 715.10, 715.15, 715.16, 715.18, 715.2, 715.20, 715.25, 715.26, 715.28, 715.3, 715.30, 715.35, 715.36, 715.38, 715.8, 715.80, 715.89, 715.9, 715.90, 715.95, 715.96, 715.98, 716.5, 716.50, 716.55, 716.56, 716.58, 716.59, 716.8, 716.80, 716.85, 716.86, 716.88, 716.89, 716.9, 716.90, 716.95, 716.96, 716.98, 716.99, 733.42, 733.43

2a.4 Denominator Statement (*Brief, text description of the denominator - target population being measured***):**
The target population for this measure includes admissions for patients at least 65 years of age undergoing primary THA and/or TKA procedures.

2a.5 Target population gender: Female, Male
2a.6 Target population age range: 65 years of age and older

2a.7 Denominator Time Window (*The time period in which cases are eligible for inclusion in the*

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denominator):
This measure was developed using claims data from calendar year 2007 and 2008. The time period for public reporting has not been determined.

2a.8 **Denominator Details (***All information required to collect/calculate the denominator - the target population being measured - including all codes, logic, and definitions***):**
The denominator includes patients aged 65 and older admitted to non-federal acute care hospitals for an elective, primary THA and/or TKA in 2007 and 2008. Patients are eligible for inclusion in the denominator if they had a THA and/or a TKA AND had continuous enrollment in Medicare FFS one year prior to the date of index admission.

This cohort is defined using the following ICD-9-CM procedure codes identified in Medicare Part A Inpatient claims data:
81.51 Total Hip Arthroplasty
81.54 Total Knee Arthroplasty

2a.9 **Denominator Exclusions (***Brief text description of exclusions from the target population***):** Patients will be excluded from the cohort if they meet any of the followed criteria:

1. Patients with hip fractures
Presence of one of the following diagnosis codes: 733.1, 733.10, 733.14, 733.15, 733.19, 733.8, 733.81, 733.82, 733.95, 733.96, 733.97, 808.0, 808.1, 820.00, 820.01, 820.02, 820.03, 820.09, 820.10, 820.11, 820.12, 820.13, 820.19, 820.20, 820.21, 820.22, 820.30, 820.31, 820.32, 820.8, 820.9, 821, 821.0, 821.00, 821.01, 821.1, 821.10, 821.11, 808.xx
Rationale: Patients with hip fractures have higher mortality, complication and readmission rates and the procedure (THA) is generally not elective.

2. Patients undergoing revision procedures (with or without a concurrent THA/TKA)
Presence of one of the following procedure codes: 81.53, 81.55, 81.59, 00.70, 00.71, 00.72, 00.73, 00.80, 00.81, 00.82, 00.83, 00.84
Rationale: Revision procedures may be performed at a disproportionately small number of hospitals and are associated with higher mortality, complication, and readmission rates.

3. Patients undergoing partial hip arthroplasty procedures (with or without a concurrent THA/TKA)
Presence of the following procedure code: 81.52
Rationale: Partial arthroplasties are primarily done for hip fractures and are typically performed on patients who are older, more frail, and with more comorbid conditions.

4. Patients undergoing resurfacing procedures (with or without a concurrent THA/TKA)
Presence of one of the following procedure codes: 00.85, 00.86, 00.87
Rationale: Resurfacing procedures are a different type of procedure which are typically performed on younger, healthier patients.

5. Patients with a mechanical complication coded in the principal discharge diagnosis field of the index admission*
Rationale: A complication coded in the principal field indicates it was present on admission, and these patients underwent an arthroplasty due to a complication related to a prior procedure. Furthermore, these patients may require more technically complex arthroplasty procedures, and may be at increased risk for complications, particularly mechanical complications.

6. Patients without at least 30-days post-discharge enrolment in Medicare
Rationale: The 30-day readmission outcome cannot be assessed for the standardized time period.

7. Patients who are 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.

8. Patients 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.

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

10. Patients with more than two THA/TKA procedures codes during the index hospitalization
Rationale: Patients with more than two procedure codes for THA/TKA are excluded because it is rare that a patient would have 3 arthroplasty procedures done at one time. This is likely to be a coding error.

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

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 admission. They are considered as potential readmissions. Any THA and/or TKA admission is either an index admission or a potential readmission, but not both.

*Based on a medical record validation study of the paired hospital risk-standardized complications measure, we also excluded patients with a mechanical complication coded in the principal discharge diagnosis field of the index admission because a complication coded in the principal field indicates it was present on admission. Furthermore, these patients represent more technically complex arthroplasty procedures, and may be at increased risk for readmission, particularly for mechanical complications.

Prior to this cohort exclusion, there were 295,224 patients in the readmission measure cohort (2008). After excluding from the measure cohort, the patients who had a mechanical complication coded in the principal discharge diagnosis field on the index admission, the number of patients in the cohort decreased by 930 patients to 294,292 (less than 0.5% decrease).

The hospital risk-standardized mean readmission rate prior to this cohort exclusion was 6.25% (range 3.03 to 50.97%). The hospital risk-standardized mean readmission rate after this cohort exclusion increased slightly to 6.27% (range 3.06 to 50.72%). Thus, the additional cohort exclusion has a minimal effect on the hospital risk-standardized mean readmission rate, but the range of the rate still shows significant variation in hospital readmission rates.

Details regarding the validation study are provided in the NQF application for the paired hospital risk-standardized complications measure (section 2c, Validity Testing).

2a.10 Denominator Exclusion Details (*All information required to collect exclusions to the denominator, including all codes, logic, and definitions***):**
See "Denominator Exclusion" section

2a.11 Stratification Details/Variables (*All information required to stratify the measure including the stratification variables, all codes, logic, and definitions***):**
This measure is not stratified.

2a.12-13 Risk Adjustment Type: Risk-adjustment devised specifically for this measure/condition

2a.14 Risk Adjustment Methodology/Variables (*List risk adjustment variables and describe conceptual models, statistical models, or other aspects of model or method***):**
The measure estimates hospital-level 30-day all-cause RSRRs using hierarchical logistic regression models. In brief, the approach simultaneously models outcomes at two levels (patient and hospital) to account for the variance in patient outcomes within and between hospitals (Normand et al., 2007). To model the log-odds of 30-day all-cause readmission at the patient level, the model adjusts for age, sex, and selected clinical covariates. The second level models the hospital-specific intercepts as arising from a normal distribution. The hospital intercept represents the underlying risk of readmission at the hospital, after accounting for case mix. If there were no differences among hospitals, then after adjusting for case mix, the hospital intercepts

should be identical across all hospitals.

The measure adjusts for key variables that are clinically relevant and have strong relationships with the outcome (e.g. demographic factors, disease severity indicators, and indicators of frailty). For each patient, covariates are obtained from Medicare claims extending 12 months prior to and including the index admission. The model adjusts for case mix differences based on the clinical status of the patient at the time of admission. We use condition categories (CCs), which are clinically meaningful groupings of more than 15,000 ICD-9-CM diagnosis and procedure codes. We do not risk-adjust for CCs that are possible adverse events of care and that are only recorded in the index admission. In addition, only comorbidities that convey information about the patient at that time or in the 12-months prior, and not complications that arise during the course of the hospitalization are included in the risk-adjustment. The risk adjustment model included 33 variables which are listed below:

Demographics
1. Age-65 (years above 65, continuous)
2. Sex

TKA/THA Procedure
3. THA procedure
4. Number of procedures (2 vs.1)

Clinical Risk Factors
5. History of Infection (CC 1, 3-6)
6. Metastatic cancer and acute leukemia (CC 7)
7. Cancer (CC 8-12)
8. Diabetes and DM complications (CC 15-20, 119, 120)
9. Protein-calorie malnutrition (CC 21)
10. Disorders of Fluid/Electrolyte/Acid-Base (CC 22, 23)
11. Rheumatoid Arthritis and Inflammatory Connective Tissue Disease (CC 38)
12. Severe Hematological Disorders (CC 44)
13. Dementia and senility (CC 49, 50)
14. Major psychiatric disorders (CC 54-56)
15. Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177-178)
16. Polyneuropathy (CC 71)
17. Congestive Heart Failure (CC 80)
18. Chronic Atherosclerosis (CC 83-84)
19. Hypertension (CC 89, 91)
20. Arrhythmias (CC 92, 93)
21. Stroke (CC 95, 96)
22. Vascular or circulatory disease (CC 104-106)
23. COPD (CC 108)
24. Pneumonia (CC 111-113)
25. End-stage renal disease or dialysis (CC 129, 130)
26. Renal Failure (CC 131)
27. Decubitus ulcer or chronic skin ulcer (CC 148, 149)
28. Cellulitis, Local Skin Infection (CC 152)
29. Other Injuries (CC162)
30. Major Symptoms, Abnormalities (CC 166)
31. Skeletal Deformities (ICD-9 code 755.63)
32. Post Traumatic Osteoarthritis (ICD-9 codes 716.15, 716.16)
33. Morbid Obesity (ICD-9 code 278.01)

Normand S-LT, Shahian DM. 2007. Statistical and Clinical Aspects of Hospital Outcomes Profiling. Stat Sci 22 (2): 206-226.

2a.15-17 Detailed risk model available Web page URL or attachment: Attachment THA-TKA Readmission Technical Report.pdf

2a.18-19 Type of Score: Rate/proportion

2a.20 Interpretation of Score: Better quality = Lower score

2a.21 Calculation Algorithm (*Describe the calculation of the measure as a flowchart or series of steps***):**
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.

The predicted hospital outcome (the numerator) is calculated by regressing the risk factors and the hospital-specific intercept on the risk of readmission, multiplying the estimated regression coefficients by the patient characteristics in the hospital, transforming, and then summing over all patients attributed to the hospital to get a value. The expected number of readmissions (the denominator) is obtained by regressing the risk factors and a common intercept on the readmission outcome using all hospitals in our sample, multiplying the subsequent estimated regression coefficients by the patient characteristics observed in the hospital, transforming, and then summing over all patients in the hospital to get a value.

Please see attachment for more details on the calculation algorithm.

2a.22 Describe the method for discriminating performance *(e.g., significance testing)***:**
The method for discriminating hospital performance has not been determined. For the six publicly reported measures of hospital outcomes developed with similar methodology and reported on the CMS website www.hospitalcompare.hhs.gov, CMS currently estimates an interval estimate for each risk-standardized rate to characterize the amount of uncertainty associated with the rate, compares the interval estimate to the national crude rate for the outcome, and categorizes hospitals as "better than the US national rate," "worse than the US national rate," or "no different than the US national rate." However, the decision to publicly report this measure and the approach has not been determined.

2a.23 Sampling (Survey) Methodology *If measure is based on a sample (or survey), provide instructions for obtaining the sample, conducting the survey and guidance on minimum sample size (response rate)*:
This measure is not based on a survey or sample.

2a.24 Data Source (*Check the source(s) for which the measure is specified and tested)*
Administrative claims

2a.25 Data source/data collection instrument (*Identify the specific data source/data collection instrument, e.g. name of database, clinical registry, collection instrument, etc.***):**
We obtained index admission, readmission, and in-hospital comorbidity data from Medicare's Standard Analytic File (SAF). Comorbidities were also assessed using Part A inpatient, outpatient, and Part B office visit Medicare claims in the 12 months prior to 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.

1. 2008 Part A (inpatient) data

Part A inpatient data includes claims for Medicare inpatient hospital care, skilled nursing facility care, some home health agency services, and hospice care. For purposes of this project, Part A is used to refer to inpatient services only and includes data from 2 time periods:
a. Index admission: Index admission data are based on the inclusion/exclusion criteria for THA/TKA, and comorbidities (if any) are identified from the secondary diagnoses associated with the index admission.
b. Pre-index: 12 months prior to the index admission ("pre-index").

2. 2008 Part A (outpatient) data – 12 months pre-index

Hospital outpatient refers to Medicare 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.

3. Part B data – 12 months pre-index

Part B data refers to Medicare claims for the services of physicians (regardless of setting) and other outpatient care, services, and supplies. For purposes of this project, Part B services included only face-to-face encounters between a care provider and patient. We thus do not include services such as laboratory tests, medical supplies, or other ambulatory services.

2a.26-28 Data source/data collection instrument reference web page URL or attachment:

2a.29-31 Data dictionary/code table web page URL or attachment: URL N/A
http://www.qualitynet.org/dcs/ContentServer?c=Page&pagename=QnetPublic%2FPage%2FQnetTier3&cid=1182785083979

2a.32-35 Level of Measurement/Analysis (*Check the level(s) for which the measure is specified and tested)*
Facility

2a.36-37 Care Settings (*Check the setting(s) for which the measure is specified and tested)*
Hospital/Acute Care Facility

2a.38-41 Clinical Services (*Healthcare services being measured, check all that apply*)

TESTING/ANALYSIS

2b. Reliability testing

2b.1 Data/sample *(description of data/sample and size)*: Medicare Part A inpatient claims data for calendar year 2007 and 2008 were used to test reliability. The 2008 cohort included 296,224 admissions and the 2007 cohort included 300,338 admissions.

2b.2 Analytic Method *(type of reliability & rationale, method for testing)*:
The reliability of the model was tested using identical cohort inclusion/exclusion criteria for patients who underwent THA and/or TKA. We randomly selected 50% of the THA and/or TKA admissions that met all inclusion and exclusion criteria in 2008 and created a development sample, which we used to build the model. We used the remaining 50% of THA/TKA admissions in 2008 as the validation sample. We also used all qualifying THA and/or TKA admissions in 2007 data as an additional sample to validate the model. Model performance was assessed in the development dataset and both validation datasets. In addition we will run the model in additional datasets and compare the risk-standardized readmission rates for each hospital.

2b.3 Testing Results *(reliability statistics, assessment of adequacy in the context of norms for the test conducted)*:
Preliminary results indicate similar model performance in the three cohorts (e.g., ROC=0.64 in all models). See additional results for these cohorts in the "testing results" section below.

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2c. Validity testing

2c.1 Data/sample *(description of data/sample and size)*: Face validity: model performance.

2c.2 Analytic Method *(type of validity & rationale, method for testing)*:
During measure development, we consulted with representatives from potential users of this measure including clinicians, professional societies, payers, and consumers. We use this field to describe the role that these representatives played on the working group and Technical Expert Panel (TEP). We used a structured measure evaluation tool to assess face validity and other measure properties.

We developed this measure in consultation with national guidelines for publicly reported outcomes measures, with outside experts, and with the public. The measure is consistent with the technical approach to outcomes measurement set forth in National Quality Forum (NQF) guidance for outcomes measures (National Quality Forum, 2010), CMS Measure Management System guidance, and the guidance articulated in the American Heart Association scientific statement, "Standards for Statistical Models Used for Public Reporting of Health Outcomes" (Krumholz et al., 2006). We obtained expert and stakeholder input on the measure through three mechanisms: first, through regular discussions with a working group; second, through

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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, we assembled a working group that included individuals with clinical and methodological expertise relevant to orthopedic quality measurement. We held regular conference calls throughout the development process, and the Yale team 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 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 including clinicians, consumers, hospitals, purchasers, and experts in quality improvement. Finally, we solicited public comment on the proposed measure through CMS' Measure Management System Public Comment site (https://www.cms.gov/MMS/17_CallforPublicComment.asp#TopOfPage). Public comments were summarized and publicly posted for 30 days. The resulting content was taken into consideration during the final stages of measure development.

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.

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.

2c.3 Testing Results *(statistical results, assessment of adequacy in the context of norms for the test conducted)*:
The experts agree the measure accurately reflects the quality of care and distinguishes levels of quality for patients undergoing THA and/or TKA.

2d. Exclusions Justified

2d.1 Summary of Evidence supporting exclusion(s):
Rationale for exclusion is described in "Denominator Exclusions."

2d.2 Citations for Evidence:
See "Denominator Exclusions"

2d.3 Data/sample *(description of data/sample and size)*: N/A

2d.4 Analytic Method *(type analysis & rationale)*:
N/A

2d.5 Testing Results *(e.g., frequency, variability, sensitivity analyses)*:
N/A

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NA ☐

2e. Risk Adjustment for Outcomes/ Resource Use Measures

2e.1 Data/sample *(description of data/sample and size)*: 2008 Medicare Part A inpatient and outpatient data and Part B outpatient data are used to identify candidate variables for risk adjustment. Specifically, Medicare Part A inpatient data is used to identify variables for risk adjustment in the index admission. Part A outpatient and Part B data are used to identify comorbid conditions to include in the risk adjustment in the 12-month period preceding the index date of admission. As described in section 2b, we developed and validated the model in three separate cohorts to assess and compare model performance: (1) development

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sample of 148,132 admissions in 2008 data; (2) validation sample of 148,092 in 2008 data; and (3) validation sample of 300,338 admissions in 2007 data.

2e.2 Analytic Method *(type of risk adjustment, analysis, & rationale)*:
This measure is fully risk-adjusted using a hierarchical logistic regression model to calculate hospital RSRRs. (see "risk adjustment methodology" for additional details).

Approach to assessing model performance:

For the development and validation cohorts, we computed five summary statistics for assessing model performance (Harrell, 2001):
(1) over-fitting indices (over-fitting refers to the phenomenon in which a model accurately describes the relationship between predictive variables and outcome in the development dataset but fails to provide valid predictions in new patients)

(2) predictive ability

(3) area under the receiver operating characteristic (ROC) curve

(4) distribution of residuals

(5) model chi-square (A test of statistical significance usually employed for categorical data to determine whether there is a good fit between the observed data and expected values; i.e., whether the differences between observed and expected values are attributable to true differences in characteristics or instead the result of chance variation.

F.E. Harrell and Y.C.T. Shih, Using full probability models to compute probabilities of actual interest to decision makers, Int. J. Technol. Assess. Health Care 17 (2001), pp. 17–26.

2e.3 Testing Results *(risk model performance metrics)*:
Performance Metrics in Development Cohort: Development cohort consisted of 148,132 patient stays at 3,223 hospitals (half of 2008 cohort), with a risk-adjusted median readmission rate of 6.04%. The development model has strong discrimination and fit. The risk-standardized readmission rate ranges from 3.2% to 46.8%, a range of 43.6%. Results are summarized below:

Over-fitting indices: (0,1)
Residuals lack of fit: <-2 = 0.0%; [-2, 0) = 93.8%; [0, 2) = 0.1%; [2+ = 6.0%
Model Chi-square [# of covariates]: 2492 [33]
Predictive ability (lowest decile %, highest decile %): (2.4, 13.4)
Area under the ROC curve = 0.65 (GLM)

The discrimination and the explained variation of the model are consistent with those of models currently used to publicly report condition specific rates of both mortality and readmission.

Model Validation using 2008 Validation Cohort: 2008 Validation cohort consisted of 148,092 admissions (other half of the 2008 cohort) randomly selected from 3,213 hospitals, with a risk-standardized median readmission rate of 6.02%. The model performance was not substantively different in this validation sample, as compared to the development sample. Results are summarized below:

Over-fitting indices: (-0.06, 0.98)
Residuals lack of fit: <-2 = 0.0%; [-2, 0) = 93.8%; [0, 2) = 0.1%; [2+ = 6.0%
Model Chi-square[# of covariates]: 2406 [33]
Predictive ability (lowest decile %, highest decile %):(2.6, 13.2)
Area under the ROC curve = 0.64

Model Validation using 2007 Validation Cohort: 2007 validation cohort consisted of 300,338 admissions from 3,295 hospitals. The model performance was not substantively different in this validation sample, as compared to the development sample. Results are summarized below:

Over-fitting indices: (-0.11, 0.94) Residuals lack of fit: <-2 = 0.0%; [-2, 0) = 93.6%; [0, 2) = 0.1%; [2+ = 6.2% Model Chi-square[# of covariates]: 4596 [33] Predictive ability (lowest decile %, highest decile %):(2.8, 13.4) Area under the ROC curve = 0.64 We also examined the temporal variation of the standardized estimates and frequencies of the variables in the models. The frequencies and regression coefficients are fairly consistent over the three cohorts. 2e.4 **If outcome or resource use measure is not risk adjusted, provide rationale:** N/A	
2f. Identification of Meaningful Differences in Performance 2f.1 **Data/sample from Testing or Current Use** *(description of data/sample and size)*: 2008 Medicare Part A inpatient claims data 2f.2 **Methods to identify statistically significant and practically/meaningfully differences in performance** *(type of analysis & rationale)*: Unadjusted median hospital-level readmission rates following THA and/or TKA were assessed across hospitals. 2f.3 **Provide Measure Scores from Testing or Current Use** *(description of scores, e.g., distribution by quartile, mean, median, SD, etc.; identification of statistically significant and meaningfully differences in performance)*: Median hospital-level risk-standardized readmission rate of 2008 was 6.06% and ranged from 3.06% to 50.94%. This is likely a signal of differences in the quality of care received for patients undergoing THA and/or TKA. Total hip replacement and TKA are elective procedures typically performed on healthy patients. Therefore, readmission rates are expected to be lower than that for an emergent procedures and conditions. The variation observed for readmissions is likely a signal that though rates may be relatively low there are differences in the quality of care delivered across hospitals that result in variation in outcomes.	**2f** C☐ P☐ M☐ N☐
2g. Comparability of Multiple Data Sources/Methods 2g.1 **Data/sample** *(description of data/sample and size)*: No comparable data source is available at this time. We will perform validity testing of the development model in data from a different time frame. 2g.2 **Analytic Method** *(type of analysis & rationale)*: N/A 2g.3 **Testing Results** *(e.g., correlation statistics, comparison of rankings)*: N/A	**2g** C☐ P☐ M☐ N☐ NA☐
2h. Disparities in Care 2h.1 **If measure is stratified, provide stratified results** *(scores by stratified categories/cohorts)*: This measure is not stratified. 2h.2 **If disparities have been reported/identified, but measure is not specified to detect disparities, provide follow-up plans:** There were no hospital-level disparities detected during measure development. Please see "Summary of Data on Disparities by Population Group" for additional information.	**2h** C☐ P☐ M☐ N☐ NA☐
TAP/Workgroup: What are the strengths and weaknesses in relation to the subcriteria for *Scientific Acceptability of Measure Properties?*	**2**
Steering Committee: Overall, to what extent was the criterion, *Scientific Acceptability of Measure Properties*, met? **Rationale:**	**2** C☐ P☐ M☐ N☐

3. USABILITY	
Extent to which intended audiences (e.g., consumers, purchasers, providers, policy makers) can understand the results of the measure and are likely to find them useful for decision making. (evaluation criteria)	Eval Rating
3a. Meaningful, Understandable, and Useful Information **3a.1 Current Use:** Not in use but testing completed **3a.2 Use in a public reporting initiative (disclosure of performance results to the public at large)** (*If used in a public reporting initiative, provide name of initiative(s), locations, Web page URL(s). If not publicly reported, state the plans to achieve public reporting within 3 years*)**:** CMS plans to use the measures for public reporting and will propose the measures through rulemaking process. **3a.3 If used in other programs/initiatives (***If used in quality improvement or other programs/initiatives, name of initiative(s), locations, Web page URL(s). If not used for QI, state the plans to achieve use for QI within 3 years***):** The measure is not currently in use. **Testing of Interpretability** (*Testing that demonstrates the results are understood by the potential users for public reporting and quality improvement*) **3a.4 Data/sample** *(description of data/sample and size)***:** N/A **3a.5 Methods** *(e.g., focus group, survey, QI project)***:** No consumer or other field testing has been completed at this time. However, this measure was systematically evaluated by an expert group of orthopedists and a TEP over a period of eight months. Regular meetings were held throughout the development of this measure, during which we received input and feedback on key methodological and other measure decisions (see section 2c-Validity Testing for more details on process of TEP input). **3a.6 Results** *(qualitative and/or quantitative results and conclusions)***:** The TEP agreed that the measure would be useful in informing consumers and hospitals.	**3a** C☐ P☐ M☐ N☐
3b/3c. Relation to other NQF-endorsed measures **3b.1 NQF # and Title of similar or related measures:**	
(for NQF staff use) **Notes on similar/related endorsed or submitted measures:**	
3b. Harmonization If this measure is related to measure(s) already endorsed by NQF (e.g., same topic, but different target population/setting/data source or different topic but same target population): **3b.2 Are the measure specifications harmonized? If not, why?**	**3b** C☐ P☐ M☐ N☐ NA ☐
3c. Distinctive or Additive Value **3c.1 Describe the distinctive, improved, or additive value this measure provides to existing NQF-endorsed measures:** **5.1 If this measure is similar to measure(s) already endorsed by NQF (i.e., on the same topic and the same target population), Describe why it is a more valid or efficient way to measure quality:** N/A	**3c** C☐ P☐ M☐ N☐ NA ☐
TAP/Workgroup: What are the strengths and weaknesses in relation to the subcriteria for *Usability?*	**3**
Steering Committee: Overall, to what extent was the criterion, *Usability*, met?	**3**

Rationale:	**C☐ P☐ M☐ N☐**
4. FEASIBILITY	
Extent to which the required data are readily available, retrievable without undue burden, and can be implemented for performance measurement. (evaluation criteria)	**Eval Rating**
4a. Data Generated as a Byproduct of Care Processes **4a.1-2 How are the data elements that are needed to compute measure scores generated?** Coding/abstraction performed by someone other than person obtaining original information (E.g., DRG, ICD-9 codes on claims, chart abstraction for quality measure or registry)	**4a** **C☐ P☐ M☐ N☐**
4b. Electronic Sources **4b.1 Are all the data elements available electronically?** (*elements that are needed to compute measure scores are in defined, computer-readable fields, e.g., electronic health record, electronic claims*) Yes **4b.2 If not, specify the near-term path to achieve electronic capture by most providers.**	**4b** **C☐ P☐ M☐ N☐**
4c. Exclusions **4c.1 Do the specified exclusions require additional data sources beyond what is required for the numerator and denominator specifications?** No **4c.2 If yes, provide justification.**	**4c** **C☐ P☐ M☐ N☐ NA☐**
4d. Susceptibility to Inaccuracies, Errors, or Unintended Consequences **4d.1 Identify susceptibility to inaccuracies, errors, or unintended consequences of the measure and describe how these potential problems could be audited. If audited, provide results.** Using administrative claims variables for risk adjustment This measure uses variables from claims data submitted by hospitals to CMS for payment as "clinical" risk adjusters. Prior research has demonstrated that administrative claims data can be used to develop risk-adjusted outcomes measures for mortality following admission for myocardial infarction, heart failure, and death and that the models produce estimates of risk-standardized mortality rates (RSMRs) that are very similar to rates estimated by models based on chart data. This high level of agreement between the clinical and claims-based models supports the use of the claims-based models for public reporting. The models have also demonstrated consistent performance across years of claims data. The approach to identifying risk factors for patients also mitigates the potential limitations of claims data. Because not every diagnosis is coded at every visit, we identified comorbid conditions for risk adjustment in inpatient, outpatient, and physician claims data coded in the year prior to admission, as well as those coded in the secondary diagnosis fields during the index admission. This strategy allows for comprehensive review of patients' medical histories. If a diagnosis appeared only once, in some visits and not others, it was included, minimizing the effect of incomplete coding. 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 covariate in a risk-adjusted model could attenuate the measure's ability to characterize the quality of care delivered by hospitals Potentially creating access barrier These are elective procedures, and therefore publicly reporting this measure could reduce access to care for certain populations, particularly for patients who may be healthy enough to undergo the procedure but who carry a higher risk for readmission. We do not anticipate this; however, we recommend close monitoring of	**4d** **C☐ P☐ M☐ N☐**

any unexpected consequences, once the measure is implemented.	
4e. Data Collection Strategy/Implementation **4e.1 Describe what you have learned/modified as a result of testing and/or operational use of the measure regarding data collection, availability of data/missing data, timing/frequency of data collection, patient confidentiality, time/cost of data collection, other feasibility/ implementation issues:** N/A **4e.2 Costs to implement the measure** (*costs of data collection, fees associated with proprietary measures*)**:** This measure uses claims data submitted by hospitals to CMS for payment, There are no costs associated with data collection, as hospitals are mandated by CMS to submit claims for reimbursement purposes. There is no additional cost/burden on hospitals. **4e.3 Evidence for costs:** N/A **4e.4 Business case documentation:** Key points as noted in various sections of this document are as follows: 1. The median 30-day all-cause risk-standardized readmission rate is high (6.06%) 2. There is substantial variation in risk-standardized readmission rates across hospitals, ranging from 3.06% to 50.94%. 3. Reducing readmission is a key focus of the health care reform bill. 4. Quality of care should be addressed as THA and TKA procedures are associated with high volume and cost (relative to other elective procedures performed in the Medicare population).	**4e** C☐ P☐ M☐ N☐
TAP/Workgroup: What are the strengths and weaknesses in relation to the subcriteria for *Feasibility?*	**4**
Steering Committee: Overall, to what extent was the criterion, *Feasibility*, met? **Rationale:**	**4** C☐ P☐ M☐ N☐
RECOMMENDATION	
(for NQF staff use) **Check if measure is untested and only eligible for time-limited endorsement.**	**Time-limited** ☐
Steering Committee: Do you recommend for endorsement? **Comments:**	Y☐ N☐ A☐
CONTACT INFORMATION	
Co.1 Measure Steward (Intellectual Property Owner) **Co.1 Organization** Centers for Medicare & Medicaid Services (CMS), 7500 Security Blvd, Mail Stop S3-02-01, Baltimore, Maryland, 21244-9045 **Co.2 Point of Contact** Lein, Han, PhD, lein.han@cms.hhs.gov, 410-786-0205-	
Measure Developer If different from Measure Steward **Co.3 Organization** New Haven Health Services Corporation/Center for Outcomes Research and Evaluation (YNHHSC/CORE), 1 Church Street Suite 200, New Haven, Connecticut, 06510 **Co.4 Point of Contact**	

Laura, Grosso, PhD, laura.grosso@yale.edu, 203-764-5742-

Co.5 Submitter If different from Measure Steward POC
Laura, Grosso, PhD, laura.grosso@yale.edu, 203-764-5742-, New Haven Health Services Corporation/Center for Outcomes Research and Evaluation (YNHHSC/CORE)

Co.6 Additional organizations that sponsored/participated in measure development

ADDITIONAL INFORMATION

Workgroup/Expert Panel involved in measure development
Ad.1 Provide a list of sponsoring organizations and workgroup/panel members' names and organizations. Describe the members' role in measure development.
Working Group

Role: To provide technical expertise on key methodological decisions during measure development.

Members:

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, Rheumatology (West Haven Veterans Association Hospital)

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)

Technical Expert Panel

Role: To provide feedback on recommendations for measure development.

Members:

Mark L. Francis, MD
Professor of Medicine and Biomedical Sciences, Chief, Division of Rheumatology, Department of Internal Medicine, Texas 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, University of Pittsburgh
Associate Chief and Director of Clinical Research,
Division of Rheumatology and Clinical Immunology

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, M.Sc.
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, UnitedHealthcare

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

Ad.2 If adapted, provide name of original measure:
Ad.3-5 If adapted, provide original specifications URL or attachment

Measure Developer/Steward Updates and Ongoing Maintenance
Ad.6 Year the measure was first released:
Ad.7 Month and Year of most recent revision:
Ad.8 What is your frequency for review/update of this measure?
Ad.9 When is the next scheduled review/update for this measure?

Ad.10 Copyright statement:

Ad.11 Disclaimers:

Ad.12 -14 Additional Information web page URL or attachment: Attachment Readmission calculation algorithm.pdf

Date of Submission (*MM/DD/YY*)**:** 12/14/2010

THA/TKA Readmission Calculation Algorithm

We estimate a generalized linear model and a hierarchical generalized linear model which accounts for the clustering of observations within hospitals. The generalized linear model (GLM) links the outcome to the patient-level risk factors,[20] Let Y_{ij} denote the outcome (equal to 1 if patient has a readmission, 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

GLM $h(Y_{ij}) = \alpha + \beta\mathbf{Z}_{ij}$ (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 an HGLM that links the risk factors to the same outcome and a hospital-specific random effect,

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

$\alpha_i = \mu + \omega_i;\ \omega_i \sim N(0, \tau^2)$ (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 HGLMs and GLMs are estimated using the SAS software system (GLIMMIX and LOGISTIC procedures, respectively).

We first fit the GLM described in Equation (1) using the logit link.

Having identified the covariates that were selected, we next fit the HGLM described in Equations (2) and (3), again using the logit link function; e.g.,

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

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

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

Hospital performance reporting

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

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

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

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

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

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. The bootstrapping simulation has the advantage of avoiding unnecessary distributional assumptions.

Calculation 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.

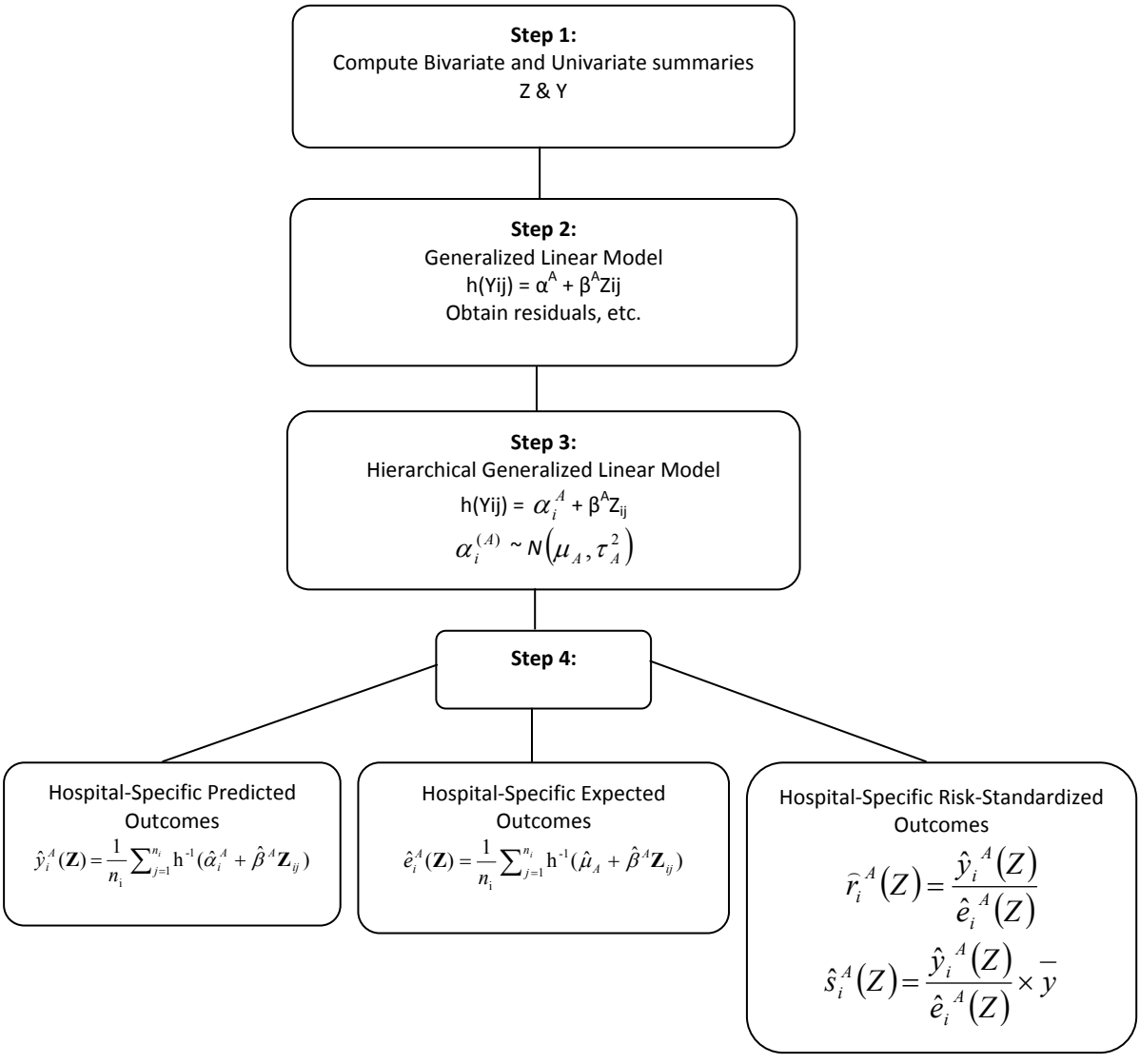
2. Fit the HGLM using all patients within each sampled hospital. We use as starting values the parameter estimates obtained by fitting the model to all hospitals. If some hospitals are selected more than once in a bootstrapped sample, we treat them as distinct so that we have *I* random effects to estimate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

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 $\alpha_i^{(b*)} \sim N\left(\hat{\alpha}_i^{(b)}, \hat{\mathrm{var}}\left(\hat{\alpha}_i^{(b)}\right)\right)$ 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 the B estimates (or the percentiles corresponding to the alternative desired intervals).

Figure 1. Analysis Steps



Hospital-level 30-Day All-Cause Risk-Standardized Readmission Following Elective Total Hip Arthroplasty (THA) and 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, MPH
Yongfei Wang, MS
Elizabeth E. Drye, MD, SM
Harlan M. Krumholz, MD, SM

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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, 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)

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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, M.Sc.
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, UnitedHealthcare

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

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1. INTRODUCTION

1.1 Overview of Measure

Total hip and knee arthroplasties (THA and TKA, respectively) are priority areas for outcomes measure development, as they 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]

Given the high volume and cost associated with these procedures (relative to other elective procedures performed in the Medicare population), it is imperative to address quality of care. Readmissions increase costs associated with THA and TKA and affect the quality, and potentially quantity, of life for patients. A quality measure to address readmission following THA and TKA provides an opportunity to provide targets for efforts to improve the quality of care and reduce costs for patients undergoing these elective procedures.

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 THA and TKA procedures and are suitable for public reporting. YNHHS/CORE, in consultation with CMS, developed a model that estimates hospital-specific, risk-standardized, 30-day all-cause readmission rates following elective THA and TKA procedures. The goal of this readmission measure is to improve the quality of care delivered to patients undergoing THA and TKA procedures.

This report provides the background and detailed technical information on the measure. In brief, we developed a model that estimates hospital-specific, risk-standardized, 30-day all-cause readmission rates following THA/TKA. We used Medicare claims data and linked them to CMS claims and enrollment data to identify readmissions within 30 days from the discharge date of the index admission. To account for the clustering of observations within hospitals and

differences in the number of admissions across hospitals, we used hierarchical logistic regression to estimate the risk-standardized readmission rates (RSRRs).

This measure was developed concurrently with a second CMS outcomes measure-hospital risk-standardized complications for THA/TKA procedures. These are complementary measures that assess separate domains of quality. The complications measure will inform quality improvement efforts targeted toward minimizing medical and surgical complications during surgery and in the recovery phase. The readmission measure captures an additional domain of care provided in the transitions to outpatient settings. The complications measure is presented in a separate technical report.

These two measures expand a set of hospital outcomes measures CMS has developed to improve hospital quality and meet its mandate under the Deficit Reduction Act (DRA) of 2005 to publicly report outcomes and efficiency measures on the consumer Web site, Hospital Compare (http://www.hospitalcompare.hhs.gov). CMS began publicly reporting acute myocardial infarction (AMI) and heart failure (HF) 30-day mortality measures as outcomes measures in June 2007, and added a pneumonia 30-day mortality measure in August 2008. In addition, CMS began publicly reporting 30-day readmission measures for AMI, HF, and pneumonia in July 2009.

1.2 Approach to Measure Development

We developed this measure in consultation with national guidelines for publicly reported outcomes measures, with outside experts, and with the public. The measure is consistent with the technical approach to outcomes measurement set forth in National Quality Forum (NQF) guidance for outcomes measures,[5] CMS Measure Management System guidance, and the guidance articulated in the American Heart Association scientific statement, "Standards for Statistical Models Used for Public Reporting of Health Outcomes."[6] We obtained expert and stakeholder input on the measure through three mechanisms: first, through regular discussions with a working group; 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, we assembled a working group that included individuals with clinical and methodological expertise relevant to orthopedic quality measurement. We held regular conference calls throughout the development process and the Yale team 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 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 including clinicians, consumers, hospitals, purchasers, and experts in quality improvement. Finally, we solicited public comment on the proposed measure through CMS' Measure Management System Public Comment site (https://www.cms.gov/MMS/17_CallforPublicComment.asp#TopOfPage). Public comments were summarized and publicly posted for 30 days. The resulting content was taken into consideration during the final stages of measure development.

1.3 Importance of a Readmission Measure

THA and TKA are priority areas for outcomes measure development, as they are costly and commonly performed procedures. Hospital readmission is an outcome that is likely attributable to care processes and is an important outcome for patients. Measuring and reporting readmission rates will inform health care providers about opportunities to improve care, strengthen incentives for quality improvement, and ultimately improve the quality of care received by Medicare patients. The measure will also provide patients with information that could guide their choices. Furthermore, the measure will increase transparency for consumers and has the potential to lower health care costs associated with readmissions.

Research has shown that readmission rates are influenced by the quality of inpatient and outpatient care, as well as hospital system characteristics, such as the bed capacity of the local health care system.[7] In addition, specific hospital processes such as discharge planning, medication reconciliation, and coordination of outpatient care have been shown to affect readmission rates.[8]

Preliminary analyses using 2008 Medicare Part A inpatient claims indicate that readmission rates post THA and TKA are high for elective procedures and vary across hospitals. Preliminary analyses indicated the median 30-day risk-standardized hospital readmission rate was 6.1%. This rate is high given these are elective procedures typically performed on healthier Medicare patients. Additionally, results demonstrated that the rates varied across hospitals (5^{th} percentile, 4.6%; 95^{th} percentile, 8.4%) indicating there is room for quality improvement.

2. METHODS

2.1 Overview

We developed a hospital-level 30-day, all-cause risk-standardized measure of readmission to any acute care hospital following THA/TKA. We developed this model for all inpatient admissions with a primary elective THA and/or TKA using hierarchical generalized linear modeling (HGLM), to account for the clustering of patients within hospitals. To adjust for differences in hospital case mix, the model adjusted for patient risk factors, including age and comorbidities present at the time of admission. A detailed description of the risk-adjustment variables and the measure methodology is in Sections 2.6 and 2.7.

We identified index admissions for inclusion in the measure via ICD-9 procedure codes for THA and TKA in 2008 Medicare Part A inpatient claims. Because there are no dates associated with procedure codes in Part A data, we use the date of the index admission as the starting point for all follow-up. We used Medicare Part A data for years 2008 and 2009 to identify readmissions. We identified Information on comorbid conditions for risk adjustment using ICD-9 codes in inpatient, outpatient, and part B Medicare claims data in the 12 months prior to the date of the index admission.

The measure calculates the hospital risk-standardized readmission rate (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 raw readmission rate. For each hospital, the "numerator" of the ratio is the number of readmissions predicted on the basis of the hospital's performance with its observed case mix (using an estimated hospital-specific intercept term), and the "denominator" is the number of expected readmissions, based on the nation's performance using the hospital's observed case mix and the national intercept term.

The model estimates the hospital-specific intercept term used in the numerator based on how well each hospital performs relative to other hospitals with a similar case mix. Among hospitals with similar case mixes, hospitals that have a lower rate of readmission will have a lower intercept term; hospitals that have a higher rate of readmission will have a higher intercept term.

2.2 Data Sources

We obtained index admission, readmission, and in-hospital comorbidity data from Medicare's Standard Analytic File (SAF). Comorbidities were also assessed using Part A inpatient, outpatient, and Part B office visit Medicare claims in the 12 months prior to 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.

2.3 Outcome Definition

The outcome for this measure is 30-day all-cause readmission. We define a readmission as a subsequent acute care hospital inpatient admission within 30 days of the discharge date for the index admission.

2.3.1 Planned Readmissions

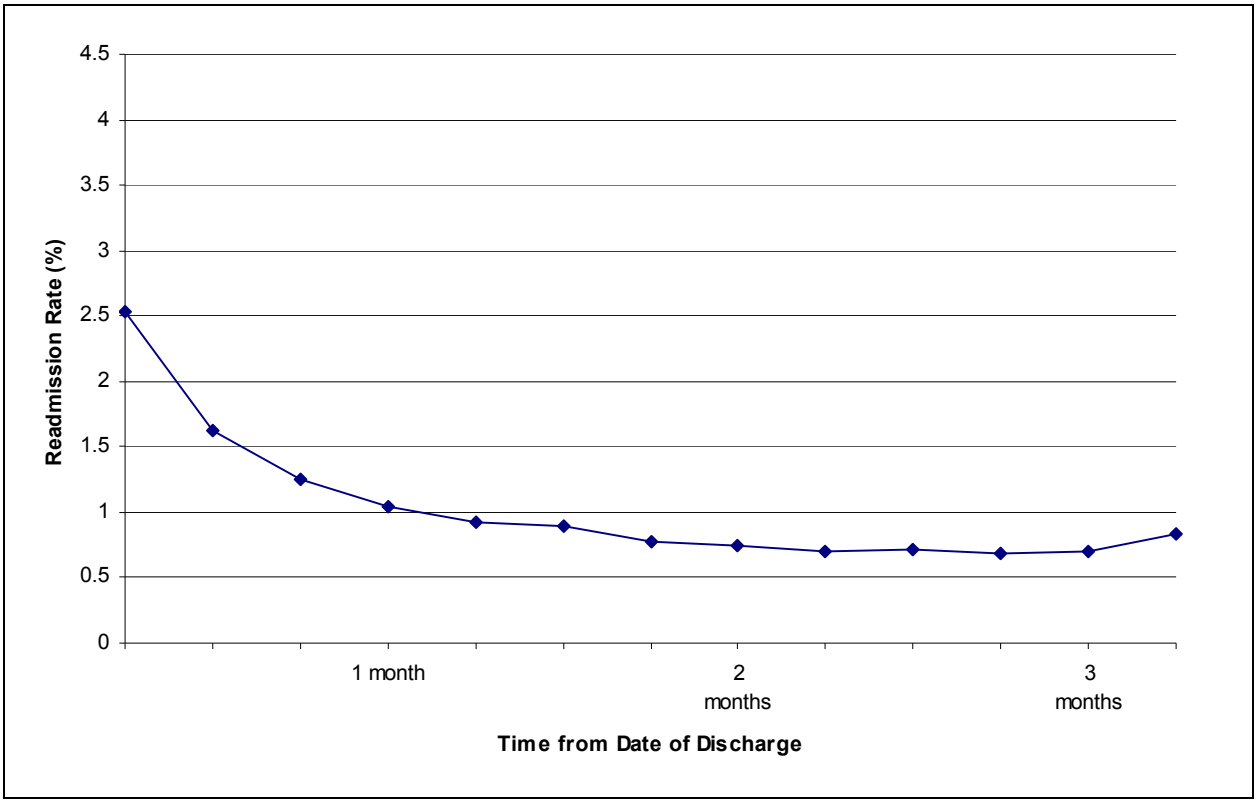
Some patients are admitted within 30 days of the index hospitalization to undergo another THA/TKA procedure. Some of these are considered planned readmissions and we do NOT count them as readmissions in the measure. If a patient undergoes a second primary THA/TKA and is admitted to the hospital within 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, and arthropathy (excluding septic arthropathy), the readmission is likely planned and is not counted as a readmission in the measure. Appendix A lists the ICD-9 codes used to identify these discharge diagnoses.

2.3.2 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 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 National Quality Forum (NQF).

Based on preliminary analyses of the hazard of readmission over a 90-day period, risk of readmission is highest within the first two weeks after the discharge date from the index admission (Figure 1). The rate plateaus between 30 and 45 days post discharge, suggesting that a 30-day timeframe would capture the period of highest risk of readmission.

Figure 1. Hazard of Readmission Following THA/TKA (Medicare Part A Inpatient, 2008)



2.3.3 All-Cause Readmission

We used all-cause readmission (excluding planned readmissions), rather than readmission for 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 assess hospital performance relative to what is expected given the performance of other hospitals with similar case mixes.

2.4 Cohort Definition

In consultation with the working group, 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. We combined these patient cohorts 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 (Table 1)
- The mortality and readmission rates are similar (Table 1)
- 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 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		6.9	5.9
	Hospital level: median	5 (0 - 25)	5 (0 - 18)
90-day All-cause Readmission		12.2	10.7
	Hospital level: median	11 (0 - 38)	10 (0 - 27)
Complications		**% (30-day / 90-day)**	**% (30-day / 90-day)**
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		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 ** Includes ICD-9 code 81.54			

Patients undergoing non-elective THA or TKA have greater risk of complications and receive a wider variety of surgical procedures than individuals undergoing elective THA or TKA. In consultation with the working group and with the goal of defining a comprehensive yet reasonably homogeneous cohort for quality

assessment, we selected inclusion and exclusion criteria in order to identify patients undergoing elective THA and TKA for degenerative (either primary or secondary) arthritis.

Patients eligible for inclusion in the measure are those aged 65 and older admitted to non-federal acute care hospitals with an ICD-9 code for THA and/or TKA. Patients must have had continuous enrollment in Medicare fee-for-service (FFS) for one year prior to the date of index admission to ensure full data availability for risk adjustment. The flow chart depicting cohort selection is presented in Figure 2.

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

- 81.51 Total Hip Arthroplasty
- 81.54 Total Knee Arthroplasty

2.5 Exclusion Criteria

1. Patients with hip fractures
   Rationale: Patients with hip fractures have higher mortality, complication, and readmission rates and the procedures are not elective

2. Patients undergoing revision procedures (with or without 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

3. Patients undergoing partial hip arthroplasty (PHA) procedures (with or without a concurrent THA/TKA)
   Rationale: Partial arthroplasties are primarily done for hip fractures and are typically performed on patients who are older, more frail, and with more comorbid conditions

4. Patients undergoing resurfacing procedures (with or without 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. Furthermore, resurfacing procedures are typically performed on younger, healthier patients

5. Patients 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.

6. Patients 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.

7. Patients 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.

8. Patients 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.

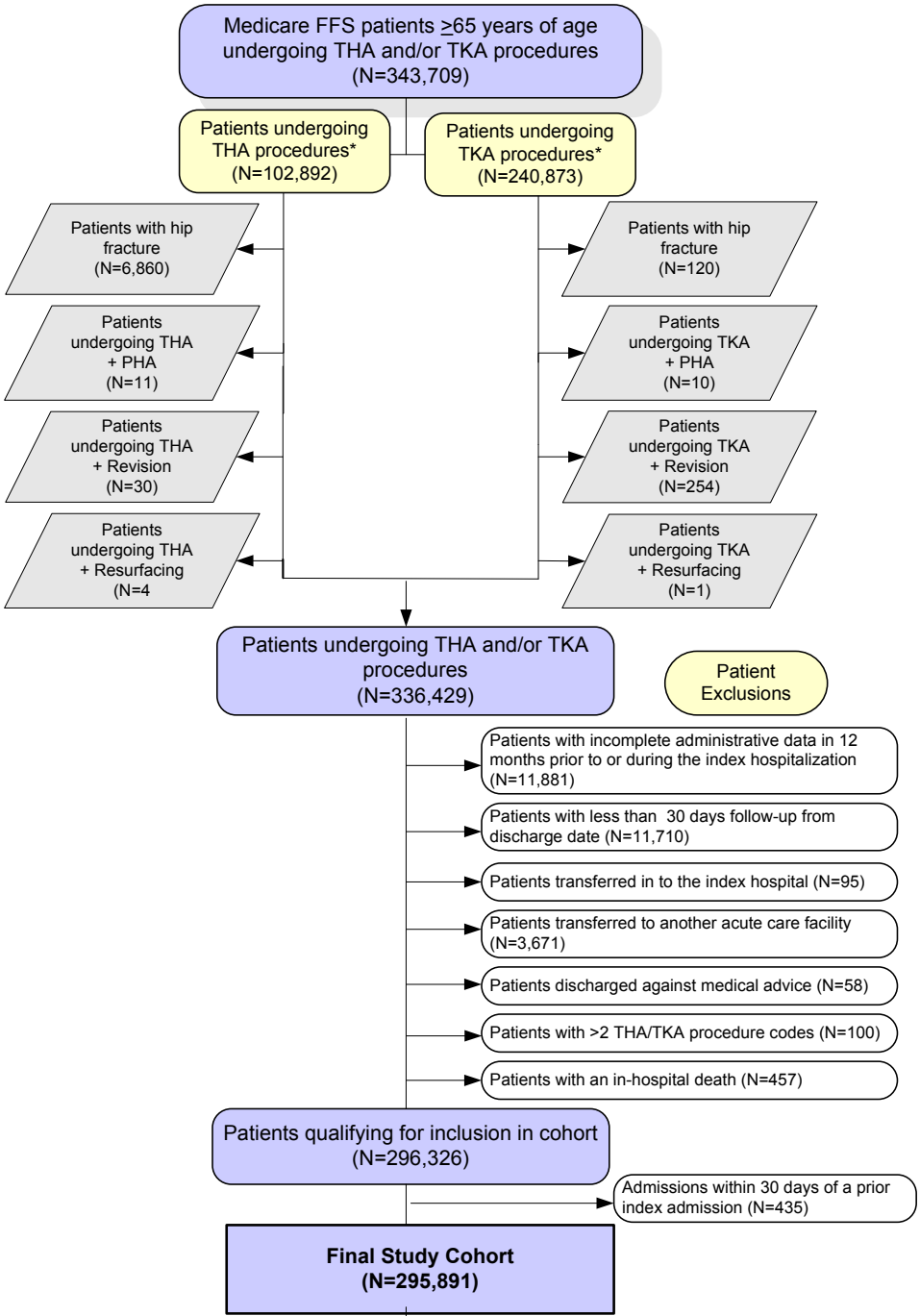
9. Patients without at least 30-days post-discharge enrollment in Medicare FFS.
   Rationale: The 30-day readmission outcome cannot be assessed for the standardized time period.

10. Patients with inconsistent or unknown mortality status or other unreliable data (e.g. date of death precedes admission date)
    Rationale: Outcome status is unreliable, although this is rare.

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

Appendix B lists the ICD-9-CM codes for hip fracture, revision procedures, partial hip arthroplasty procedure, and resurfacing procedures.

Figure 2. Cohort for Model Development



Procedure	N (%)
1 THA procedure	84,094
1 TKA Procedure	202,286
THA + THA	304
TKA + TKA	9,158
THA + TKA	49

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

2.6 Approach to Risk Adjustment

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

Consistent with NQF guidelines, the model does not adjust for socioeconomic status (SES), race, or ethnicity because risk-adjusting for SES would hold hospitals with a large proportion of low SES patients to a different standard of care than hospitals treating a larger proportion of high SES patients. The model does not adjust for patients' admission source and their discharge disposition either (e.g. skilled nursing facility) because these factors are associated with structure of the health care system, and may reflect the quality of care delivered by the system.

2.7 Candidate and Final Risk-adjustment Variables

Our goal 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 inpatient Part A data, outpatient hospital data, and Part B physician data.

For administrative model development, we started with the 189 Condition Categories (CCs). CCs are clinically relevant diagnostic groups of the more than 15,000 ICD-9 codes.[9] We used the April 2010 version of the ICD-9 to CC assignment map, which is maintained by CMS and posted at www.qualitynet.org.

To select candidate variables, a team of clinicians reviewed all 189 CCs and excluded those that were not relevant to the Medicare population (Appendix D) or that were not clinically relevant to the readmission outcome (e.g., attention deficit disorder, female infertility, 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 complications and readmission following THA/TKA. We reviewed these comorbidities and 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, both), and number of procedures (one versus two) and are listed in Table 2.

Table 2. THA/TKA Readmission Model Candidate 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 (one versus two)	
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 Tissue Disease	CC 38
	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

Category	Variable	ICD-9 Code(s) or CC(s)
	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
	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

Category	Variable	ICD-9 Code(s) or CC(s)
	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 129, 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

To inform final variable selection, a modified approach to stepwise logistic regression was performed. A subsample of the data was used to create 500 “bootstrap” samples. For each sample, we ran a logistic stepwise regression that included the 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 (CC 67-69, 100-102, 177-178)
- stroke (CC 95-96)

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

- cancer (CC 8-12)

Final model variables are listed in Table 3.

Table 3. THA/TKA Readmission 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 (1 vs. 2)	
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
	Joint/Muscle Infections/Necrosis	CC 37
	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 129, 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

2.8 Statistical Approach to Model Development

We randomly selected 50% of the THA and/or TKA admissions that met all inclusion and exclusion criteria and created a development sample, which we used to build the model. We used the remaining 50% of THA/TKA admissions as the validation sample. We also used all qualifying THA and/or TKA admissions in 2007 data as an additional sample to validate the model. Model performance was assessed in the development dataset and both validation datasets.

Due to the natural clustering of observations within hospitals, we used hierarchical generalized linear models (HGLMs) to model the log-odds of readmission. Readmission was modeled as a function of patient-level demographic and clinical characteristics and a random hospital-specific intercept. This strategy accounts for within-hospital correlation of the observed outcomes and models the assumption that underlying differences in quality among the health care facilities being evaluated lead to systematic differences in outcomes.

We then calculated hospital risk-standardized readmission rates (RSRRs) using a hierarchical logistic regression model (given the hierarchical nature of the data). These rates are calculated as the ratio of the predicted number of readmissions to the expected number of readmissions, multiplied by the national unadjusted readmission rate. The expected number of readmissions for each hospital was estimated using that hospital's patient mix and the national intercept. Specifically, for each patient in the data set, the estimated regression coefficients are multiplied by the observed characteristics and the average of the hospital-specific intercepts is added to this quantity. Then, the quantity is transformed to the probability scale. For each patient within a hospital, these probabilities are summed. The predicted number of readmissions in each hospital employs a similar calculation. The predicted number of readmissions for each hospital is calculated by summing the predicted readmission rates for all patients in the hospital. The predicted readmission rate for each patient is calculated through the hierarchical model by applying the estimated regression coefficients to the patient characteristics observed and adding the hospital-specific intercept. In order to assess hospital performance in any specific year (e.g. the validation cohort), we re-estimate the model coefficients using that year's data.

More specifically, we estimate a generalized linear model and a hierarchical generalized linear model which accounts for the clustering of observations within hospitals. The generalized linear model (GLM) links the outcome to the patient-level risk factors.[10] Let Y_{ij} denote the outcome (equal to 1 if 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

GLM $h(Y_{ij}) = \alpha + \beta \mathbf{Z}_{ij}$ (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 an HGLM that links the risk factors to the same outcome and a hospital-specific random effect,

HGLM $h(Y_{ij}) = \alpha_i + \beta \mathbf{Z}_{ij}$ (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.[11] This model separates within-hospital variation from between-hospital variation. Both HGLMs and GLMs are estimated using the SAS software system (GLIMMIX and LOGISTIC procedures, respectively).

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

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

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

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

2.9 Hospital Performance Reporting

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

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

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

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

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

2.9.1 Creating Interval Estimates

Because the statistic described in Equation (6) is a complex function of parameter estimates, we use re-sampling and simulation techniques to derive an interval estimate. The bootstrapping simulation has the advantage of avoiding unnecessary distributional assumptions.

2.9.2 Algorithm

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

1. Sample *I* hospitals with replacement.

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

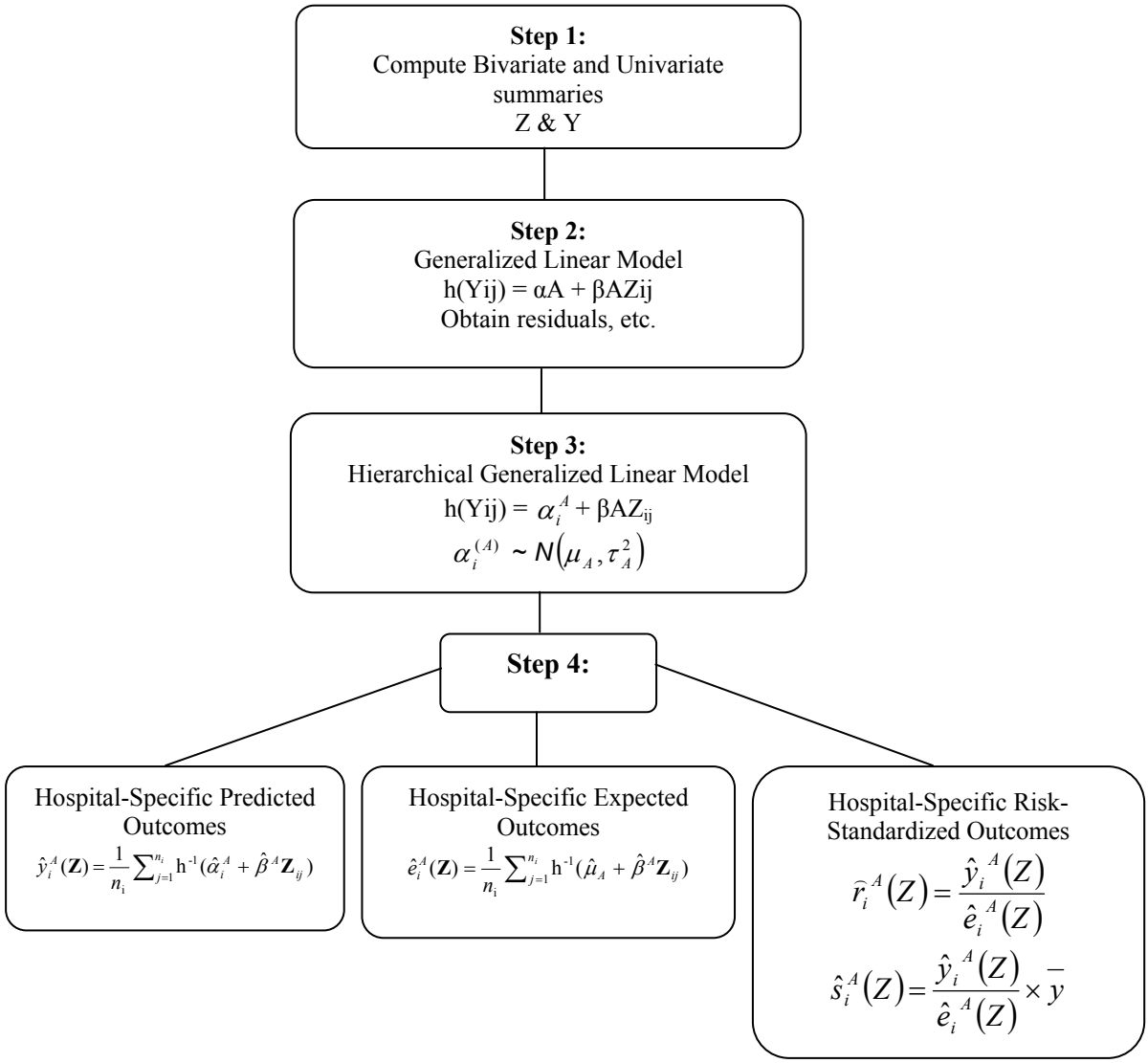
3. We generate a hospital random effect by sampling from the distribution of the hospital-specific distribution obtained in Step 2c. We approximate the distribution for each random effect by a normal

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).[12]

Figure 3. Analysis Steps



3. RESULTS

3.1 Model Results

3.1.1 Development and Validation Models

Table 4 conveys the GLM model results for the 2008 development sample. The standardized estimates are regression coefficients expressed in units of standard deviations and can range between -1 and 1, with ±1 indicating a perfect linear relationship and 0 indicating no linear relationship.[1] The area under the receiver operating characteristic (ROC) curve is 0.64 indicating good discrimination.

Table 5 conveys the HGLM model results for the 2008 development sample. The T value is the parameter estimate divided by its standard error, and its associated probability indicates whether the variable is significantly associated with the outcome. The estimated between-hospital variance in the adjusted log-odds of readmission is 0.156 based on the 2008 full dataset. This result implies that the odds of readmission for patients at a high-readmission hospital (+1 SD) are 2.20 times that in a low-readmission hospital (-1 SD). If there were no differences between hospitals, the between-hospital variance would be 0 and the odds ratio would be 1.0.Table 6 conveys the GLM results for the validation sample.

3.1.2 Model Performance

Table 7 conveys model performance results for both the developmental and validation samples. We computed the following summary statistics for assessing model performance[13]: over-fitting indices[2], predictive ability, area under the (ROC) curve, distribution of residuals, and model chi-square[3]. The models for both the development and validation samples

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

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

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

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

where O = observed value
E = expected value, and

have strong discrimination and fit. Model predictive ability ranges from 2.5% in the lowest predictive decile to 13.2% in the highest decile in the development sample and the validation sample from 2008. Predictive ability ranges from 2.8% in the lowest predictive decile to 13.3% in the highest decile in the 2007 validation sample, indicating the model can reasonably classify patients on the outcome, based on their risk. The area under the ROC curve (C statistic) is 0.64 for the development model and for both validation models (Table 7). The discrimination ability is consistent with models currently used to publicly report condition specific rates of mortality and readmission.

Table 8 conveys the standardized estimates by year of discharge in the full datasets for 2007 and 2008. There are no notable differences in the standardized estimates between the two years. Table 9 conveys the risk factor frequency for the development and validation samples by year of discharge. The prevalence of morbid obesity increased slightly to 3.5% in 2008, compared with 2.97% in 2007. There were no other notable changes in risk factor frequency over the two-year period.

degrees of freedom (df) = (rows-1)(columns-1)

Table 4. GLM Model Results for 2008 Development Sample (ROC = 0.64)

Description	Estimate	Standard Error	Standardized Estimates	Odds Ratio	95% Confidence Interval for OR
Intercept	-3.86	0.04			
Demographics					
Age-65‡ (mean)	0.03	0.00	0.11	1.03	(1.03 – 1.04)
Male	0.09	0.02	0.02	1.10	(1.05 – 1.15)
THA/TKA Procedure					
THA procedure	0.14	0.02	0.03	1.15	(1.10 – 1.21)
Number of procedures (one vs. two)	0.19	0.06	0.02	1.21	(1.08 – 1.37)
Comorbid Conditions					
Skeletal deformities (ICD-9 code 755.63)	0.12	0.28	0.00	1.13	(0.65 – 1.96)
Post traumatic osteoarthritis (ICD-9 codes 716.15, 716.16)	-0.10	0.15	0.00	0.90	(0.67 – 1.22)
Morbid obesity (ICD-9 code 278.01)	0.26	0.06	0.03	1.30	(1.16 – 1.44)
History of infection (CC 1, 3-6)	0.11	0.03	0.02	1.11	(1.05 – 1.17)
Metastatic cancer and acute leukemia (CC 7)	0.06	0.13	0.00	1.06	(0.82 – 1.37)
Cancer (CC 8-12)	-0.05	0.03	-0.01	0.95	(0.90 – 1.00)
Diabetes and DM complications (CC 15-20, 119, 120)	0.14	0.02	0.03	1.15	(1.10 – 1.21)
Protein-calorie malnutrition (CC 21)	0.29	0.10	0.01	1.33	(1.08 – 1.63)
Disorders of fluid/electrolyte/acid-base (CC 22, 23)	0.15	0.03	0.03	1.16	(1.09 – 1.23)
Rheumatoid arthritis and inflammatory connective tissue Disease (CC 38)	0.08	0.04	0.01	1.08	(1.00 – 1.16)
Severe hematological disorders (CC 44)	0.43	0.10	0.02	1.54	(1.28 – 1.86)
Dementia and senility (CC 49, 50)	0.14	0.05	0.02	1.15	(1.05 – 1.26)
Major psychiatric disorders (CC 54-56)	0.23	0.05	0.02	1.26	(1.15 – 1.40)
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177-178)	0.13	0.08	0.01	1.14	(0.99 – 1.32)
Polyneuropathy (CC 71)	0.17	0.04	0.02	1.19	(1.10 – 1.29)
Congestive heart failure (CC 80)	0.16	0.03	0.03	1.17	(1.10 – 1.25)
Chronic atherosclerosis (CC 83-84)	0.23	0.02	0.06	1.26	(1.20 – 1.32)
Hypertension (CC 89, 91)	0.18	0.03	0.04	1.19	(1.12 – 1.28)
Arrhythmias (CC 92, 93)	0.18	0.03	0.04	1.20	(1.14 – 1.26)
Stroke (CC 95, 96)	0.04	0.06	0.00	1.04	(0.92 – 1.18)
Vascular or circulatory disease (CC 104-106)	0.12	0.03	0.03	1.13	(1.07 – 1.18)
COPD (CC 108)	0.29	0.03	0.06	1.34	(1.27 – 1.42)
Pneumonia (CC 111-113)	0.17	0.04	0.02	1.19	(1.10 – 1.29)
End-stage renal disease or dialysis (CC 129, 130)	0.62	0.18	0.01	1.86	(1.30 – 2.65)
Renal failure (CC 131)	0.18	0.04	0.02	1.19	(1.10 – 1.29)
Decubitus ulcer or chronic skin ulcer (CC 148, 149)	0.15	0.06	0.01	1.16	(1.04 – 1.29)
Cellulitis, local skin infection (CC 152)	0.16	0.04	0.02	1.17	(1.09 – 1.26)
Other injuries (CC162)	0.16	0.02	0.04	1.18	(1.12 – 1.24)
Major symptoms, abnormalities (CC 166)	0.13	0.02	0.04	1.14	(1.09 – 1.19)

Table 5. HGLM Model Results for 2008 Development Sample

Description	Estimate	Standard Error	T-Value	Pr > T-Value	Odds Ratio	95% Confidence Interval for OR
Intercept	-3.87	0.04	-93.90	<.0001		
Demographics						
Age-65‡ (mean)	0.03	0.00	18.99	<.0001	1.04	(1.03 – 1.04)
Male	0.10	0.02	4.36	<.0001	1.11	(1.06 – 1.16)
THA/TKA Procedure						
THA procedure	0.14	0.02	5.93	<.0001	1.15	(1.10 – 1.20)
Number of procedures (one vs. two)	0.20	0.06	3.34	0.001	1.23	(1.09 – 1.38)
Comorbid Conditions						
Skeletal deformities (ICD-9 code 755.63)	0.14	0.28	0.51	0.610	1.15	(0.67 – 1.97)
Post traumatic osteoarthritis (ICD-9 codes 716.15, 716.16)	-0.10	0.15	-0.65	0.517	0.91	(0.68 – 1.22)
Morbid obesity (ICD-9 code 278.01)	0.24	0.05	4.41	<.0001	1.27	(1.14 – 1.42)
History of infection (CC 1, 3-6)	0.10	0.03	3.82	0.000	1.11	(1.05 – 1.17)
Metastatic cancer and acute leukemia (CC 7)	0.08	0.13	0.61	0.543	1.08	(0.84 – 1.39)
Cancer (CC 8-12)	-0.06	0.03	-2.20	0.028	0.94	(0.89 – 0.99)
Diabetes and DM complications (CC 15-20, 119, 120)	0.13	0.02	5.63	<.0001	1.14	(1.09 – 1.20)
Protein-calorie malnutrition (CC 21)	0.30	0.10	2.90	0.004	1.35	(1.10 – 1.65)
Disorders of fluid/electrolyte/acid-base (CC 22, 23)	0.14	0.03	4.39	<.0001	1.15	(1.08 – 1.22)
Rheumatoid arthritis and inflammatory connective Tissue disease (CC 38)	0.08	0.04	2.09	0.037	1.08	(1.00 – 1.16)
Severe hematological disorders (CC 44)	0.44	0.09	4.66	<.0001	1.55	(1.29 – 1.86)
Dementia and senility (CC 49, 50)	0.15	0.05	3.28	0.001	1.16	(1.06 – 1.27)
Major psychiatric disorders (CC 54-56)	0.24	0.05	4.86	<.0001	1.27	(1.15 – 1.40)
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177-178)	0.13	0.07	1.81	0.070	1.14	(0.99 – 1.32)
Polyneuropathy (CC 71)	0.18	0.04	4.38	<.0001	1.20	(1.10 – 1.30)
Congestive heart failure (CC 80)	0.17	0.03	5.23	<.0001	1.19	(1.11 – 1.27)
Chronic atherosclerosis (CC 83-84)	0.23	0.02	9.62	<.0001	1.26	(1.20 – 1.32)
Hypertension (CC 89, 91)	0.17	0.03	5.29	<.0001	1.19	(1.11 – 1.27)
Arrhythmias (CC 92, 93)	0.19	0.03	7.61	<.0001	1.21	(1.15 – 1.27)
Stroke (CC 95, 96)	0.04	0.06	0.72	0.474	1.04	(0.93 – 1.18)
Vascular or circulatory disease (CC 104-106)	0.12	0.03	4.61	<.0001	1.12	(1.07 – 1.18)
COPD (CC 108)	0.29	0.03	10.55	<.0001	1.34	(1.27 – 1.41)
Pneumonia (CC 111-113)	0.18	0.04	4.39	<.0001	1.19	(1.10 – 1.29)
End-stage renal disease or dialysis (CC 129, 130)	0.60	0.18	3.32	0.001	1.82	(1.28 – 2.58)
Renal failure (CC 131)	0.18	0.04	4.56	<.0001	1.19	(1.11 – 1.29)
Decubitus ulcer or chronic skin ulcer (CC 148, 149)	0.15	0.06	2.78	0.005	1.17	(1.05 – 1.30)
Cellulitis, local skin infection (CC 152)	0.16	0.04	4.53	<.0001	1.18	(1.10 – 1.26)
Other injuries (CC162)	0.16	0.02	6.92	<.0001	1.18	(1.12 – 1.23)
Major symptoms, abnormalities (CC 166)	0.12	0.02	4.97	<.0001	1.13	(1.07 – 1.18)

Table 6. GLM Model Results for 2008 Validation Sample (ROC = 0.64)

Label	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq	Standardized Estimates	Odds Ratio	95% Confidence Interval for OR
Intercept	-3.85	0.04	8920.02	<.0001			
Demographics							
Age-65‡ (mean)	0.03	0.00	314.50	<.0001	0.11	1.03	(1.03 – 1.04)
Male	0.11	0.02	22.57	<.0001	0.03	1.12	(1.07 – 1.17)
THA/TKA Procedure							
THA procedure	0.13	0.02	29.15	<.0001	0.03	1.14	(1.09 – 1.19)
Number of procedures (one vs. two)	0.24	0.06	16.01	<.0001	0.02	1.27	(1.13 – 1.43)
Comorbid Conditions							
Skeletal deformities (ICD-9 code 755.63)	0.01	0.29	0.00	0.965	0.00	1.01	(0.57 – 1.79)
Post traumatic osteoarthritis (ICD-9 codes 716.15, 716.16)	-0.03	0.15	0.04	0.833	0.00	0.97	(0.73 – 1.30)
Morbid obesity (ICD-9 code 278.01)	0.24	0.06	17.52	<.0001	0.02	1.27	(1.13 – 1.41)
History of Infection (CC 1, 3-6)	0.11	0.03	15.98	<.0001	0.02	1.12	(1.06 – 1.18)
Metastatic cancer and acute leukemia (CC 7)	0.29	0.11	6.19	0.013	0.01	1.33	(1.03 – 1.67)
Cancer (CC 8-12)	-0.02	0.03	0.48	0.489	0.00	0.98	(0.93 – 1.04)
Diabetes and DM complications (CC 15-20, 119, 120)	0.12	0.02	22.91	<.0001	0.03	1.12	(1.07- 1.18)
Protein-calorie malnutrition (CC 21)	0.03	0.11	0.08	0.779	0.00	1.03	(0.83 – 1.28)
Disorders of fluid/electrolyte/acid-base (CC 22, 23)	0.14	0.03	20.62	<.0001	0.03	1.15	(1.08 – 1.23)
Rheumatoid arthritis and inflammatory connective tissue disease (CC 38)	0.11	0.04	8.92	0.003	0.02	1.12	(1.04 – 1.20)
Severe hematological disorders (CC 44)	0.38	0.10	16.20	<.0001	0.02	1.47	(1.22 – 1.77)
Dementia and senility (CC 49, 50)	0.25	0.04	32.73	<.0001	0.03	1.29	(1.18 – 1.41)
Major psychiatric disorders (CC 54-56)	0.34	0.05	48.31	<.0001	0.04	1.40	(1.27 – 1.54)
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177-178)	0.11	0.07	2.15	0.143	0.01	1.12	(0.96 – 1.29)
Polyneuropathy (CC 71)	0.12	0.04	8.61	0.003	0.02	1.13	(1.04 – 1.23)
Congestive heart failure (CC 80)	0.26	0.03	64.55	<.0001	0.04	1.30	(1.22 – 1.38)
Chronic atherosclerosis (CC 83-84)	0.22	0.02	85.83	<.0001	0.06	1.25	(1.19 – 1.31)
Hypertension (CC 89, 91)	0.19	0.03	31.46	<.0001	0.04	1.21	(1.13 – 1.29)
Arrhythmias (CC 92, 93)	0.13	0.03	25.99	<.0001	0.03	1.14	(1.08 – 1.20)
Stroke (CC 95, 96)	0.06	0.06	1.08	0.299	0.01	1.07	(0.95 – 1.20)
Vascular or circulatory disease (CC 104-106)	0.09	0.03	13.76	0.000	0.02	1.10	(1.05 – 1.16)
COPD (CC 108)	0.21	0.03	53.50	<.0001	0.04	1.23	(1.16 – 1.30)
Pneumonia (CC 111-113)	0.23	0.04	33.33	<.0001	0.03	1.26	(1.17 – 1.37)
End-stage renal disease or dialysis (CC 129, 130)	0.87	0.17	26.58	<.0001	0.02	2.40	(1.72 – 3.34)
Renal failure (CC 131)	0.21	0.04	28.03	<.0001	0.03	1.23	(1.14 – 1.33)
Decubitus ulcer or chronic skin ulcer (CC 148, 149)	0.14	0.06	6.07	0.014	0.01	1.15	(1.03 – 1.28)
Cellulitis, local skin infection (CC 152)	0.13	0.04	12.74	0.000	0.02	1.14	(1.06 – 1.23)
Other injuries (CC162)	0.14	0.02	32.21	<.0001	0.03	1.15	(1.09 – 1.20)
Major symptoms, abnormalities (CC 166)	0.15	0.02	40.49	<.0001	0.04	1.17	(1.11 – 1.22)

Table 7. Model Performance for GLM Model

Indices	Development Sample	Validation Sample	Validation Sample
Year	2008 (50%)	2008 (50%)	2007 (100%)
Number of Admissions	147, 959	147,932	300,012
Number of Hospitals	3,227	3,225	3,295
Number of Readmissions	8,978	9,116	19,007
Calibration (γ0, γ1)[1]	(0, 1)	(0.01, 1.00)	(-0.08, 0.95)
Discrimination -Predictive Ability (lowest decile %, highest decile %)	(2.5%, 13.2%)	(2.5%, 13.2%)	(2.8%, 13.3%)
Discrimination – Area Under Receiver Operator Curve	0.64	0.64	0.64
Residuals Lack of Fit (Pearson Residual Fall %)			
<-2	0	0	0
[-2, 0)	93.9	93.8	93.7
[0, 2)	0.1	0.1	0.1
[2+	5.9	6.0	6.2
Model Wald χ^2 [Number of Covariates]	2346 [33]	2462 [33]	4546 [33]

[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 8. Standardized Estimates by Year of Discharge (GLM)

Description	2008 (100%)			2007 (100%)		
	Standardized Estimates	OR	95% CI for Odds Ratio	Standardized Estimates	OR	95% CI for Odds Ratio
Demographics						
Age-65‡ (mean)	0.11	1.03	(1.03 - 1.04)	0.11	1.03	(1.03 – 1.04)
Male	0.03	1.11	(1.07 - 1.14)	0.02	1.10	(1.05 – 1.15)
THA/TKA Procedure						
THA procedure	0.03	1.14	(1.11 - 1.18)	0.03	1.15	(1.10 – 1.21)
Number of procedures (one vs. two)	0.02	1.24	(1.14 - 1.35)	0.02	1.21	(1.08 – 1.37)
Comorbid Conditions						
Skeletal deformities (ICD-9 code 755.63)	0.00	1.07	(0.72 - 1.59)	0.00	1.13	(0.65 – 1.96)
Post traumatic osteoarthritis (ICD-9 codes 716.15, 716.16)	0.00	0.94	(0.76 - 1.15)	0.00	0.90	(0.67 – 1.22)
Morbid obesity (ICD-9 code 278.01)	0.02	1.28	(1.19 - 1.38)	0.03	1.30	(1.16 – 1.45)
History of Infection (CC 1, 3-6)	0.02	1.11	(1.07 - 1.16)	0.02	1.11	(1.05 – 1.17)
Metastatic cancer and acute leukemia (CC 7)	0.01	1.20	(1.01 - 1.42)	0.00	1.06	(0.82 – 1.37)
Cancer (CC 8-12)	-0.01	0.96	(0.93 - 1.00)	-0.01	0.95	(0.90 – 1.00)
Diabetes and DM complications (CC 15-20, 119, 120)	0.03	1.14	(1.10 - 1.18)	0.03	1.15	(1.10 – 1.21)
Protein-calorie malnutrition (CC 21)	0.01	1.17	(1.01 - 1.36)	0.01	1.33	(1.08 – 1.63)
Disorders of Fluid/Electrolyte/Acid-Base (CC 22, 23)	0.03	1.16	(1.11- 1.21)	0.03	1.16	(1.09 – 1.23)
Rheumatoid Arthritis and Inflammatory Connective Tissue Disease (CC 38)	0.01	1.10	(1.04 - 1.16)	0.01	1.08	(1.00 – 1.16)
Severe Hematological Disorders (CC 44)	0.02	1.51	(1.32 - 1.72)	0.02	1.54	(1.28 – 1.86)
Dementia and senility (CC 49, 50)	0.02	1.22	(1.15 - 1.30)	0.02	1.15	(1.05 – 1.26)
Major psychiatric disorders (CC 54-56)	0.03	1.33	(1.25 - 1.43)	0.02	1.26	(1.15 – 1.40)
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177-178)	0.01	1.13	(1.02 - 1.25)	0.01	1.14	(0.99 – 1.32)
Polyneuropathy (CC 71)	0.02	1.16	(1.10 - 1.23)	0.02	1.19	(1.10 – 1.29)
Congestive Heart Failure (CC 80)	0.03	1.24	(1.18 - 1.29)	0.03	1.17	(1.10 – 1.25)
Chronic Atherosclerosis (CC 83-84)	0.06	1.26	(1.21 - 1.30)	0.06	1.26	(1.20 – 1.32)
Hypertension (CC 89, 91)	0.04	1.20	(1.15 - 1.26)	0.04	1.19	(1.12 – 1.28)
Arrhythmias (CC 92, 93)	0.04	1.17	(1.13 - 1.21)	0.04	1.20	(1.14 – 1.26)
Stroke (CC 95, 96)	0.00	1.05	(0.97 - 1.15)	0.00	1.04	(0.92 – 1.18)
Vascular or circulatory disease (CC 104-106)	0.02	1.11	(1.07 - 1.15)	0.03	1.13	(1.07 – 1.18)
COPD (CC 108)	0.05	1.28	(1.23 - 1.33)	0.06	1.34	(1.27 – 1.42)
Pneumonia (CC 111-113)	0.03	1.22	(1.16 - 1.29)	0.02	1.19	(1.10 – 1.29)
End-stage renal disease or dialysis (CC 129, 130)	0.02	2.10	(1.65 - 2.68)	0.01	1.86	(1.30 – 2.65)
Renal Failure (CC 131)	0.03	1.21	(1.15 - 1.28)	0.02	1.19	(1.10 – 1.29)
Decubitus ulcer or chronic skin ulcer (CC 148, 149)	0.01	1.15	(1.07 - 1.25)	0.01	1.16	(1.04 – 1.29)
Cellulitis, Local Skin Infection (CC 152)	0.02	1.16	(1.10 - 1.22)	0.02	1.17	(1.09 – 1.26)
Other injuries (CC162)	0.04	1.16	(1.12 - 1.20)	0.04	1.18	(1.12 – 1.24)
Major Symptoms, Abnormalities (CC 166)	0.04	1.15	(1.11 - 1.19)	0.04	1.14	(1.09 – 1.19)

Table 9. Risk Factor Frequency by Year of Discharge (GLM)

Description	2008 Development Sample	2008 Validation Sample	2007 Validation Sample
Male	35.93	35.56	35.57
THA procedure	28.40	28.68	28.49
Number of procedures (one vs. two)	3.21	3.22	3.52
Skeletal deformities (ICD-9 code 755.63)	0.13	0.14	0.15
Post traumatic osteoarthritis (ICD-9 codes 716.15, 716.16)	0.51	0.53	0.49
Morbid obesity (ICD-9 code 278.01)	3.50	3.42	2.97
History of Infection (CC 1, 3-6)	17.88	17.89	17.63
Metastatic cancer and acute leukemia (CC 7)	0.58	0.62	0.64
Cancer (CC 8-12)	18.73	18.73	18.65
Diabetes and DM complications (CC 15-20, 119, 120)	27.31	27.36	26.70
Protein-calorie malnutrition (CC 21)	0.61	0.63	0.55
Disorders of Fluid/Electrolyte/Acid-Base (CC 22, 23)	11.98	11.97	11.85
Rheumatoid Arthritis and Inflammatory Connective Tissue Disease (CC 38)	8.61	8.55	8.34
Severe Hematological Disorders (CC 44)	0.74	0.76	0.73
Dementia and senility (CC 49, 50)	4.33	4.33	4.19
Major psychiatric disorders (CC 54-56)	3.69	3.72	3.56
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177-178)	1.58	1.59	1.50
Polyneuropathy (CC 71)	5.67	5.64	5.50
Congestive Heart Failure (CC 80)	9.55	9.74	9.81
Chronic Atherosclerosis (CC 83-84)	30.55	30.63	30.90
Hypertension (CC 89, 91)	82.59	82.52	82.07
Arrhythmias (CC 92, 93)	22.40	22.25	21.90
Stroke (CC 95, 96)	2.41	2.43	2.49
Vascular or circulatory disease (CC 104-106)	22.67	22.44	22.15
COPD (CC 108)	14.63	14.65	15.15
Pneumonia (CC 111-113)	5.40	5.44	5.43
End-stage renal disease or dialysis (CC 129, 130)	0.14	0.14	0.14
Renal Failure (CC 131)	6.10	6.12	5.53
Decubitus ulcer or chronic skin ulcer (CC 148, 149)	2.68	2.73	2.74
Cellulitis, Local Skin Infection (CC 152)	7.78	7.89	7.65
Other injuries (CC162)	27.32	27.69	27.50
Major Symptoms, Abnormalities (CC 166)	52.62	52.42	52.76

3.1.3 Unadjusted and Adjusted Readmission Rate Distributions

Figure 4 displays the unadjusted frequency distribution of the hospital-specific readmission rates in the 2008 cohort. The unadjusted mean readmission rate is 6.72% and ranged from 0% to 100% across the 3,310 hospitals. The median unadjusted readmission rate is 6.72%.

After adjusting for patient and clinical characteristics, the risk-standardized rates are more normally distributed (Figure 5) with a mean of 6.25%, ranging from 3.03% to 50.97%. The median adjusted readmission rate is 6.01%.

Figure 4. Unadjusted Hospital Readmission Rates (2008 Sample; N=3,310 Hospitals)

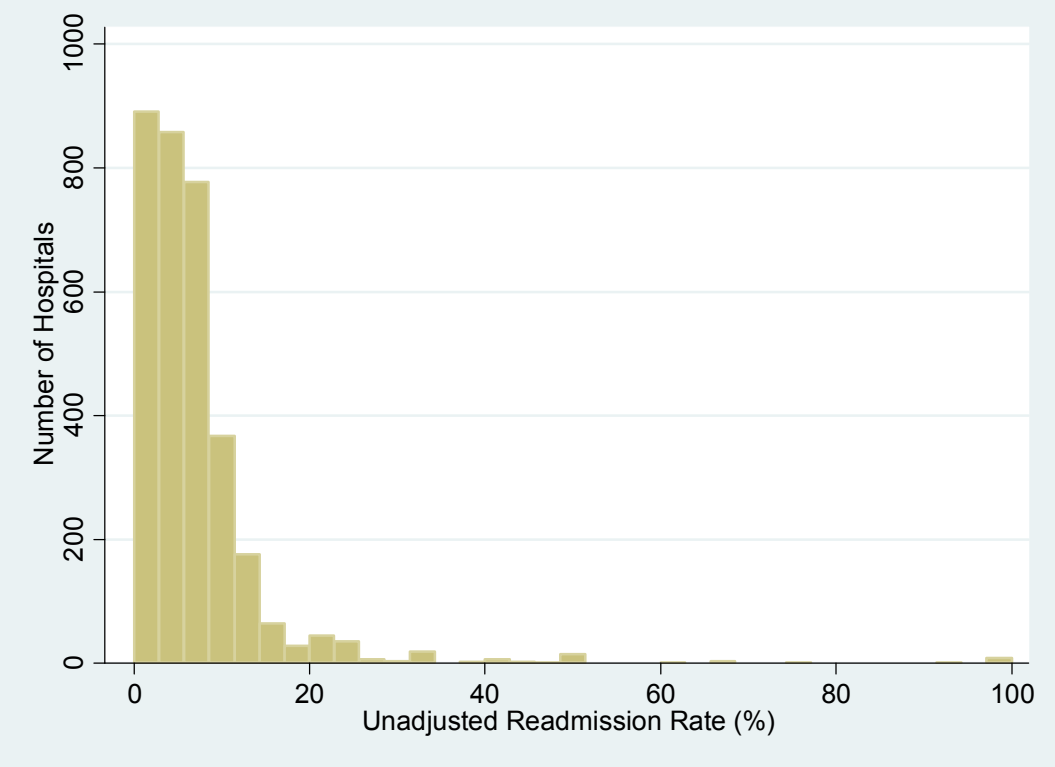
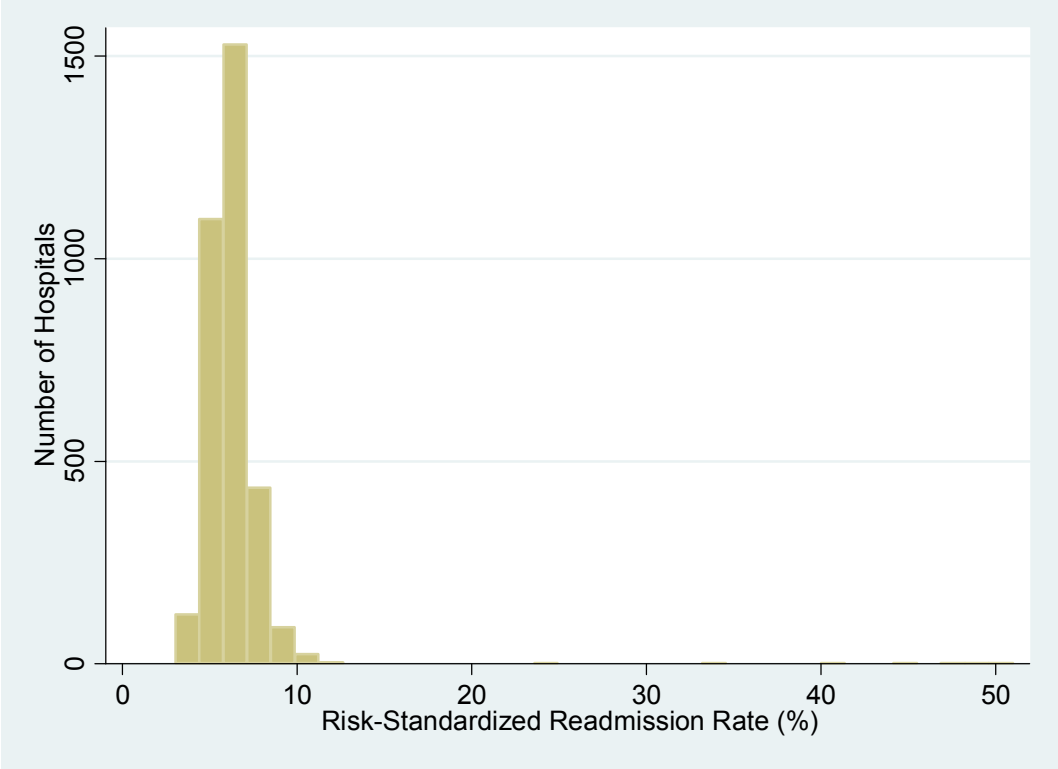


Figure 5. Distribution of Hospital Risk-Standardized Readmission Rates (2008 Sample; N=3,310 Hospitals) – HGLM



4. MAIN FINDINGS / SUMMARY

The proposed 30-day all-cause readmission measure has the potential to significantly improve the quality of care delivered to patients undergoing elective primary THA and TKA procedures. The risk standardized model is consistent with the consensus standards for publicly reported outcomes measures, and can be implemented using available data. This measure was developed with extensive input from experts with clinical and methodological expertise relevant to orthopedic quality measurement. The study sample is appropriately defined, consisting of patients undergoing elective primary THA and/or TKA and will allow for valid comparisons of hospital quality. We excluded covariates that are not appropriate for inclusion in a quality measure such as race, socioeconomic status, and hospital-level factors (e.g., hospital bed size and volume of THA/TKA procedures). 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.

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6. APPENDIX

6.1 Appendix A: 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

6.2 Appendix B: ICD-9-CM Codes for Hip Fracture, Revision Procedures, Partial Hip Arthroplasty, and Resurfacing Procedure

ICD-9-CM Codes for Hip Fracture	
733.1	Pathologic fracture
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
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
820.10	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
820.20	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
820.30	Fracture of unspecified trochanteric section of femur open
820.31	Fracture of intertrochanteric section of femur open
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

ICD-9-CM Codes for THA and TKA Revision Procedures	
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)
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

ICD-9-CM Code for Partial Hip Arthroplasty Procedure	
81.52	Partial Hip Replacement

ICD-9-CM Codes for THA Resurfacing Procedure	
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

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

CC	Description
2	Septicemia/Shock
6	Other Infectious Diseases
17	Diabetes with Acute Complications
23	Disorders of Fluid/Electrolyte/Acid-Base
24	Other Endocrine/Metabolic/Nutritional Disorders
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
82	Unstable angina
85	Heart Infection/Inflammation, Except Rheumatic
95	Cerebral Hemorrhage
96	Ischemic or Unspecified Stroke
97	Precerebral Arterial Occlusion and Transient Cerebral Ischemia
100	Hemiplegia/Hemiparesis
101	Cerebral Palsy and Other Paralytic Syndromes
102	Speech, Language, Cognitive, Perceptual
104	Vascular Disease with Complications
105	Vascular Disease
106	Other Circulatory Disease
111	Aspiration and Specified Bacterial Pneumonias
112	Pneumococcal Pneumonia, Emphysema, Lung Abscess
114	Pleural Effusion/Pneumothorax
130	Dialysis Status
131	Renal failure
132	Nephritis
133	Urinary Obstruction and Retention
135	Urinary Tract Infection
148	Decubitus Ulcer of Skin
152	Cellulitis, Local Skin Infection
154	Severe Head Injury
155	Major Head Injury
156	Concussion or Unspecified Head Injury

CC	Description
157	Vertebral Fractures
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

6.4 Appendix D: CCs Not Considered for Risk Adjustment

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