

**Draft Summary of Technical Expert Panel (TEP) Evaluation of Measure  
Risk-Standardized Payment Measures:  
Hip/Knee Episode of Care**

September 22, 2014

**Prepared by:**

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

This material was prepared by YNHHSC/CORE under contracts to the Centers for Medicare & Medicaid Services (CMS), an agency of the U.S. Department of Health and Human Services. The contents presented do not necessarily reflect CMS policy.

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## **Background**

The Centers for Medicare & Medicaid Services (CMS) contracted with Yale New Haven Health Services Corporation/Center for Outcomes Research and Evaluation (CORE) to develop an outcome measure of payments associated with elective primary total hip arthroplasty (THA) and/or total knee arthroplasty (TKA).

During development, CORE has and will continue to obtain expert and stakeholder input on the proposed payment measure. The CORE measure development team meets regularly and is comprised of experts in healthcare economics, internal medicine, orthopedics, quality outcomes measurement, and measure development. Additionally, CORE convened a Technical Expert Panel (TEP) of clinicians, healthcare economists, consumers, purchasers, patients, and experts in quality improvement to provide input on key methodological decisions.

This report summarizes the feedback and recommendations provided by the TEP regarding the proposed measure as of September 24, 2014.

## **Measure Development Team**

The CORE measure development team is led by Drs. Nancy Kim and Lisa Suter. Dr. Kim is an Assistant Professor of Medicine at Yale School of Medicine, health services researcher, and practicing hospitalist with experience in outcomes research and measure development. Dr. Suter is an Assistant Professor of Medicine at Yale School of Medicine, health services researcher, and practicing rheumatologist with experience in outcomes research and orthopedic outcome measure development specifically. See [Appendix A](#) for the full list of members of the CORE development team.

## **The Technical Expert Panel**

In alignment with the CMS Measures Management System (MMS), CORE released a 30-day public call for nominations and convened a TEP for the THA/TKA payment measure. CORE solicited potential members via email per recommendations by the measure development team, stakeholder groups, CMS hospital listservs, and through a posting on CMS's public comment site. We also reached out on social media and public forums to recruit a patient representative.

The role of the TEP is to provide feedback on key methodological and clinical decisions made in consultation with the measure development team. The TEP is comprised of individuals with diverse perspectives and backgrounds and includes clinicians, healthcare economists, consumers, purchasers, patients, and experts in quality improvement. The appointment term for the TEP is from May 2014 to December 2014.

## Specific Responsibilities of the TEP Members

- Review background materials provided by CORE prior to each TEP meeting
- Participate in TEP conference calls
- Provide input to CORE on key clinical, methodological, and other decisions
- Provide feedback to CORE on key policy or other non-technical issues
- Review the TEP summary report prior to public release
- Potentially discuss recommendations following submission of the measure to the National Quality Forum (NQF)

### TEP Members

Name	Organization	Location
Blair Biase, MMSc, PA-C, MBA	Global Knee Reconstruction, OrthoSensor, Inc.	Dania Beach, FL
John Birkmeyer, MD	University of Michigan, Department of Surgery	Ann Arbor, MI
Kate Chenok, MBA <i>(May 2014 to July 2014)</i>	Pacific Business Group on Health	San Francisco, CA
Cheryl Crumpton, MS, RN, CEN	Cheyenne Regional Medical Center	Cheyenne, WY
Vinod Dasa, MD	Louisiana State University Health Sciences Center: Adult Reconstruction and Sports Medicine; Ochsner Kenner Medical Center	New Orleans, LA
Cheryl Fahlman, PhD, MBA, BSP	Premier Healthcare Solutions, Inc.	Washington, DC
Vivian Ho, PhD	Rice University, Department of Economics	Houston, TX
David Hopkins, PhD <i>(July 2014 to December 2014)</i>	Pacific Business Group on Health	San Francisco, CA
Cynthia Jacelon, PhD, RN, CRRN, FAAN	University of Massachusetts School of Nursing	Amherst, MA
Brian McCardel, MD	Sparrow Health System, Orthopedic Surgery Section	Lansing, MI
Derek Nordman, MPT, ATC	Gentiva Health Services	Atlanta, GA
Amita Rastogi, MD, MHA, CHE, MS	Health Care Incentives Improvement Institute (HCI3)	Munster, IN
Jonathan Schaffer, MD, MBA	The Cleveland Clinic Foundation: Department of Orthopaedic Surgery, Information Technology Division	Cleveland, OH
Kathleen Willhite, MS	BayCare Health Systems	Green Bay, WI
AJ Yates, MD	University of Pittsburgh School of Medicine, Dept. of Orthopaedic Surgery	Pittsburgh, PA
Patient <i>(has chosen to remain anonymous)</i>		

## TEP Meetings

CORE conducted the first meeting on May 19, 2014 and the second meeting on August 25, 2014 (see [Appendix B](#) for TEP meeting schedule), and will potentially hold a third meeting in November 2014. The TEP meetings follow a structured format consisting of a presentation of key milestones achieved during measure development and CORE's proposed approaches to addressing any issues that may have arisen, followed by an open discussion of the measure development steps and issues by the TEP members.

During the first TEP meeting, the measure developer reviewed several key aspects of the measure and responded to requests for clarification and additional analyses from the TEP. Below is a high-level summary of what was discussed during the first TEP meeting:

- Measure Cohort Definition  
Cohort aligned with the THA/TKA complications measure: Medicare fee-for-service (FFS) patients age 65 and older undergoing an elective primary THA or TKA ([Appendix C](#)), excluding patients with fractures, partial replacements, revisions, resurfacing, mechanical complications, malignant neoplasms, and device removals.
- Payment Methodology  
Methodology removes or averages geography and policy adjustments to Medicare payments.
- Outcome Window  
Reviewed pros and cons of using a shorter (30 days) versus a longer (60 or 90 days) episode of care window and results of testing indicating that hospitals are profiled similarly using a 30 or 60 day window.
- Risk adjustment  
Proposed to adjust for age, gender, and comorbidities listed in patients' acute inpatient hospital stays, hospital outpatient care, and physician, radiology, and laboratory services for the 12 months prior to the index admission as well as select conditions indicated by secondary diagnoses codes on index admission. Requested TEP input on additional variables to add to the model.

During the second TEP meeting, the measure development reviewed the results of analyses conducted in response to TEP members' concerns raised at the first meeting, and presented the final measure. Below is a high-level summary of what was discussed during the second TEP meeting:

- Analyses Conducted in Response to TEP Member Concerns  
Presented results of analyses conducted in response to concerns raised by TEP members during the first TEP meeting, including the frequencies of Common Procedural Terminology (CPT) codes 27130 (total hip replacement) versus 27132 (conversion of previous hip surgery to total hip replacement); the frequencies of diagnostic-related

groups (DRGs) with and without major comorbidities or complications of care (MCCs) in the cohort; and an explanation of how CMS reimburses hospitals for anesthesia and how this would affect the measure.

- Episode Window

Reviewed decision to use a 90-day episode window with all payments included from days 0-30 and only payments related to the index admission from days 31-90 following the feedback of the first TEP. Presented list of related payments and analyses that showed the difference in patients undergoing index single, index bilateral, and staged procedures. Requested TEP input on decision to risk adjust for index bilateral and staged procedures.

- Risk Adjustment Methodology

Reviewed the specific conditions suggested by TEP members for inclusion as risk-adjustment variables independently of their CMS condition category (CC). Presented the final risk-adjustment variables.

- Hip/Knee Payment Model

Presented the results of the final hierarchical generalized linear model. Reviewed the use of the inverse Gaussian distribution and log link for optimal model performance. Presented the median risk-standardized payment.

- Index and Post-Acute Care Payment Breakdowns

Reviewed the proportion of total 90-day payments attributable to the index admission and to post-acute care, showing that 40% of payments are attributable to the index admission, and 60% of payments are attributable to post-acute care.

## **Public Comment**

The measures will undergo a 30-day public comment period in October-November 2014. After the close of the public comment period, we will coordinate with the TEP to review the public comments and proposed changes to the measure (if any).

## TEP Meeting Discussion and Feedback

**Table 1: Key Issues Discussed During First TEP Meeting and Feedback**

Topic	Key Issues Discussed	TEP Feedback/Discussion
<b>Cohort Definition</b>	<p><b>CORE reviewed the cohort definition and International Classification of Diseases, Ninth Revision (ICD-9) codes (<a href="#">Appendix C</a>) included in the measure and noted that the cohort definition was closely aligned with the CMS THA/TKA complications measure.</b></p>	<p>One TEP member asked about exclusion of hematologic cancers, such as lymphoma, leukemia, or myeloproliferative disease, as these are systemic diseases which may be the reason for needing a hip or knee replacement. The same member also wondered if the measure differentiates between the Diagnosis Related Group (DRG) codes 470 and 469. DRG 469 is a replacement associated with an existing comorbidity or complication and if the model risk adjusts for comorbidities it may double-count the patient’s risk. The suggestion was to assign all DRG 469 to DRG 470.</p> <p>CORE responded that the only exclusions are for widespread metastases and malignant neoplasms of relevant limb structures or bone, as well as pathological fractures. Other cancer diagnoses are included in the risk model. The team at CORE will also investigate differences between DRG 469 and 470.</p> <p><b>Summary: TEP members agreed with the current cohort but suggested analyzing differences between DRG 469 and 470. CORE will complete analyses comparing these groups.</b></p>
<b>Payment Methodology</b>	<p><b>CORE reviewed the methods for removing or averaging geographic and policy adjustments and the decision to prorate payments that begin during the measurement window but end after the window. CORE also noted that the patient-level payments are Winsorized, which reassigns extreme value to the value of the Xth percent.</b></p>	<p>One TEP member asked how bilateral, or multiple procedures would be handled and how complications that occur during the index admission are treated.</p> <p>CORE responded that adjusting for bilateral or multiple procedures is something that is currently being considered. Regarding complications, a complication could increase the index payment by increasing the DRG weight. In that way, the complication would be captured in the total payment amount. Moreover, the measures do not adjust for conditions that could be potential complications of care.</p> <p><b>Summary: TEP members agreed with the payment methodology and the decision to Winsorize extreme outliers. CORE will examine adjusting the measure for patients with bilateral or multiple procedures.</b></p>

Topic	Key Issues Discussed	TEP Feedback/Discussion
<p><b>Outcome Window</b></p>	<p><b>CORE reviewed the options for outcome windows for this measure. Based on reviews of existing studies and programs, 30, 60 or 90 days are appropriate outcome windows. CORE recommended a 30-day measure, based on enrollment and payment profile analyses.</b></p>	<p>One TEP member expressed support for a 30-day measure. Their research had found similar correlations between 30- and 60-day episode payments. Further, they found that the later days picked up a signal that reflected the intensity or overall spending patterns of that health system, rather than of the orthopedic service line.</p> <p>Other TEP members disagreed with a 30-day measure. One TEP member noted that recovery extends past 30 days to at least the six-week mark. Another TEP member expressed concern that higher lengths of stay have a shorter post-discharge period. Another TEP member expressed concern that by cutting the episode at 30 days, the measure may miss a bimodal distribution of complications. For instance, loosening, recurring dislocation, and drainage may appear at 70-90 days.</p> <p>TEP members noted that pre-surgery costs may contribute greatly to episode costs. For example, axial imaging and stress tests. There is concern that hospitals are off-loading operating room costs to the pre-surgery period.</p> <p><b>Summary: The TEP members did not agree with a 30-day outcome measure. CORE will re-consider the outcome window and communicate findings with TEP members.</b></p>
<p><b>Risk-Adjustment and Risk-Standardization</b></p>	<p><b>CORE reviewed the purpose and the standard approach to risk-adjustment. In brief, the measure is adjusted for clinical variables, but not for variables related to health system structure or socio-economic status. CORE reviewed the methodology of risk-standardization.</b></p>	<p>One TEP member noted that post-discharge costs will be driven by systemic and other musculoskeletal or neurologic diseases that are not typically considered as complications, such as rheumatoid arthritis, ankylosing spondylitis, history of amputation, spinal stenosis, Parkinson's disease, Alzheimer's and history of stroke.</p> <p>One TEP member noted that if the model predicted payments with the DRG codes (469 and 470), then the coefficients will predict complications and effectively adjust for them.</p> <p><b>Summary: TEP members noted specific comorbidities that may contribute to higher payment. CORE will communicate with TEP members about individual codes of interest, and progress through the risk-adjustment variable selection.</b></p>

**Table 2: Key Issues Discussed During Second TEP Meeting and Feedback**

Topic	Key Issues Discussed	TEP Feedback/Discussion
<p><b>Analyses Conducted in Response to TEP Member Concerns</b></p>	<p><b>CORE reviewed the results of analyses that were conducted in response to concerns raised by TEP members during the first TEP meeting. These included analyses that looked at the following:</b></p> <ol style="list-style-type: none"> <li><b>1. The frequencies of CPT codes 27130 (total hip replacement) and 27132 (conversion of previous hip surgery to total hip replacement) in the final measure cohort</b></li> <li><b>2. The frequencies of patients coded for DRGs with or without major comorbidities or complications of care (MCC)</b></li> <li><b>3. Medicare reimbursements for anesthesia</b></li> </ol>	<p>One TEP member expressed concern that the measure may miss the impact on the outcome of those patients that do not have CPT codes associated with their surgery but who are still included in the cohort due to their ICD-9 procedure codes of either 81.51 or 81.54.</p> <p>TEP members suggested that anesthesia services may be billed separately from the hospital bill, and that hospitals may vary in how they bill for anesthesia services. Payments made for anesthesia services outside of the general Medicare reimbursement formula would be made under Medicare Part B for appropriate CPT codes, and would therefore be captured in the total payment outcome.</p> <p><b>Summary: TEP members were concerned that the payment outcome was not fully accounting for the impact of patients who do not have CPT codes associated with their index hospitalization. CORE will conduct additional analyses of those patients that were found not to have a CPT code associated with their surgery.</b></p>
<p><b>Episode Window</b></p>	<p><b>CORE presented the 90-day episode window, which includes all payments from days 0 through 30 and only related payments from days 31 through 90. CORE reviewed the settings for which payments are considered “related” and included in the payment calculation after day 30.</b></p>	<p>The TEP members agreed that the list of “related” payments as included in the payment outcome do not clearly convey whether physician claims in the 31- through 90-day time period.</p> <p>Several TEP members suggested that the payment outcome include payments made for manipulation under anesthesia of the knee as related payment, while several other TEP members suggested that including it as a related payment is not necessary.</p> <p>A TEP member suggested that ambulatory surgical centers be considered settings for which payments are considered “related.” This would allow for the capture of joint manipulation and of radiology services that may currently be excluded from the payment outcome.</p> <p><b>Summary: CORE will revisit the list of related payment settings to clarify that all claims for those settings are considered “related,” including physician claims. CORE will consider including manipulations as potential related</b></p>

Topic	Key Issues Discussed	TEP Feedback/Discussion
		<p><b>costs to be included in the outcome, and also ambulatory surgical centers as related payment settings.</b></p>
<p><b>Risk Adjustment Methodology</b></p>	<p><b>CORE reviewed the risk-adjustment methodology. The model does not adjust for complications of care, socioeconomic status, race, ethnicity, hospital characteristics, or a patient's admission source.</b></p> <p><b>CORE reviewed the list of 56 final risk-adjustment variables, which included age, gender, procedure location, the procedure type (single, bilateral, or staged), and clinical comorbidities, including the individual ICD-9 codes discussed during the first TEP. Of the ICD-9 individual ICD-9 codes discussed in the first TEP, only morbid obesity remained significantly associated with the payment outcome.</b></p>	<p>The TEP members agreed that risk adjusting for type of procedure (hip versus knee replacement) and index bilateral and staged procedures in the model is appropriate.</p> <p>A TEP member expressed concern that using CMS CCs to group ICD-9 codes would mask the effect of individual ICD-9 codes on the outcome.</p> <p><b>Summary: The TEP members agreed to risk adjust for type of procedure (hip versus knee replacement) and index bilateral and staged procedures.</b></p>
<p><b>Hip/Knee Payment Model</b></p>	<p><b>CORE reviewed the final hip/knee payment model. CORE used a hierarchical generalized linear model with an inverse Gaussian distribution and log link. Risk-standardization of the outcome narrowed the range of \$15,000-\$41,600 (unadjusted) to \$16,400-\$35,000.</b></p>	<p>A TEP member requested that CORE clarify why only hospitals with more than 25 hip/knee arthroplasty cases were included in the model results, and how patients may be clustered within the hospital.</p> <p>CORE responded that hospitals with fewer than 25 cases will have more uncertainty around their RSPs, which is also why CMS only reports results on <i>Hospital Compare</i> for hospitals that have more than 25 cases (for example, in the hip/knee arthroplasty complication measure). The patients at these hospitals were included in the model. In response to the question about patient clustering, CORE responded that patients are clustered within a given hospital and therefore related to each other because they receive care from the same provider. This requires statistical adjustment.</p> <p><b>Summary: CORE explained that hospitals with fewer than 25 hip/knee arthroplasty are not included in the measure results due to uncertainty around their RSP. Further, CORE noted that patients are clustered within hospitals and this relationship must be accounted for statistically. Finally, risk-standardized results are generally publicly</b></p>

Topic	Key Issues Discussed	TEP Feedback/Discussion
<p><b>Index and Post-Acute Care Payment Breakdowns</b></p>	<p><b>CORE reviewed additional analyses conducted that explored the breakdown of payments in the index hospitalization and the post-acute period. In brief, approximately 40% of all payments in the 90-day episode window were attributed to the index stay, and 60% were attributed to post-acute care. The largest proportions of post-acute care payments were attributed to outpatient physician visits (22.3% of all post-acute care payments) and skilled nursing facilities (19.5% of all post-acute care payments).</b></p>	<p><b>reported as comparisons to the national average.</b></p> <p>A TEP member noted that the proportion of payments made for post-acute care seemed higher than was expected.</p> <p>A TEP member suggested that payments in post-acute care settings may be correlated to payments that are captured under outpatient physician visits.</p> <p>A TEP member expressed concern that some readmissions may incorrectly be categorized as an emergency department (ED) stay or observation stay.</p> <p>CORE responded that readmissions are defined as inpatient hospitalizations, and only ED visits that lead to inpatient admission will be billed to CMS as inpatient admissions. Reimbursements for ED and observation stays are billed by CMS as outpatient care.</p> <p>A TEP member expressed concern that the outpatient physician proportion of post-acute care payments is so large given that physician visit payments are captured in other settings. A second TEP member suggested that the large proportion may result from including all physician visits in the payment outcome in the first 30 days of the episode window. Furthermore, medical complications that are not coded as such but seen by a non-surgeon may be captured in this setting.</p> <p><b>Summary: TEP members did not expect the proportion of post-acute care payments to be as high as it was. There was some additional concern about readmissions being counted as ED or observation stays, although CORE clarified that only ED stays that lead to inpatient admission will count as inpatient readmissions.</b></p>

## Appendix A. YNHHS/CORE New Measure Development Team

**Table A 1: CORE Members on the Measure Development Team**

Name	Title/Affiliation	Contact Information
Susannah Bernheim, MD, MHS	Director, Quality Measurement	susannah.bernheim@yale.edu
Kanchana Bhat, MPH	Project Manager	kanchana.bhat@yale.edu
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Amena Keshawarz, MPH	Project Coordinator	amena.keshawarz@yale.edu
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Shengfan Zhou, MS, MS	Supporting Analyst	shengfan.zhou@yale.edu
Rachelle Zribi, BA	Research Assistant	rachelle.zribi@yale.edu

**Table A 2: Outside Consultants on the Measure Development Team**

Name	Title/Affiliation	Contact Information
Kevin Bozic, MD, MBA	Professor and Vice Chair University of California, San Francisco Department of Orthopaedic Surgery Core Faculty, Philip R. Lee Institute for Health Policy Studies	kevin.bozic@ucsf.edu

## **Appendix B. TEP Call Schedule**

1. May 19, 2014 – 6:00pm-8:00pm EST
2. August 25, 2014 – 6:00pm-8:00pm EST
3. TBD

## Appendix C. ICD-9 Cohort Codes

**Table C 1. ICD-9 Cohort Codes**

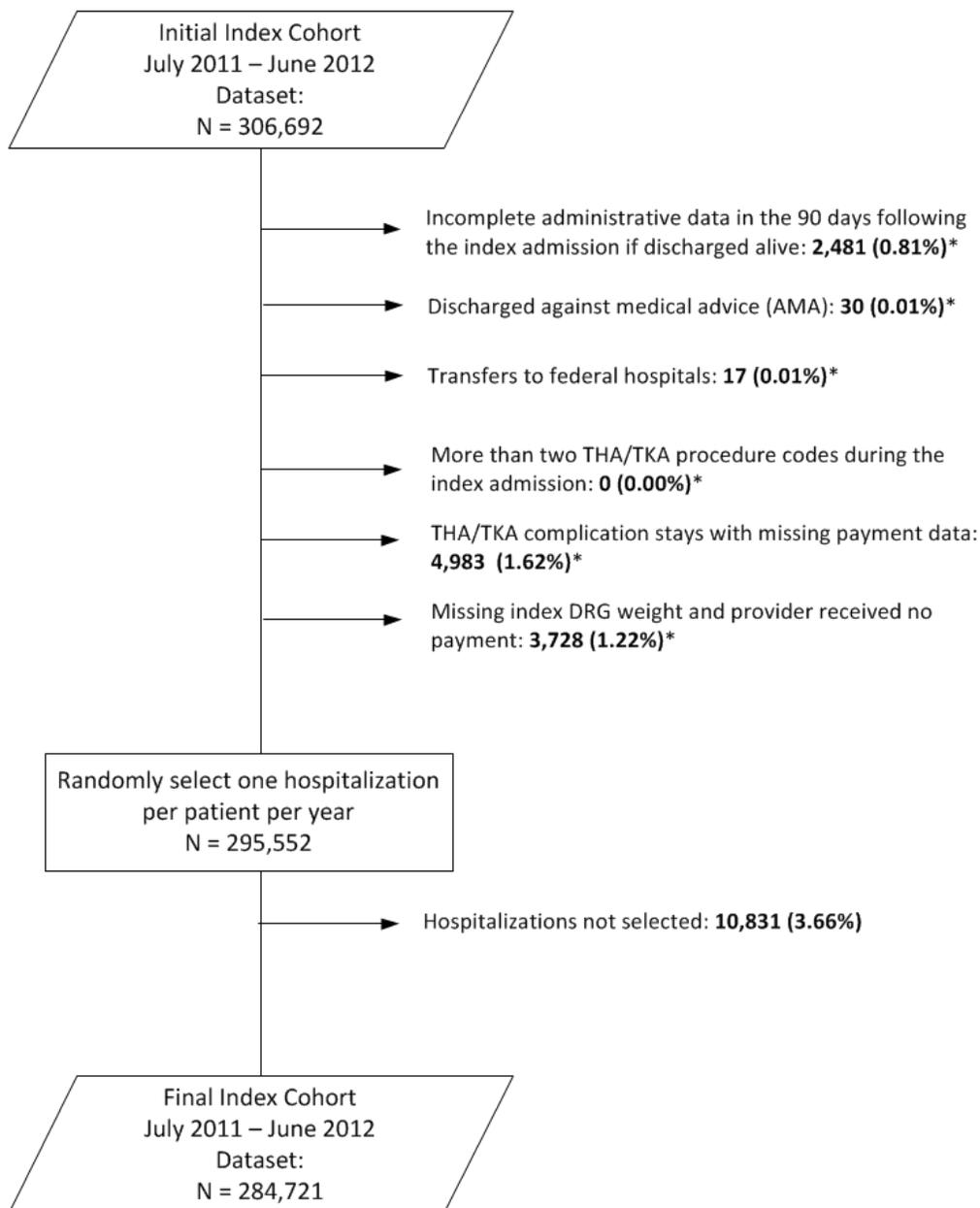
ICD-9 Code	Description
81.51	Total Hip Replacement
81.54	Total Knee Replacement

Elective primary THA/TKA procedures included in the measure cohort are defined as those procedures without any of the following:

- Femur, hip, or pelvic fractures coded in principal or secondary discharge diagnosis fields of the index admission;
- Partial hip arthroplasty (PHA) procedures with a concurrent THA/TKA;
- Revision procedures with a concurrent THA/TKA;
- Resurfacing procedures with a concurrent THA/TKA;
- Mechanical complication coded in the principal discharge diagnosis field;
- Malignant neoplasm of the pelvis, sacrum, coccyx, lower limbs, or bone/bone marrow or a disseminated malignant neoplasm coded in the principal discharge diagnosis field;
- Removal of implanted devices/prostheses; or
- Transfer from another acute care facility for the index THA/TKA.

## Appendix D. Cohort Definition

**Figure D 1. Index Cohort for Hip/Knee Payment Measure, July 2011-June 2012**



The initial index cohort includes Medicare FFS patients aged 65 or older with a qualifying elective primary THA/TKA procedure; admitted to non-federal acute care hospitals; enrolled in Part A and Part B Medicare for the 12 months prior to the date of admission, and enrolled in Part A and Part B during the index admission; who were not transferred from another acute care facility.

\* These categories are not mutually exclusive

## Appendix E. Potential Complications of Care

- A team of clinicians carefully reviewed the 189 Condition Categories (CCs) and determined those that could be considered potential complications of care if they occur during the index admission.
- We do not risk adjust for those CCs that are considered potential complications of care if they appear only as a secondary diagnoses during the index admission and nowhere else in the patient’s 12-month history.

**Table E 1. Potential Complications in the Index Admission**

CC #	Description
CC 2	Septicemia/Shock
CC 6	Other Infectious Diseases
CC 17	Diabetes with Acute Complications
CC 23	Disorders of Fluid/Electrolyte/Acid-Base
CC 28	Acute Liver Failure/Disease
CC 31	Intestinal Obstruction/Perforation
CC 34	Peptic Ulcer, Hemorrhage, Other Specified Gastrointestinal Disorders
CC 46	Coagulation Defects and Other Specified Hematological Disorders
CC 48	Delirium and Encephalopathy
CC 75	Coma, Brain Compression/Anoxic Damage
CC 77	Respirator Dependence/Tracheostomy Status
CC 78	Respiratory Arrest
CC 79	Cardio-Respiratory Failure and Shock
CC 80	Congestive Heart Failure
CC 81	Acute Myocardial Infarction
CC 82	Unstable Angina and Other Acute Ischemic Heart Disease
CC 92	Specified Heart Arrhythmias
CC 93	Other Heart Rhythm and Conduction Disorders
CC 94	Other and Unspecified Heart Disease
CC 95	Cerebral Hemorrhage
CC 96	Ischemic or Unspecified Stroke
CC 97	Precerebral Arterial Occlusion and Transient Cerebral Ischemia
CC 100	Hemiplegia/Hemiparesis
CC 101	Diplegia (Upper), Monoplegia, and Other Paralytic Syndromes
CC 102	Speech, Language, Cognitive, Perceptual
CC 104	Vascular Disease with Complications
CC 105	Vascular Disease
CC 106	Other Circulatory Disease
CC 111	Aspiration and Specified Bacterial Pneumonias
CC 112	Pneumococcal Pneumonia, Emphysema, Lung Abscess
CC 114	Pleural Effusion/Pneumothorax
CC 129	End Stage Renal Disease
CC 130	Dialysis Status
CC 131	Renal Failure
CC 132	Nephritis
CC 133	Urinary Obstruction and Retention

CC #	Description
CC 135	Urinary Tract Infection
CC 148	Decubitus Ulcer of Skin
CC 152	Cellulitis, Local Skin Infection
CC 154	Severe Head Injury
CC 155	Major Head Injury
CC 156	Concussion or Unspecified Head Injury
CC 158	Hip Fracture/Dislocation
CC 159	Major Fracture, Except of Skull, Vertebrae, or Hip
CC 163	Poisonings and Allergic Reactions
CC 165	Other Complications of Medical Care
CC 174	Major Organ Transplant Status
CC 175	Other Organ Transplant/Replacement
CC 176	Artificial Openings for Feeding or Elimination
CC 177	Amputation Status, Lower Limb/Amputation
CC 178	Amputation Status, Upper Limb
CC 179	Post-Surgical States/Aftercare/Elective

## Appendix F. Candidate and Final Model Variables

**Table F 1. Candidate Variables**

Category	Variable	ICD-9/CC
Demographics	Age-65 (years above 65, continuous)	N/A
Demographics	Male	N/A
Procedure	Index Admission with an Elective THA Procedure	N/A
Procedure	Procedure Type (Single Joint Replacement, Bilateral Joint Replacement, or Staged Joint Replacements)	N/A
Other Comorbidity	Morbid obesity	ICD-9 278.01
Other Comorbidity	Aseptic necrosis of medial femoral condyle	ICD-9 733.43
Other Comorbidity	Respiratory Arrest/Cardiorespiratory Failure/Respirator Dependence	CC 77-79
Other Comorbidity	Congestive Heart Failure	CC 80
Other Comorbidity	Acute Coronary Syndrome	CC 81-82
Other Comorbidity	Chronic Atherosclerosis	CC 83-84
Other Comorbidity	Heart Infection/Inflammation, Except Rheumatic	CC 85
Other Comorbidity	Valvular or Rheumatic Heart Disease	CC 86
Other Comorbidity	Congenital Cardiac/Circulatory Defect	CC 87-88
Other Comorbidity	Hypertension and Hypertension complications	CC 89-91
Other Comorbidity	History of Infection	CC 1, 3-6
Other Comorbidity	Septicemia/Shock	CC 2
Other Comorbidity	Other Infectious Diseases and Pneumonias	CC 6, 111-113
Other Comorbidity	Metastatic Cancer and Acute Leukemia	CC 7
Other Comorbidity	Cancer	CC 8-12
Other Comorbidity	Other Neoplasms	CC 13
Other Comorbidity	Benign Neoplasms of Skin, Breast, Eye	CC 14
Other Comorbidity	Diabetes and Diabetes Complications	CC 15-19, 119-120
Other Comorbidity	Protein-Calorie Malnutrition	CC 21
Other Comorbidity	Other Significant Endocrine and Metabolic Disorders	CC 22
Other Comorbidity	Disorders of Fluid/Electrolyte/Acid-Base	CC 23
Other Comorbidity	Obesity/Disorders of Thyroid, Cholesterol, Lipids	CC 24 excluding ICD-9 278.01
Other Comorbidity	Liver and Biliary Disease	CC 25-30
Other Comorbidity	Intestinal Obstruction/Perforation	CC 31
Other Comorbidity	Pancreatic Disease	CC 32
Other Comorbidity	Inflammatory Bowel Disease	CC 33
Other Comorbidity	Peptic Ulcer, Hemorrhage, Other Specified Gastrointestinal Disorders	CC 34
Other Comorbidity	Appendicitis	CC 35
Other Comorbidity	Other Gastrointestinal Disorders	CC 36
Other Comorbidity	Bone/Joint/Muscle Infections/Necrosis	CC 37 excluding ICD-9 733.43
Other Comorbidity	Rheumatoid Arthritis and Inflammatory Connective Tissue Disease	CC 38
Other Comorbidity	Disorders of the Vertebrae and Spinal Discs	CC 39
Other Comorbidity	Osteoarthritis of Hip or Knee	CC 40
Other Comorbidity	Osteoporosis and Other Bone/Cartilage Disorders	CC 41
Other Comorbidity	Congenital/Developmental Skeletal and Connective Tissue Disorders	CC 42
Other Comorbidity	Other Musculoskeletal and Connective Tissue Disorders	CC 43
Other Comorbidity	Severe Hematological Disorders	CC 44
Other Comorbidity	Disorders of Immunity	CC 45

Category	Variable	ICD-9/CC
Other Comorbidity	Coagulation Defects and Other Specified Hematological Disorders	CC 46
Other Comorbidity	Iron Deficiency and Other/Unspecified Anemias and Blood Disease	CC 47
Other Comorbidity	Delirium and Encephalopathy	CC 48
Other Comorbidity	Dementia and Senility	CC 49-50
Other Comorbidity	Drug/Alcohol Abuse/Dependence/Psychosis	CC 51-53
Other Comorbidity	Major Psychiatric Disorders	CC 54-57
Other Comorbidity	Depression/Anxiety	CC 58-59
Other Comorbidity	Other Psychiatric Disorders	CC 60
Other Comorbidity	Mental Retardation or Developmental Disability	CC 61-65
Other Comorbidity	Hemiplegia, Paraplegia, Paralysis, Functional Disability	CC 67-69, 100-102, 177, 178
Other Comorbidity	Muscular Dystrophy	CC 70
Other Comorbidity	Polyneuropathy	CC 71
Other Comorbidity	Multiple Sclerosis	CC 72
Other Comorbidity	Parkinson's and Huntington's Diseases	CC 73
Other Comorbidity	Seizure Disorders and Convulsions	CC 74
Other Comorbidity	Coma, Brain Compression/Anoxic Damage	CC 75
Other Comorbidity	Mononeuropathy, Other Neurological Conditions/Injuries	CC 76
Other Comorbidity	Arrhythmias	CC 92-93
Other Comorbidity	Other and Unspecified Heart Disease	CC 94
Other Comorbidity	Stroke	CC 95-96
Other Comorbidity	Cerebrovascular Disease	CC 97-99, 103
Other Comorbidity	Vascular or Circulatory Disease	CC 104-106
Other Comorbidity	Cystic Fibrosis	CC 107
Other Comorbidity	Chronic Obstructive Pulmonary Disease (COPD)	CC 108
Other Comorbidity	Fibrosis of lung or other chronic lung disorder	CC 109
Other Comorbidity	Asthma	CC 110
Other Comorbidity	History of Pneumonia	CC 111-113
Other Comorbidity	Pleural Effusion/Pneumothorax	CC 114
Other Comorbidity	Other Lung Disorders	CC 115
Other Comorbidity	Legally Blind	CC 116
Other Comorbidity	Major Eye Infections/Inflammations	CC 117
Other Comorbidity	Retinal Detachment	CC 118
Other Comorbidity	Retinal Disorders, Except Detachment and Vascular Retinopathies	CC 121
Other Comorbidity	Glaucoma	CC 122
Other Comorbidity	Other Eye Disorders	CC 124
Other Comorbidity	Significant Ear, Nose, and Throat Disorders	CC 125
Other Comorbidity	Hearing Loss	CC 126
Other Comorbidity	Other Ear, Nose, Throat, and Mouth Disorders	CC 127
Other Comorbidity	Kidney Transplant Status	CC 128
Other Comorbidity	End-stage Renal Disease of Dialysis	CC 130
Other Comorbidity	Renal Failure	CC 131
Other Comorbidity	Nephritis	CC 132
Other Comorbidity	Urinary Obstruction and Retention	CC 133
Other Comorbidity	Incontinence	CC 134
Other Comorbidity	Urinary Tract Infection	CC 135
Other Comorbidity	Other urinary tract disorders	CC 136
Other Comorbidity	Pelvic Inflammatory	CC 138
Other Comorbidity	Other Female Genital Disorders	CC 139
Other Comorbidity	Male genital disorders	CC 140
Other Comorbidity	Decubitus Ulcer or Chronic Skin Ulcer	CC 148-149
Other Comorbidity	Extensive Burns	CC 150-151

Category	Variable	ICD-9/CC
Other Comorbidity	Cellulitis, Local Skin Infection	CC 152
Other Comorbidity	Other Dermatological Disorders	CC 153
Other Comorbidity	Trauma	CC 154-156, 158-161
Other Comorbidity	Vertebral Fractures	CC 157
Other Comorbidity	Other Injuries	CC 162
Other Comorbidity	Poisonings and Allergic Reactions	CC163
Other Comorbidity	Major Complications of Medical Care and Trauma	CC 164
Other Comorbidity	Other Complications of Medical Care	CC 165
Other Comorbidity	Major Symptoms, Abnormalities	CC 166
Other Comorbidity	Minor Symptoms, Signs, Findings	CC 167
Other Comorbidity	Major Organ Transplant Status	CC 174
Other Comorbidity	Other Organ Transplant/Replacement	CC 175

**Table F 2. Final Variables and Frequencies over Development and Validation Samples, July 2010-June 2012**

Variable	ICD-9/CC	2011-2012 Development Sample A1 (%)	2011-2012 Validation Sample A2 (%)	2010-2011 Validation Sample B (%)
Mean Age Minus 65 (SD)	N/A	9.46 (6.01)	9.44 (6.00)	9.50 (6.00)
Male	N/A	36.09	35.88	36.03
Index Admission with an Elective THA Procedure	ICD-9 81.51	30.26	30.06	28.85
Procedure Type (Bilateral Joint Replacement)	N/A	2.50	2.49	2.78
Procedure Type (Staged Joint Replacement)	N/A	0.74	0.73	0.73
Procedure Type (Single Joint Replacement)	N/A	96.76	96.78	96.49
Morbid Obesity	ICD-9 278.01	5.23	5.30	4.54
Congestive Heart Failure	CC 80	9.04	9.01	9.14
Acute Coronary Syndrome	CC 81-82	28.50	28.63	29.33
Valvular or Rheumatic Heart Disease	CC 86	15.39	15.29	15.20
Hypertension and Hypertension Complications	CC 89-91	83.60	83.39	83.73
History of Infection	CC 1, 3-6	17.79	18.14	17.82
Metastatic Cancer and Acute Leukemia	CC 7	0.53	0.57	0.54
Cancer	CC 8-12	18.85	18.66	18.56
Benign Neoplasms of Skin, Breast, Eye	CC 14	18.34	18.84	17.92
Diabetes and Diabetes Complications	CC 15-19, 119-120	28.99	28.89	28.67
Protein-Calorie Malnutrition	CC 21	0.73	0.75	0.67
Other Significant Endocrine and Metabolic Disorders	CC 22	4.07	4.07	3.74
Obesity/Disorders of Thyroid, Cholesterol, Lipids	CC 24, excluding ICD-9 278.01	70.37	70.05	68.99
Appendicitis	CC 35	0.10	0.10	0.10
Bone/Joint/Muscle Infections/Necrosis	CC 37	2.71	2.69	2.65
Rheumatoid Arthritis and Inflammatory Connective Tissue Disease	CC 38	9.15	9.11	8.84
Disorders of the Vertebrae and Spinal Discs	CC 39	28.77	28.87	28.07
Osteoarthritis of Hip or Knee	CC 40	96.16	96.16	96.06
Other Musculoskeletal and Connective Tissue Disorders	CC 43	89.42	89.16	88.56
Severe Hematological Disorders	CC 44	0.61	0.63	0.68
Coagulation Defects and Other Specified Hematological Disorders	CC 46	4.81	4.62	4.72
Delirium and Encephalopathy	CC 48	0.93	0.92	0.90
Dementia and Senility	CC 49-50	4.31	4.32	4.17
Major Psychiatric Disorders	CC 54-57	4.51	4.52	4.25
Depression/Anxiety	CC 58-59	15.45	15.46	13.45
Other Psychiatric Disorders	CC 60	10.30	10.28	8.24
Mental Retardation or Developmental Disability	CC 61-65	0.12	0.10	0.10
Hemiplegia, Paraplegia, Paralysis, Functional Disability	CC 67-69, 100-102, 177, 178	1.74	1.69	1.62
Polyneuropathy	CC 71	6.77	6.70	6.33
Multiple Sclerosis	CC 72	0.20	0.20	0.21
Parkinson's and Huntington's Diseases	CC 73	1.05	1.07	1.05
Seizure Disorders and Convulsions	CC 74	1.49	1.47	1.44
Arrhythmias	CC 92-93	23.86	23.59	23.32

Variable	ICD-9/CC	2011-2012 Development Sample A1 (%)	2011-2012 Validation Sample A2 (%)	2010-2011 Validation Sample B (%)
Stroke	CC 95-96	2.09	2.18	2.18
Vascular or Circulatory Disease	CC 104-106	22.58	22.63	22.75
Chronic Obstructive Pulmonary Disease (COPD)	CC 108	14.03	13.90	13.90
Pleural Effusion/Pneumothorax	CC 114	1.51	1.52	1.44
Other Lung Disorders	CC 115	18.20	18.39	18.75
Legally Blind	CC 116	0.21	0.21	0.20
End-stage Renal Disease or Dialysis	CC 130	0.18	0.15	0.14
Renal Failure	CC 131	8.39	8.32	7.69
Incontinence	CC 134	5.51	5.72	5.48
Urinary Tract Infection	CC 135	15.66	15.84	15.61
Other Urinary Tract Disorders	CC 136	13.14	13.23	12.88
Decubitus Ulcer or Chronic Skin Ulcer	CC 148-149	2.53	2.50	2.59
Cellulitis, Local Skin Infection	CC 152	7.74	7.65	7.69
Other Dermatological Disorders	CC 153	38.95	39.06	38.25
Trauma	CC 154-156, 158-161	4.62	4.70	4.54
Vertebral Fractures	CC 157	1.19	1.19	1.23
Other Injuries	CC 162	28.37	28.27	27.58
Major Symptoms, Abnormalities	CC 166	51.69	51.93	51.98
Minor Symptoms, Signs, Findings	CC 167	79.97	79.71	78.58