Hospital-Level, Risk-Standardized Payment Associated with a 90-Day Episode of Care for Elective Primary Total Hip Arthroplasty (THA) and/or Total Knee Arthroplasty (TKA) (Version 1.0)

2014 Measure Methodology Report

Submitted By

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

Nancy Kim, M.D., Ph.D.*– Project Lead
Lesli S. Ott, M.A., M.A. – Lead Analyst
Zhenqiu Lin, Ph.D. – Supporting Analyst
Shengfan Zhou, M.S., M.S. – Supporting Analyst
Amena Keshawarz, M.P.H. – Project Coordinator
Steven Spivack, M.P.H. – Project Coordinator
Xiao Xu, M.A., Ph.D.* – Consulting Health Economist
Elizabeth George, M.P.H. – Research Associate
Madeline Parisi, B.A. – Research Assistant
Emily Reilly, M.P.H. – Research Assistant
Rachelle Zribi, B.A. – Research Assistant
Lisa G. Suter, M.D.* – Project Director
Harlan M. Krumholz, M.D., S.M.* – Principal Investigator

*Yale School of Medicine

Prepared For:

Centers for Medicare & Medicaid Services (CMS)

December 2014

ACKNOWLEDGEMENTS

This study is a collaborative effort, and the study authors gratefully acknowledge and thank Elizabeth Drye, Kanchana Bhat, and Lori Geary from Yale-New Haven Health Services Corporation/Center for Outcomes Research & Evaluation; Sharon-Lise Normand from Harvard School of Public Health; Kevin Bozic from the University of California, San Francisco; and Lein Han, Karen Nakano, Michael Rapp, and Kate Goodrich at the Centers for Medicare & Medicaid Services for their contributions to this work.

We also thank the Technical Expert Panel members, who provided helpful insight on key measure decisions. These members include:

AJ Yates, MD - Associate Professor of Medicine, University of Pittsburgh School of Medicine: Department of Orthopedic Surgery

Amita Rastogi, MD, MHA, CHE, MS - Chief Medical Officer, Health Care Incentives Improvement Institute

Blair Biase, MMSc, PA-C, MBA - Product Director, Global Knee Reconstruction, OrthoSensor, Inc.

Brian McCardel, MD - Chief of Orthopedics, Sparrow Health System, Orthopedic Surgery Section

Cheryl Crumpton, MS, RN, CEN - Orthopedic/ Neurosurgery Service Line Coordinator, Cheyenne Regional Medical Center

Cheryl Fahlman, PhD, MBA, BSP - Principal Research Scientist, Premier Healthcare Solutions, Inc.

Cynthia Jacelon, PhD, RN, CRRN, FAAN - Associate Professor, University of Massachusetts School of Nursing

David Hopkins, PhD, MS - Senior Advisor, Pacific Business Group on Health

Derek Nordman, MPT, ATC - Vice President, Specialty Operations, Gentiva Health Services

John Birkmeyer, MD - George D. Zuidema Professor and Chair of Health Services Research; Attending General Surgeon, University of Michigan: Department of Surgery

Jonathan Schaffer, MD, MBA - Managing Director, Information Technology Division, The Cleveland Clinic Foundation: Department of Orthopedic Surgery

Kate Chenok, AB, MBA - Director of New Initiatives, Pacific Business Group on Health

Kathleen Willhite, MS - Director of Payor Contracting, BayCare Health Systems

Vinod Dasa, MD - Associate Professor, Department of Orthopedic Surgery, Louisiana State University Health Sciences Center, Oschsner Kenner Medical Center

Vivian Ho, PhD - James A. Baker III Institute Chair in Health Economics, Rice University: Department of Economics

Patient, Anonymous

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EXECUTIVE SUMMARY

This technical report describes the development of a hospital-level, risk-standardized 90-day episode-of-care payment measure for elective primary total hip arthroplasty (THA) and/or total knee arthroplasty (TKA) developed by Yale New Haven Health Services Corporation/Center for Outcomes Research & Evaluation (CORE) under contract with the Centers for Medicare & Medicaid Services (CMS). A risk-standardized payment (RSP) measure for a THA/TKA episode of care that spans from admission through 90 days post-admission provides information that will support hospital and national efforts to optimize efficiency and to coordinate care.

Context of Medicare Spending and Value Assessments

In 2012, total Medicare expenditures were $574.2 billion, representing 3.6% of gross domestic product (GDP).[1] Current estimates suggest that Medicare spending will increase to 5.6% of GDP by 2040.[1] The growth in Medicare spending highlights the need to incentivize high-value care. A critical first step in moving toward high-value care is to provide transparency of costs of care that is comparable across providers. In this report, we describe the development of a "cost" measure that evaluates the costs of caring for Medicare patients. We developed this measure to include a 90-day episode of care to provide insight into the costs of practice patterns that occur during inpatient admission and immediately thereafter. The measure specifications are aligned with current quality-of-care measures so that the costs of care can be interpreted in the context of the health outcomes they deliver. In this way, the measure can facilitate the profiling of hospital value and encourage the most efficient delivery of high-quality care.

Using Payments for Medicare Patients

Costs are often approximated using hospital charges, converting hospital charges to costs based on cost-to-charge ratios, or estimating Medicare payments. Because we are interested in measuring costs for the care of Medicare patients, we focused on payments made for Medicare patients for a 90-day episode of care for THA/TKA. Payments for Medicare patients are calculated using both Medicare claims and CMS data. Using CMS's clearly defined Prospective Payment Systems (PPS) and Fee Schedules in combination with Medicare claims allows for the removal of payment adjustments that are not directly related to care (for example, geographic factors and policy adjustments) across all care settings, services, and supplies.

Measuring THA/TKA

By focusing on specific procedures, value assessments may provide actionable feedback to hospitals and incentivize targeted improvements in care. THA and TKA are common procedures among the elderly with substantial variability in payments due to different practice patterns. Quality measures for THA/TKA, such as the 90-day risk-standardized complication rate (RSCR) following THA/TKA, are already publicly reported, making THA/TKA an ideal procedure in which to assess payments for Medicare patients and relative hospital value.

90-Day Episode of Care

When considering hospital payments, we focused on a 90-day "episode of care" triggered by admission for several key reasons. First, THA and TKA procedures require ongoing post-discharge care. Second, the 90-day preset window incentivizes hospitals to optimize post-discharge care. Third, mechanical complications and wound or joint infections may present after 30 days. Fourth, the 90-day post-admission timeframe is consistent with CMS's THA/TKA complication measure, which captures specific complications up to 90 days after admission. Finally, a 90-day window was consistent with the timeframe recommended by members of our Technical Expert Panel (TEP). The THA/TKA payment measure captures payments for Medicare patients across multiple care settings, services, and supplies (inpatient, outpatient, skilled nursing facility, home health, hospice, physician/clinical laboratory/ambulance services, and durable medical equipment, prosthetics/orthotics, and supplies).

Payment Calculation

The overarching goal of the measure is to calculate payments that reflect differences in the care provided for patients undergoing THA/TKA rather than differences based on geography or policy adjustments. In order to remove payment adjustments unrelated to clinical care we developed the measure by "stripping" or "standardizing" payments as detailed below:

- Stripping refers to removing geographic differences and policy adjustments in payment rates for individual services.
- Standardizing refers to averaging payments across geographic areas for those services where geographic differences in payment cannot be stripped.

By removing payment adjustments unrelated to clinical care, our risk-adjusted measure reflects differences in payment due to practice variation at the hospital level. The body of this report presents the current measure specifications, methodology, and results in detail. This same methodology has been used to estimate payments for an episode of care triggered by several other specific disease conditions, such as acute myocardial infarction (AMI), heart failure, and pneumonia.

Risk-Adjustment and Statistical Model

To compare relative hospital payments, we adjusted for hospital case mix by including patient age, gender, procedure characteristics, and comorbid conditions that are clinically relevant to THA/TKA and have strong relationships with the payment outcome. To calculate hospital-specific risk-standardized payments, we estimated hierarchical generalized linear models. This strategy accounts for within-hospital correlation of the outcomes (total episode-of-care payments) and accommodates the assumption that underlying differences in care across hospitals lead to systematic differences in outcomes.

Findings

Wide variation in payments for an elective THA/TKA episode of care persists after removing Medicare payment adjustments that are not related to clinical care (for example, geographic factors and policy adjustments) and adjusting for patient case mix.

1. INTRODUCTION

1.1. Background

In 2012, total Medicare expenditures were $574.2 billion, representing 3.6% of gross domestic product (GDP).[1] Current estimates suggest that Medicare spending will increase to 5.6% of GDP by 2040 due to both an increase in the Medicare population as well as an increase in Medicare spending on each beneficiary.[1] The growth in Medicare spending is unsustainable and highlights the need to create incentives for high-value care. A critical first step in moving toward high-value care is to define an approach to calculate costs that is transparent to consumers and fair to providers. In this report, we describe the development of a "cost" measure that evaluates the costs of caring for Medicare patients from the perspective of the Centers for Medicare and Medicaid Services (CMS). This measure uses standardized payments to reflect differences in the management of care for patients with an elective primary total hip arthroplasty (THA) and/or total knee arthroplasty (TKA) both during hospitalization and after discharge.

Payments, however, are difficult to interpret in isolation. Some high-payment hospitals may have better clinical outcomes when compared with low-payment hospitals; other high-payment hospitals may not. In an effort to identify practice patterns that may be expensive without conferring a quality benefit, the THA/TKA payment measure specifications are aligned with current quality-of-care measures, such as CMS's 90-day THA/TKA complication measure. In this way, the measure can facilitate the profiling of hospital value and encourage the most efficient delivery of high-quality care.

A payment measure that fairly profiles hospitals by adjusting for hospital case mix and that standardizes payments for geography is congruent with national efforts to increase the transparency of our healthcare system. Although the THA/TKA payment measure is not intended to be used in payment programs, it can provide key insights into those systems of care at hospitals that provide high value as a patient moves from the inpatient to the outpatient setting when interpreted in the context of CMS's THA/TKA complication measure. Because the payment measure spans an episode of care, it is complementary to and may uniquely inform innovative payment models such as bundled payments and Accountable Care Organizations (ACOs), both of which seek to improve healthcare value by optimizing the coordination of care across care settings.[2]

1.2. Assessing Cost of Care by Measuring Payments for Medicare Patients

There are many different ways to measure cost including, but not limited to, approximations using hospital charges, conversions of charges to costs using cost-to-charge ratios, and estimations based on Medicare payments. **For this task, we have defined the "cost" of care as payments made for Medicare patients for a THA/TKA episode of care.**

1.3. Measuring THA/TKA Payments

Due to their frequency and cost, THA and TKA are priority areas for payment measure development. More than one-third of the US population 65 years and older suffers from osteoarthritis,[3] a disabling condition for which elective THA/TKA are most commonly performed. Between 2009 and 2012, there were 337,419 THA procedures and 750,569 TKA procedures for Medicare fee-for-service (FFS) patients 65 years and older.[4] Estimates place the annual insurer cost of osteoarthritis in the US at $149 billion,

with Medicare payments to hospitals for THA/TKA exceeding $15 billion annually.[5] Furthermore, there is evidence suggesting great variation in the costs of a full episode of care for THA and TKA.[6,7]

THA/TKA provides a suitable environment for optimizing value across an episode of care, as there are many opportunities to improve value for pre-, peri-, and post-operative care. Ultimately, clinical outcomes for THA and TKA depend not just on the surgeon performing the procedure, but on care coordination across provider groups and specialties, as well as the patient's engagement in his or her recovery. The goal of hospital-level resource use measurement is to capture the full spectrum of care in order to incentivize collaboration and shared responsibility for improving patients' health and reducing the burden of their procedure.

1.4.   Episode of Care

When considering payments for Medicare patients, we focused on a 90-day "episode of care" triggered by admission for several key reasons. First, THA and TKA procedures require ongoing post-discharge care. Second, the 90-day preset window incentivizes hospitals to optimize post-discharge care. Third, mechanical complications and wound or joint infections may present after 30 days and rates of these complications remain elevated for at least 90 days. Fourth, the 90-day post-admission timeframe is consistent with CMS's THA/TKA complication measure, which captures specific complications up to 90 days after admission. Furthermore, we obtained input from a national Technical Expert Panel (TEP) on the most appropriate window for the episode of care. Based on TEP feedback, we chose a measure follow-up period of 90 days that includes all payments for the initial 30 days of the episode, and payments defined as "related" to the index procedure for days 31 through 90. Related payments are further defined in Section 2.4.2.

Using the Chronic Condition Warehouse (CCW) data, we tracked payments for Medicare patients through the 90-day post-admission period. The CCW data are derived from Medicare claims in the Standard Analytic Files and contain payment information for all care settings, services, and supplies. The CCW data provide a unique opportunity to gain insight into a cascade of medical events triggered by THA/TKA hospitalization and the payments associated with those events. The specific goal of this task is to sum payments for Medicare patients, including index admission as well as post-discharge payments, for: readmission or other post-discharge inpatient care, skilled nursing facilities, outpatient providers, home health agencies, hospice care, physician/clinical laboratory/ambulance services, and durable medical equipment, prosthetics/orthotics, and supplies. This work will be used to better understand differences in the patterns of post-discharge care and associated payments for Medicare patients across a continuum of care beginning with a hospitalization for THA/TKA and following patients 90 days after admission.

1.5.   Approach to Measure Development

We developed this measure in accordance with national guidelines and in consultation with clinical and measurement experts, key stakeholders, and the public. The proposed measure is consistent with the technical approach to outcomes measurement set forth in the National Quality Forum (NQF) guidance for outcomes measures,[8] CMS's Measure Management System (MMS),[9] and the guidance articulated in the American Heart Association's scientific statements, "Standards for Statistical Models Used for Public Reporting of Health Outcomes",[10] and "Standards for Measures Used for Public Reporting of Efficiency in Health Care."[11] During the measure development process, we obtained expert and stakeholder input

via two mechanisms: first, through regular discussions with an advisory working group, and second, through meetings with our TEP.

We held regular conference calls with our working group throughout the measure development phase. The working group included clinicians and other professionals with expertise in orthopedics, biostatistics, health economics, measure development, and quality improvement. The working group meetings addressed key issues surrounding measure development, including detailed discussions regarding specific decisions (for example, defining the appropriate measure cohort) to ensure the methodological rigor of the measure.

In addition to the working group and in alignment with CMS's MMS, we convened a TEP consisting of a group of recognized experts and stakeholders in relevant fields to provide input and feedback during measure development. To form the TEP, we posted a public call for nominations and selected individuals representing a range of perspectives, including those of physicians, nurses, physical therapists, health economists, consumers, hospitals, and purchasers. In contrast to the working group meetings, the TEP meetings followed a more structured format consisting of the presentation of key issues, relevant data, and our proposed approach. This presentation was followed by open discussion of these issues with TEP members.

We posted the measure specifications and a summary of the TEP discussions publicly, after which we underwent a 30-day public comment period. We collected these comments through the MMS website and summarized them for CMS. We also posted the comments verbatim on the MMS website. We considered all submitted comments during the final stages of measure development.

1.6. Aims of the Measure

The primary objective of this work is to develop a 90-day episode-of-care THA/TKA payment measure that:

1. Captures differences in the payments for patients undergoing THA/TKA,
2. Accounts for differences in the payments across hospitals,
3. Removes variation in payments due to payment adjustments that are not directly related to clinical care (for example, geography and policy adjustments),
4. Adjusts for hospital case mix,
5. Assesses relative performance of hospitals, and
6. Aligns with THA/TKA quality outcome measures.

Using administrative claims data, we measure risk-standardized payments (RSPs) for Medicare patients for an episode of care that begins with an index admission for THA/TKA and ends 90 days after the index admission. The THA/TKA payment measure captures payments for Medicare patients across multiple care settings, services, and supplies (inpatient, outpatient, skilled nursing facility, home health, hospice, physician/clinical laboratory/ambulance services, and durable medical equipment, prosthetics/orthotics, and supplies). We remove payment adjustments unrelated to clinical care decisions. By risk-standardizing the payment measure, we are able to adjust for the case mix at any given hospital and compare a specific hospital's THA/TKA payment to an average hospital with a similar case mix. Key decisions in the development of the THA/TKA payment measure were aligned with key decisions in CMS's 90-day THA/TKA complication measure.

Our methodology was developed in accordance with accepted standards for outcomes measure development, including appropriate risk adjustment to allow for fair profiling of institutions and transparency of specifications.

Please note that for easy reference, we sometimes refer to the hospital-level, risk-standardized payment measure for a 90-day episode of care for primary elective THA/TKA simply as the THA/TKA payment measure in this document.

2. METHODS

2.1. Overview of Measure Methodology

We developed a hospital-level RSP measure for a 90-day episode of care for THA/TKA. The measure results in a single summary RSP and uses index admissions from two years of CCW data (July 2010-June 2012) to assess hospital performance. This measure is intended to capture differences in payment for a 90-day episode of care for THA/TKA at the hospital level. Payments for Medicare patients can vary for a number of reasons, including:

1. Hospital practice patterns,
2. Payment adjustments that reflect geography (for example, paying different amounts for the same service in different parts of the country),
3. Payment adjustments that reflect policies (for example, indirect medical education and disproportionate share adjustments) that serve a broader mission of CMS, but that do not reflect medical care, and
4. Patient case mix.

To isolate payment variation that reflects practice patterns rather than CMS payment adjustments, we "stripped" or "standardized" payments for each care setting. Stripping refers to removing geographic differences and policy adjustments in payment rates for individual services from the total payment for that service. Standardizing refers to averaging payments across geographic areas for those services where geographic differences in payment cannot be stripped. Stripping and standardizing the payments allowed for a fair comparison across hospitals based solely on payments for decisions related to clinical care, as described in Section 2.5.

We adjusted for case mix differences across hospitals by risk adjusting for patients' comorbid conditions identified in claims for 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 diagnosis codes on index admission. We did not risk adjust for diagnoses that may be complications of care during the index admission (Appendix A), which are described in Section 2.7.1. We used CMS Condition Category groups (CCs) to define the comorbid risk-adjustment variables. Additionally, we risk adjusted for the patients' age, gender, procedure location (hip or knee), and procedure type (single, bilateral, or staged procedures).

We used generalized linear modeling to estimate the risk-adjustment model and validated the model via a split-sample process. We also performed temporal validation of the risk-adjustment model using different years of data. We then used hierarchical generalized linear regression to isolate a hospital-

specific payment signal and to account for the clustering of admissions within each hospital. Finally, we calculated predicted and expected payments (as defined in [Section 2.8](#)) for each hospital.

2.2. Dataset

The CCW data are derived from the Medicare claims in the Standard Analytic Files. The CCW data contain data from the Medicare FFS institutional and non-institutional claims, enrollment and eligibility information, and assessment data for up to 100% of the Medicare FFS beneficiary population for particular conditions and procedures. The data are organized by predefined chronic conditions, but can also be used to define individualized patient cohorts, as described below. The annual CCW datasets include claims data from all seven standard files (inpatient, skilled nursing facility, outpatient, home health agency, hospice, carrier, and durable medical equipment) that can be linked across care settings, services, supplies, and years using a unique patient identifier. Specific information available in the CCW data includes diagnosis codes, procedure codes, quantity/units of services used, and payments made by CMS, patients, and other insurers to providers. We describe our methodology for estimating payments for a THA/TKA episode of care below.

2.3. Cohort

To develop the measure **we created our own elective primary THA/TKA cohort from the July 2010 to June 2012 100% sample of FFS beneficiaries to align with CMS's publicly reported 90-day THA/TKA complication measure.** Consistent with CMS's 90-day THA/TKA complication measure, the payment measure includes hospitalizations identified by a procedure code of either THA or TKA, as classified by the International Classification of Diseases, Ninth revision, Clinical Modification (ICD-9-CM) procedure codes 81.51 and 81.54, respectively. An **index hospitalization** is the initial admission for a qualifying elective THA/TKA that triggers the 90-day episode of care for this payment measure. The index cohort includes only those hospitalizations at short-stay acute care hospitals. The measure restricts the cohort to patients 65 and older and enrolled in FFS Medicare Parts A and B (with no Medicare Advantage coverage).

An index admission is the hospitalization to which the RSP outcome is attributed and includes index admissions for patients having a qualifying elective primary THA/TKA procedure. Elective primary THA/TKA procedures 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.[12]

If a patient has more than one eligible index admission for THA or TKA in the measure calculation period, a randomly selected THA/TKA admission per year is included in the measure to be consistent with CMS's 90-day THA/TKA complication measure. Additionally, the payment measure considers admissions with transfers as a single inpatient hospitalization. The measure does not include transfers directly from the emergency department (ED) to a second hospital in our transfer scenario because the CMS payment structure does not classify ED care as an inpatient admission, and this is an uncommon scenario for elective procedures. In these cases, the episode of care begins with the inpatient admission at the receiving hospital.

2.3.1. Index Cohort Exclusions

We applied several exclusion criteria to the cohort of index admissions as delineated below and in Figure 1 and Figure 2:

- Hospitalizations for patients without at least 90 days of post-admission enrollment in FFS Medicare Parts A & B
  Rationale: This was necessary in order to identify the outcome (payments) in the dataset over the analytic period.

- Hospitalizations for patients discharged against medical advice (AMA)
  Rationale: Hospitals had limited opportunity to implement high quality care.

- Hospitalizations for patients transferred to federal hospitals
  Rationale: We do not have claims data for federal hospitals, so including these patients would cause payments to be underestimated.

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

- Hospitalizations that could not be matched to admissions in the THA/TKA complication measure
  Rationale: As part of our data processing, we matched our index THA/TKA admissions to the THA/TKA complication measure cohort to obtain the risk-adjustment variables. Patients were excluded if they could not be matched between the THA/TKA payment and THA/TKA complication cohorts.

- Missing index DRG weight and provider received no payment
  Rationale: When both DRG weight and payment data were missing, we cannot calculate a payment for the patient's index admission.

Figure 1. Index Cohort for Hip/Knee Payment Measure, July 2011-June 2012
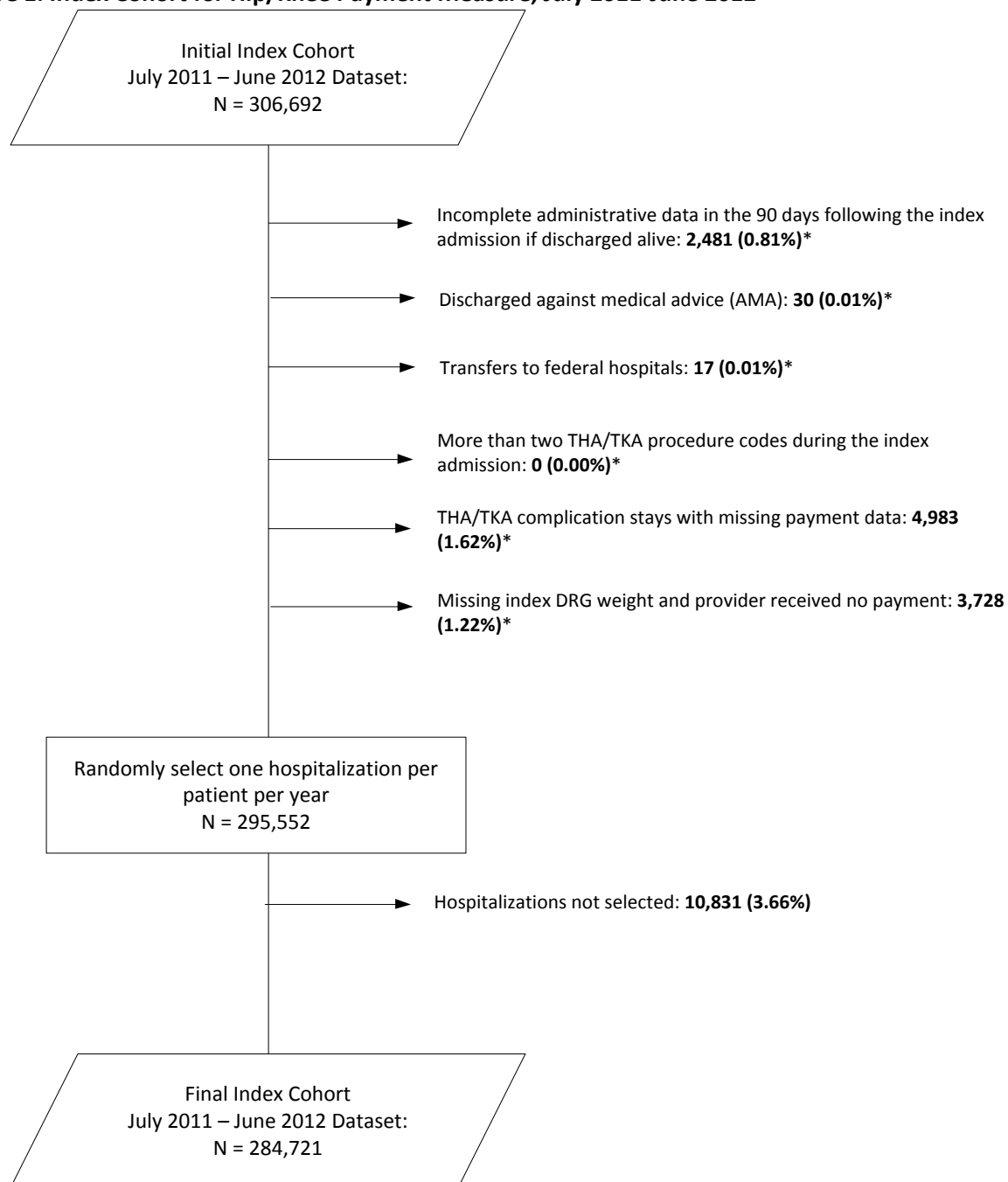
The initial index cohort includes Medicare FFS patients aged 65 or older with a qualifying elective primary THA/TKA procedure; admitted to non-federal acute care hospitals; enrolled in Part A and Part B Medicare for the 12 months prior to the date of admission, and enrolled in Part A and Part B during the index admission; who were not transferred from another acute care facility.

* These categories are not mutually exclusive

Figure 2. Index Cohort for Hip/Knee Payment Measure, July 2010 – June 2011
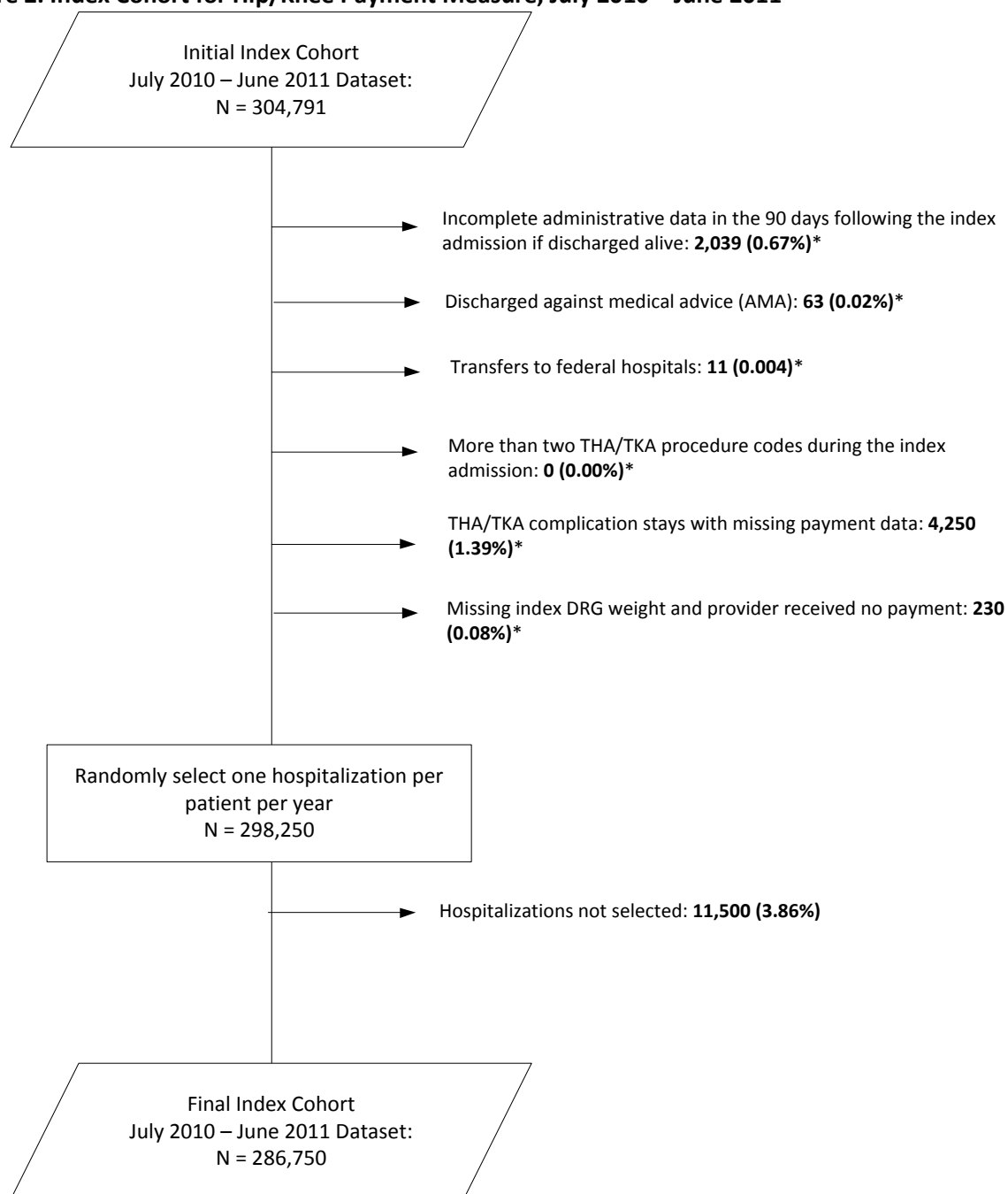
Initial Index Cohort
July 2010 – June 2011 Dataset:
N = 304,791

Incomplete administrative data in the 90 days following the index admission if discharged alive: **2,039 (0.67%)***

Discharged against medical advice (AMA): **63 (0.02%)***

Transfers to federal hospitals: **11 (0.004)***

More than two THA/TKA procedure codes during the index admission: **0 (0.00%)***

THA/TKA complication stays with missing payment data: **4,250 (1.39%)***

Missing index DRG weight and provider received no payment: **230 (0.08%)***

Randomly select one hospitalization per patient per year
N = 298,250

Hospitalizations not selected: **11,500 (3.86%)**

Final Index Cohort
July 2010 – June 2011 Dataset:
N = 286,750

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

2.4. Outcome

The primary outcome of this measure is the hospital-level RSP for a THA/TKA episode of care. The THA/TKA payment measure captures payments for Medicare patients across multiple care settings, services, and supplies (inpatient, outpatient, skilled nursing facility, home health, hospice, physician/clinical laboratory/ambulance services, and durable medical equipment, prosthetics/orthotics, and supplies). We remove payment adjustments unrelated to clinical care decisions. By risk standardizing the payment measure, we are able to adjust for case mix at any given hospital and compare a specific hospital's THA/TKA payment to an average hospital with a similar case mix. We define our analytic timeframe as beginning with the index admission for THA/TKA to 90 days post-admission (Figure 3). The measurement includes all payments for the first 30 days after admission and only THA/TKA-related claims for days 31-90.

2.4.1. 90-Day Episode of Care

We chose a 90-day window which includes all payments made for Medicare patients from day 0 (i.e., day of admission) through day 30, and only payments related to the index procedure from day 31 through day 90. We considered 90 days from the date of admission as a clinically reasonable timeframe for multiple reasons:

1. THA and TKA procedures require ongoing post-discharge care.
2. The 90-day preset window incentivizes hospitals to optimize post-discharge care.
3. Mechanical complications and wound or joint infections, which are included in the CMS's 90-day THA/TKA complication measure, may present after 30 days.
4. The 90-day post-admission timeframe is consistent with CMS's 90-day THA/TKA complication measure.

2.4.2. THA/TKA-Related Payments

We have defined THA/TKA-related payments as any claims, including physician claims, for the following care settings or services:

- Durable Medical Equipment (DME)
- Inpatient rehabilitation
- Outpatient rehabilitation
- Skilled Nursing Facilities (SNFs)
- Home health
- Staged or repeat admission for single-site surgeries within 90 days of index admission
- Readmissions for complications as defined in the CMS THA/TKA Complication measure (wound/joint infection or mechanical complication) (Table 1)

Table 1. ICD-9-CM Codes Defining Complications in CMS's THA/TKA Complication Measure

Complication	ICD-9 Codes Defining Complication
Mechanical Complications	996.4 Mechanical complication of internal orthopedic device implant and graft 996.40 Unspecified mechanical complication of internal orthopedic device, implant, and graft 996.41 Mechanical loosening of prosthetic joint 996.42 Dislocation of prosthetic joint 996.44 Peri-prosthetic fracture around prosthetic joint 996.47 Other mechanical complication of prosthetic joint implant 996.49 Other mechanical complication of other internal orthopedic device, implant, and graft
Peri-prosthetic Joint Infection/Wound Infection	998.6 Persistent postoperative fistula not elsewhere classified 998.83 Non-healing surgical wound 998.3 Disruption of wound 998.30 Disruption of wound, unspecified 998.31 Disruption of internal operation (surgical) wound 998.32 Disruption of external operation (surgical) wound 998.33 Disruption of traumatic wound repair 998.5 Postoperative infection not elsewhere classified 998.51 Infected postoperative seroma 998.59 Other postoperative infection 996.67 Infection and inflammatory reaction due to other internal orthopedic device implant and graft 996.66 Infection and inflammatory reaction due to internal joint prosthesis **One of the above codes AND at least one of the following procedure codes:** 86.22 Excisional debridement of wound, infection, or burn 86.28 Non-excisional debridement of wound, infection, or burn 86.04 Other incision with drainage of skin and subcutaneous tissue 81.53 Revise Hip Replacement, NOS 81.55 Revision of Knee replacement, NOS 81.59 Revision of joint replacement of lower extremity, not elsewhere classified 00.70 REV Hip Repl-acetab/fem 00.71 REV Hip Repl-acetab comp 00.72 REV Hip Repl-fem comp 00.73 REV Hip Repl-liner/head 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) 80.05 Arthrotomy for removal of prosthesis, hip 80.06 Arthrotomy for removal of prosthesis, knee 80.09 Arthrotomy for removal of prosthesis, other unspecified sites 78.65 Removal of implanted devices for femur 78.66 Removal of implanted devices from bone; patella 78.67 Removal of implanted devices from bone; tibia and fibula

2.4.3. Prorating Payments

Some claims overlap the beginning or end date of the analytic timeframe. If a claim for payment began prior to the index admission but ended in the analytic timeframe, it was excluded from our calculation. If a claim for payment began within the analytic timeframe, but ended after the last date of our 90-day post-admission period, we prorated the payment for the claim over the days in the analytic timeframe (Appendix B).

Additionally, if a claim for a payment in an "unrelated" care setting began within the 30-day timeframe, but ended later (during the 31- to 90-day related-only timeframe or after the 90-day timeframe), we prorated the payment for the claim over the days within the 30-day timeframe.

Figure 3. Measurement Timeframe for THA/TKA Payment Measures
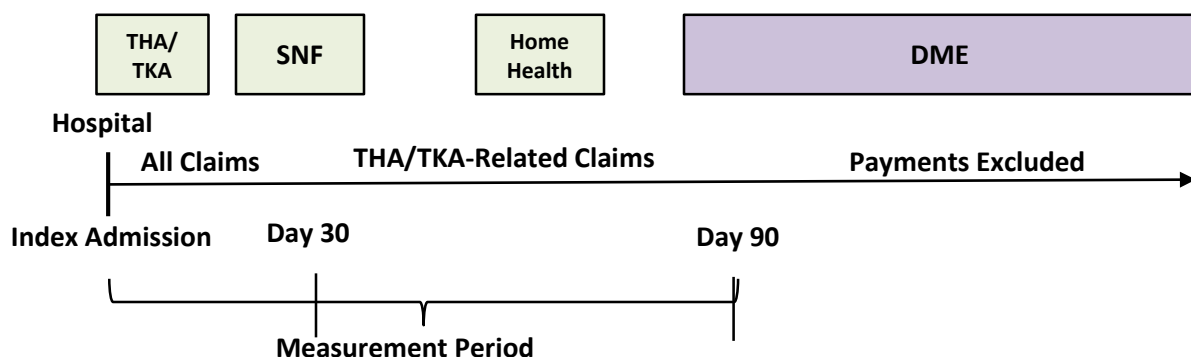
2.4.4. Transfer Scenarios

Medicare reduces payments when patients are transferred to another inpatient prospective payment system (IPPS) hospital and have a length of stay at least one day less than the geometric mean length of stay for the diagnosis-related group (DRG). Under this policy, transferring hospitals are paid a per diem rate. For stays at the transferring hospital that are equal to or greater than the geometric mean length of stay for the DRG, transferring hospitals receive a full DRG payment.[9] We assigned the per diem rate or the full DRG rate to the transferring hospital where applicable, and then added it to the payment for the hospital that received the transfer patient to calculate the payment for the index admission. We then aggregated total patient-level payments for each post-discharge care setting over the defined time period.

Because the episode of care begins at the time of index admission, we assigned this combined index admission payment along with any payments made for post-discharge care to the transferring hospital (Figure 4). We consider all payments made at Hospital A and at Hospital B to be part of the index admission. This approach aligns with CMS's 90-day THA/TKA complication measure.

Figure 4. Episode of Care for Transfer Patient
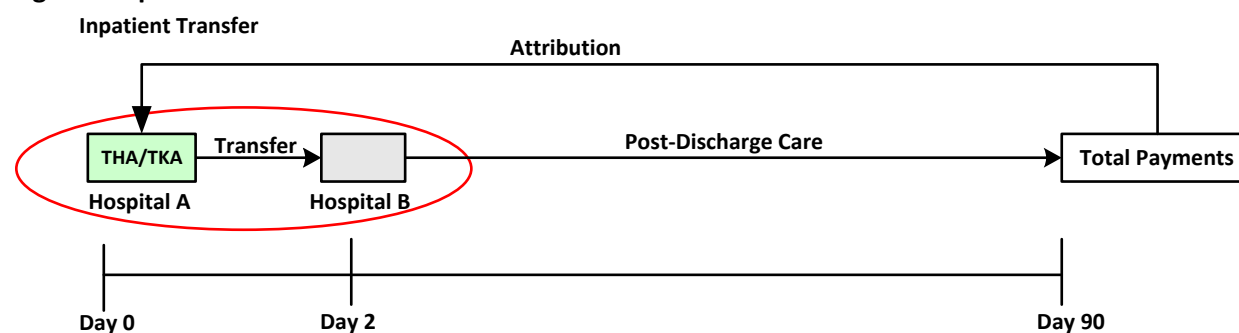
2.4.5.   Removing Payment Adjustments

The overarching goal of the measure is to calculate payments that reflect differences in the care provided for patients undergoing THA/TKA rather than differences in payments based on geography (for example, cost of living and wage index) or policy adjustments (for example, indirect medical education and disproportionate share). Because these payment adjustments do not reflect the care delivered by hospitals, we removed geography and policy adjustments when calculating payments for each care setting, service, and supply by stripping or standardizing as described below.

2.5.   Calculating Payments for Different Care Settings, Services, and Supplies

Medicare pays for healthcare services using a number of different payment systems that are generally organized by delivery setting (Appendix C). These payment systems consider not only the products the Medicare patient is buying in each setting, but also the characteristics of the care provider, the extent to which the same product may be furnished in different settings, and the market circumstances that affect providers' costs. Payment amounts within each payment system are usually updated annually (for example, the IPPS) with some fee schedules having quarterly updates (for example, Durable Medical Equipment/Prosthetics Orthotics and Supplies [DME/POS]). Information on CMS reimbursement rates for each care setting are made publicly available through either final rules published in the Federal Register or fee schedules provided on the CMS website. A summary of Medicare's reimbursement system for most care settings is publicly available at the Medicare Payment Advisory Committee (MedPAC) website.[13] Below, we describe the key features of these payment systems and how we used these CMS payment algorithms to determine an episode-of-care payment for THA/TKA that isolates clinical care decisions. Appendix C provides payment diagrams for all care settings along with our approach to stripping or standardizing payments.

2.5.1.   Inpatient Care Settings

2.5.1.1. Acute Inpatient Hospitals

Medicare beneficiaries sometimes require hospitalization for an acute illness.

How Medicare Reimburses Acute Inpatient Hospitals

Medicare pays most acute inpatient hospitals through a prospective payment system (PPS). This system uses DRG-specific weights to calculate a payment above or below the fixed payment, known as the base payment rate (operating and capital), which reflects the cost (labor and non-labor) to deliver care to a patient for an average Medicare hospitalization. The DRG payment covers routine operating costs attributable to patient care, including nursing services, room and board, and diagnostic and ancillary services. DRGs account for up to twenty-five diagnoses and up to twenty-five procedures performed during the stay. Other factors that inform DRG assignment are age, gender, and discharge destination. CMS assigns a unique weight to each DRG indicating the relative costliness of inpatient treatment for patients in a given DRG. Conditions that involve greater resource utilization (usually associated with procedures, comorbidities, or complications) are assigned higher DRG weights.

Table 2 shows the most frequent DRGs for THA/TKA patients in our cohort hospitalized in 2011-2012. These DRGs are ordered by their frequency in our cohort.

Table 2. Most Frequent DRGs in THA/TKA Patients, July 2011-June 2012

DRG Code	MS-DRG Label	Frequency	Percent	DRG Weight
470	Major joint replacement or reattachment of lower extremity without MCC	269,689	94.72	2.0866
469	Major joint replacement or reattachment of lower extremity with MCC	7,543	2.65	3.4418
462	Bilateral or multiple major joint procedures of lower extremity without MCC	6,852	2.41	3.3359
461	Bilateral or multiple major joint procedures of lower extremity with MCC	262	0.09	5.3985

Medicare makes a number of payment adjustments which affect the total payment for an inpatient stay. Three major categories of adjustments include geography, policy, and outlier payments. Medicare adjusts for differences across hospitals in cost of living (geographic factor) and labor costs (wage index). Policy adjustments can result in additional payments to reflect the cost of teaching medical trainees (indirect medical education) and providing care to low-income patients (disproportionate share). Medicare also makes "outlier payments" for admissions when the hospital's gross costs exceed a threshold amount that includes the DRG rate plus the amount payable for indirect medical education, disproportionate share payments, and a fixed dollar amount set annually by CMS. Outlier payments are not automatic: a hospital must make a specific request and must identify the actual cost associated with each outlier case. Finally, Medicare makes "new technology payments" and "blood clotting factor payments" where applicable.

Approach to Stripping Payments

In our calculation of payments for the index THA/TKA hospitalization as well as any readmission included in the 90-day window, we omitted geographic factors and policy

adjustments. We first multiplied the operating and capital base payment rates by the DRG weight for each claim to arrive at our stripped payment. Medicare reduces payments when patients are transferred to another IPPS hospital and have a length of stay at least one day less than the geometric mean length of stay for the DRG. Under this policy, transferring hospitals are paid either a per diem rate or, for stays that are equal to or greater than the geometric mean length of stay for the DRG, a full DRG payment. When applicable, we included this rule in our payment calculation. We then added any applicable outlier payments (after removing any wage index adjustment) that hospitals received for unusually high-cost claims. We also added new technology payments and blood clotting factor payments where applicable.

2.5.1.2. Inpatient Psychiatric Facilities (IPFs)

Medicare beneficiaries sometimes require hospitalization for an acute psychiatric illness.

How Medicare Reimburses IPFs

Medicare pays IPFs through a PPS. Under the IPF PPS, federal per diem base rates are adjusted for geographic factors, patient characteristics (psychiatric DRG, age, comorbidities, and length of stay), and facility characteristics (urban/rural and indirect medical education). Additional payments are made to IPFs based on the presence of a qualifying emergency department (ED), the number of electroconvulsive therapy (ECT) treatments furnished, outlier payments for cases with very high costs, and new technology payments where applicable.

Approach to Stripping Payments

We multiplied the base payment by adjustments for the patients' psychiatric DRG, age, and comorbidities, and omitted any adjustments for wage index, cost of living, or facility characteristics. We then accounted for length of stay, presence of an ED, and any ECT treatments to arrive at our stripped payment. We added outlier payments but removed the wage index adjustment for these payments where applicable. We also added new technology payments where applicable.

2.5.1.3. Inpatient Rehabilitation Facilities (IRFs)

After a hospitalization, some patients need intensive inpatient rehabilitation services such as physical, occupational, or speech therapy. To qualify for treatment in an inpatient rehabilitation setting, patients must be able to tolerate and benefit from three hours of therapy per day. These settings may be freestanding hospitals or specialized, hospital-based units.

How Medicare Reimburses IRFs

Medicare pays IRFs through a PPS. Under the IRF PPS, the IRF base rate is adjusted for geographic factors, patient characteristics (case mix group), facility characteristics (urban/rural, disproportionate share, and indirect medical education), length of stay, and outlier payments. Case mix groups are informed primarily by the patient's condition (age, comorbidities, functional and cognitive statuses, and diagnoses requiring rehabilitation). Each case mix group has a national relative weight reflecting the expected relative costliness of treatment for patients in that specific case mix group compared with the average Medicare inpatient rehabilitation patient.

Approach to Stripping Payments

We multiplied the base payment rate by the case mix group weight and omitted any adjustments for wage index or facility characteristics. We then adjusted for length of stay to arrive at our stripped payment. Where applicable, we added outlier payments but removed the wage index adjustment for these payments. We also added new technology payments and blood clotting factor payments where applicable.

2.5.1.4. Long-Term Care Hospitals (LTCHs)

Patients with clinically complex problems, such as multiple acute or chronic conditions, may need hospital care for extended periods of time. LTCHs must have an average Medicare length of stay greater than 25 days.

How Medicare Reimburses LTCHs

Medicare pays LTCHs through a PPS. Under the LTCH PPS, the LTCH base rate is adjusted for geographic factors, patient characteristics (Medicare severity long-term care [MS-LTC]-DRG), length of stay, and outlier payments. MS-LTC-DRGs are informed primarily by the patient's condition (age, gender, principal and secondary diagnoses, procedures, and discharge status). Each MS-LTC-DRG has a national relative weight reflecting the expected relative costliness of treatment for patients in that specific LTC-DRG compared with the average Medicare LTC patient. Where applicable, new technology payments and blood clotting factor payments are added.

Approach to Stripping Payments

We multiplied the base payment rate by the MS-LTC-DRG weight and omitted any adjustments for wage index. We then adjusted for length of stay to arrive at our stripped payment. Where applicable, we added outlier payments but removed the wage index adjustment for these payments. We also added new technology payments and blood clotting factor payments where applicable.

2.5.2.   Outpatient Care Settings

Medicare pays for some outpatient services under the Outpatient Prospective Payment System (OPPS), including most hospital-based outpatient services. Outpatient services that do not fall under the OPPS are reimbursed using other fee schedules or payment systems (for example, Medicare Clinical Diagnostic Laboratory Fee Schedule) as detailed later in this document.

2.5.2.1. Hospital Outpatient Services and Community Mental Health Centers (CMHCs)

Medicare beneficiaries receive a wide range of services in hospital outpatient departments. These vary from simple injections to complex procedures requiring anesthesia, and can include ED visits as well as observation stays. CMHCs provide outpatient as well as partial hospitalization services to Medicare beneficiaries, including physician services, psychiatric nursing, counseling, and social services.

How Medicare Reimburses Hospital Outpatient Services and CMHCs

Medicare pays for most hospital outpatient services provided to Medicare beneficiaries using the OPPS. Partial hospitalization services furnished by CMHCs are also reimbursed under the OPPS. All services are paid according to ambulatory payment classifications (APCs), which group services according to similar clinical characteristics and in terms of resources required. Healthcare common procedure coding system (HCPCS) codes are grouped into over 500 APCs. Each APC is weighted and has a prospective payment amount associated with it. APC payments may be discounted when certain services or procedures, such as bilateral procedures, are provided.

A conversion factor (similar to a base payment) is multiplied by a wage index to account for geographic variations in hospitals' labor costs. This number is then multiplied by the APC relative weight. In addition, add-ons such as pass-through payments for new drugs and technical devices, outlier payments for high-cost services, and hold harmless payments for certain hospitals are applied.

Approach to Stripping Payments

We multiplied the conversion factor by the APC weight and omitted any adjustments for wage index. We then accounted for reduced or discontinued procedures, where applicable, as well as unit count to arrive at our OPPS stripped payment. We did not include pass-through payments for new drugs and technical devices or hold harmless payments for certain hospitals. For outpatient hospital services not paid under the OPPS, we applied the clinical lab fee schedule, ambulance fee schedule, physician fee schedule, DME/POS/PEN fee schedule, and Part B drug fee schedule where applicable. Also, where applicable, we added outlier payments but removed the wage index adjustment for the payments.

2.5.2.2. Comprehensive Outpatient Rehabilitation Facilities (CORFs) and Outpatient Rehabilitation Facilities (ORFs)

Outpatient therapy services include physical therapy, occupational therapy, and speech-language pathology services. Medicare covers these services if they are furnished by a skilled professional, are appropriate and effective for a patient's condition, and are reasonable in terms of frequency and duration. The beneficiary must be under the care of a physician, have a treatable condition, and be improving.

How Medicare Reimburses CORFs and ORFs

Medicare pays for outpatient rehabilitation therapy according to fees established in the physician fee schedule. Under this fee schedule, a conversion factor set by Medicare is adjusted for complexity of service/expense as well as geographic factors. The unit of payment is each individual service. All services are classified and reported to CMS according to their HCPCS code. Payment rates are based on relative values units (RVUs), which account for the relative costliness of the following components of the service provided: clinician's work, practice expenses, and malpractice insurance. A separate geographic practice cost index (GPCI) for each of these work components reflects geographic differences in these costs in the market where the service is rendered. Payment modifiers, such as multiple therapy adjustments, are then applied where applicable.

Approach to Stripping Payments

We multiplied the conversion factor by the work RVU, transitioned non-facility practice expense RVU, and malpractice insurance RVU weights and omitted any adjustments for work GPCI, non-facility practice expertise GPCI, and/or malpractice insurance GPCI to arrive at our stripped payment. Payment modifiers, such as multiple therapy adjustments, were then applied where applicable.

2.5.2.3. Renal Dialysis Facilities (RDFs)

Individuals with end-stage renal disease require dialysis or renal transplant to survive. Medicare pays for both hemodialysis and peritoneal dialysis.

How Medicare Reimburses RDFs

Medicare pays RDFs through a PPS. The unit of service is a single dialysis treatment. Under the RDF PPS, the RDF base rate is adjusted for geographic factors, patient characteristics (e.g., age, body mass index, body surface area), and facility characteristic (e.g., low volume). Outlier payments and self-dialysis add-on adjustments are given where applicable.

Approach to Stripping Payments

Though a Renal Dialysis PPS was implemented in 2011, we do not have all of the patient-specific variables, such as body measurements, in our data to create stripped payments based on that algorithm. Thus, for 2010 to 2012 payments, we began with the actual payment made to an RDF for patient care (including patient out-of-pocket payments) and removed payment adjustment attributable to wages using the RDF wage index published by CMS. We also added an outlier payment, where applicable, for payments in 2011 and 2012.

2.5.2.4. Rural Health Clinics (RHCs)

RHCs are clinics that are located in areas designated as rural by the Bureau of the Census, and as underserved by the Secretary of the Department of Health and Human Services. Services rendered by approved RHCs to Medicare beneficiaries are covered under Medicare.

How Medicare Reimburses RHCs

Payments to RHCs for covered services furnished to Medicare patients are made by an all-inclusive rate for each visit. This rate includes services from providers as well as supplies. Each year Congress determines this RHC per visit payment limit.

Approach to Stripping Payments

We began with the actual payment made to an RHC for patient care and removed payment adjustment attributable to wages using the skilled nursing facility (SNF) state-specific rural wage index published by CMS.

2.5.2.5. Federally Qualified Health Clinics (FQHCs)

FQHCs provide access to primary care in areas where primary care resources are constrained. FQHCs are required to be community-centered and either not-for-profit or public organizations that emphasize coordination of care.

How Medicare Reimburses FQHCs

Payments are made much like they are made to RHCs. FQHC payments are an all-inclusive per visit amount based on reasonable costs. The FQHC payment methodology includes one urban and one rural payment limit.

Approach to Payments

Given the resources necessary to determine whether each FQHC is located in a rural or urban area, we did not adjust for wages in the current data. We used the total payment received by the FQHC as the payment for a FQHC claim.

2.5.2.6. Ambulatory Surgical Centers (ASCs)

ASCs are distinct facilities that furnish ambulatory surgery only.

How Medicare Reimburses ASCs

Medicare pays ASCs through a PPS. The unit of service is the individual surgical procedure. All services are paid according to APCs, which group services according to similar clinical characteristics and in terms of resources required. Each APC is weighted and has a prospective payment amount associated with it. APC payments may be discounted when certain services or procedures, such as bilateral procedures, are provided.

A conversion factor (similar to a base payment) is multiplied by a wage index to account for geographic variations in ASCs' labor costs. This number is then multiplied by the APC relative weight.

Approach to Stripping Payments

We began with the conversion factor, omitted any adjustments for wage index, multiplied by the APC weight, multiplied by the unit count, and made adjustments for multiple, reduced, or continued procedures where applicable.

2.5.2.7. Laboratory Services

Clinical lab services are tests on specimens taken from the human body (for example, blood or urine) and used to help physicians diagnose or assess health.

How Medicare Reimburses Laboratory Services

Medicare pays for laboratory services using state-specific fee schedules. Individual lab services are identified by a HCPCS code.

Approach to Standardizing Payments

For each lab service on the clinical diagnostic laboratory fee schedule, we calculated the standard unit payment by taking the average of the payments across all states. We then multiplied the average payment for a particular service by the unit count for that service. For lab services reimbursed under the automated multi-channel chemistry code, we used the total payment received by the lab.

2.5.2.8. Ambulance Services

Medicare beneficiaries sometimes require ambulance services for transportation.

How Medicare Reimburses Ambulance Services

Medicare pays for ambulance services using a fee schedule that pays separately for type of mileage (ground or air) and level of support (based on RVUs) provided during the trip. Reimbursements are also adjusted for geographic differences in labor cost, as well as for service within urban or rural locations. Mileage type and level of support are indicated on the ambulance fee schedule by HCPCS code.

Approach to Standardizing Payments

We first calculated the average of the urban and rural mileage rates or service rates for each type of mileage at each level of ambulance service support for each state, and used these average state mileage and service rates to calculate a national average mileage or service rate for each HCPCS code. We then multiplied this national average rate by the unit count.

2.5.2.9. Part B Drugs

Medicare makes payments for drugs or biologicals that are administered by infusion or injection and not usually self-administered.

How Medicare Reimburses Part B Drugs

Medicare pays for Part B prescription drugs using a national fee schedule (there is no variation from state to state).

Approach to Payments

We assigned the national fee schedule amount to all Part B Drug claims and multiplied this amount by the unit count.

2.5.3. Other Care Settings

2.5.3.1. Skilled Nursing Facilities (SNFs)

Beneficiaries who need short-term skilled care on an inpatient basis following a hospital stay of at least three days are eligible to receive covered services in a SNF.

How Medicare Reimburses SNFs

Medicare pays for SNFs through a PPS. Under the SNF PPS, Medicare assigns a different per diem base payment rate to SNFs based on their urban or rural status for each of three components of care: a nursing component, a therapy component, and a non-case mix-adjusted component reflecting the costs of room and board and administrative services. Daily payments to SNFs are then determined by adjusting the base payment rates for geographic differences in labor cost and by adjusting the nursing component and therapy components of the base payment rates by patient characteristics (resource

utilization groups [RUG]). RUGs are informed primarily by the patient's condition (comorbidities, activities of daily living score, therapy, and service use) and are intended to group patients with similar expected service needs. Each RUG has a nursing relative weight and a therapy relative weight reflecting the expected relative costliness of treatment for patients in that specific RUG compared with the average Medicare beneficiary in a SNF. In addition, SNFs receive a 128% increase in the Medicare PPS per diem payment for patients with acquired immunodeficiency syndrome (AIDS).

Approach to Standardizing Payments

We averaged the urban and rural SNF per diem base rates, multiplied by the RUG weights, and omitted adjustment factors for the wage index. We then multiplied this number by the number of days the patient is in a SNF and added a 128% AIDS adjustment if applicable. For critical access hospitals' swing-bed SNF claims, we used the total payment received by the SNF and removed the portion of the payment attributable to wage differences across geographic locations using the SNF state-specific rural wage index published by CMS.

2.5.3.2. Home Health Agencies (HHAs)

Beneficiaries who are generally confined to their homes and need skilled care from a nurse, physical therapist, or speech therapist on a part-time or intermittent basis are eligible to receive certain medical services at home. Covered services delivered by HHAs include: skilled nursing care; physical, occupational, and speech therapy; medical social work; and home health aide services.

How Medicare Reimburses HHAs

Medicare pays HHAs using a PPS and purchases home health services in units of 60-day episodes. Under the HHA PPS, Medicare assigns a base payment rate which is first adjusted for patient characteristics (by assigning each patient to a home health resource group [HHRG]) and then adjusted for geographic factors. HHRG assignments are based on clinical and functional status as well as service use, and have a national relative weight reflecting the costliness of patients in that group compared with the average Medicare home health patient. Then, Medicare adds payments for non-routine supplies (such as items directly identifiable with an individual patient, e.g., sterile gauze dressing). Adjustments are also made for patients who receive fewer than five home health visits, are transferred to another HHA, or are discharged and readmitted to the same HHA within the 60-day timeframe. Further adjustments are made for outlier payments and the use of additional resources such as durable medical equipment, prosthetics, or oxygen supplies. When there are fewer than five home health visits in the 60-day timeframe, Medicare pays HHAs using the Low Utilization Payment Adjustment (LUPA) per visit rate, which is discipline-specific and depends on whether the visit was for home health aide, medical social services, occupational therapy, physical therapy, skilled nursing, or speech language pathology therapy. HHAs receive

an add-on for LUPA episodes that occur as initial episodes in a sequence of adjacent episodes, or as the only episode.

Approach to Stripping Payments

We multiplied the base payment by the HHRG weight and omitted geographic adjustment factors (for example, wage index). We then added payments for non-routine supplies. We modified this total if the patient is transferred to another HHA or discharged and readmitted to the same HHA before 60 days. We then added any DME/POS/Oxygen add-ons or outlier payments (after removing the wage index adjustment) when applicable. For patients with fewer than five home health visits in the 60-day timeframe, we applied the LUPA per visit payment rates with LUPA add-ons when applicable.

2.5.3.3. Hospice

Terminally ill beneficiaries, defined as having a life expectancy of six months or less, may receive hospice care. Hospice benefits cover a wide range of services including: physicians, skilled nursing, counseling, medical social services, drugs for pain control and symptom management, physical, occupational, and speech therapy, home health aides, and inpatient respite care.

How Medicare Reimburses Hospice

Medicare pays hospices for each day a beneficiary is eligible and under hospice care regardless of the amount of services provided on any given day. Payments are made according to a fee schedule that has individual base payment amounts for four categories of care: routine home care, continuous home care, inpatient respite care, and general inpatient care. Each hospice payment rate is then adjusted for geographic factors. Routine home care, inpatient respite care, and general inpatient care are paid the geographically-adjusted daily rate. Continuous home care is paid a geographically-adjusted hourly rate when care is delivered during a period of crisis and is provided in the home for eight or more hours in a 24-hour period beginning at midnight. Any applicable physician fees are added to the total hospice payment.

Approach to Stripping Payments

For continuous home care, we divided the base payment by 24 hours and multiplied it by the number of hours of care and added any physician fees where applicable. For routine home care, inpatient respite care, and general inpatient care, we multiplied the base payment by the number of days of care and added any applicable physician fees.

2.5.4. Physicians, Physician Extenders, and Social Work Services

Medicare beneficiaries sometimes require the care of physicians or physician extenders for a number of different clinical services.

How Medicare Reimburses Physician, Physician Extenders, and Social Work Services

Medicare uses a fee schedule based on a list of services and their corresponding payment rates to compensate individual providers. Medicare pays a higher physician fee for services provided in non-facility settings, such as physicians' offices, and a lower physician fee for services furnished in facilities, such as hospitals. Physician fees are lower in facility settings because physicians' practice costs are generally lower in facilities. Also, in this case, Medicare pays both the facility and the physician. Each service has a weight, or RVU, that measures the relative costliness of three components of resources used to provide physician services: physician work, practice expenses, and malpractice insurance.

Medicare also uses three GPCIs to adjust for geographic factors related to physician work, practice expenses, and malpractice insurance, respectively. To arrive at the payment amount a conversion factor is multiplied by the total of the RVU weight multiplied by the GPCI weight for each type of resource. Adjustments are then made for certain circumstances such as multiple surgical procedures performed on the same day for the same patient, preoperative and postoperative management without surgical care, or bilateral surgery. Adjustments in payment are also made for care given by non-physicians, such as physician assistants and clinical social workers, and for care given by physicians who are not in Medicare's participating physician and supplier program. A bonus is added for Health Professional Shortage Areas (HPSAs) and incentive payments are given for primary care services furnished by eligible practitioners and for major surgical procedures for qualifying services when furnished by an eligible surgeon in a HPSA.

Approach to Stripping Payments

For services provided in a facility setting (for example, the hospital outpatient department), we multiplied the conversion factor by the work RVU, transitioned facility practice expense RVU, and malpractice insurance RVU weights, and omitted any adjustments for work GPCI, facility practice expertise GPCI, and/or malpractice insurance GPCI. For services provided in a non-facility setting (for example, a physician's office), we multiplied the conversion factor by the work RVU, transitioned non-facility practice expense RVU, and malpractice insurance RVU weights, and omitted any adjustments for work GPCI, non-facility practice expertise GPCI, and/or malpractice insurance GPCI. We adjusted this total for the circumstances such as multiple surgical procedures performed on the same day for the same patient, preoperative and postoperative management without surgical care, or bilateral surgery. We then made adjustments for care given by non-physicians. This adjusted payment amount was then multiplied by the unit count of the service provided.

2.5.5. Durable Medical Equipment/Prosthetics and Orthotics/Parenteral and Enteral Nutrition (DME/POS/PEN)

Beneficiaries who require medical equipment, prosthetics, orthotics, other supplies, or parenteral and enteral nutrition to treat their illness receive it through DME/POS/PEN.

How Medicare Reimburses DME

Medicare pays for DME/POS/PEN using a combination of state-specific fee schedules (for DME/POS) and a national fee schedule (for PEN). Where applicable, Medicare adjusts for new, used, or rental equipment.

Approach to Standardizing Payments

For DME/POS claims, we averaged the payment rate across the state for each item (identified by HCPCS code) on the fee schedule. Where applicable, we adjusted the payment rates for new, used, or rental equipment. We then multiplied by the unit count. If a patient received Part B drugs in conjunction with DME, we added the Part B drug payment.

For PEN claims, we assigned items the amounts specified in the national fee schedule.

2.6.   Model Development and Validation Samples

For model development, we used the full July 2010 - June 2011 and July 2011 - June 2012 100% samples of THA/TKA patients to derive the cohort. To define the outcome (i.e., 90-day episode of care payment), we used data through September 2012 to cover the 90-day episode-of-care period for index admissions in June 2012. All final model results presented in Section 3.2 and Section 3.3 were produced using this sample. To determine variables for inclusion in the model (variable selection), we used a randomly selected 50% sample of the July 2011-June 2012 sample (Sample A1). We used the other half of the full July 2011-June 2012 sample (Sample A2) and full July 2010-June 2011 sample (Sample B) to assess model validity. Table 3 summarizes the different data samples and their purposes.

Table 3. 2010-2012 THA/TKA Payment Model Development and Validation Samples*

Sample	% of Total Sample	Purpose
Sample A (Full Sample)	100% July 2011-June 2012	Development (cohort; outcome definition)
Sample A1 (Development)	50% July 2011-June 2012 (randomly selected)	Development (variable selection, determination of functional form of risk-adjustment model, and validity testing)
Sample A2 (Validation)	50% July 2011-June2012 (remaining 50%)	Development (validity testing)
Sample B (Validation)	100% July 2010-June 2011	Development (cohort, outcome definition, and validity testing)

*2010 and 2011 payments were inflation adjusted to 2012 dollars.

2.7.   Approach to Risk Adjustment

The goal of risk adjustment for this measure is to account for patient and procedure characteristics and comorbid conditions that are clinically relevant and have strong relationships with the outcome, while illuminating important quality differences between hospitals.

Comorbidities for inclusion in risk adjustment are identified in administrative claims during the 12 months prior to and including the index admission. To assemble the more than 15,000 ICD-9 diagnosis codes into clinically coherent variables for risk adjustment, the measure employs the publicly available

CMS CCs to group ICD-9 diagnosis codes into CCs,[14] and selects comorbidities on the basis of clinical relevance and statistical significance.

The measure does not adjust for the patient's admission source or discharge disposition (for example, a skilled nursing facility) because these factors are associated with the structure of the health care system and the different care patterns the measure seeks to illuminate. Because hospitals should not be held to different standards of care based on the demographics of their patients, the measure does not adjust for socioeconomic status (SES), race, or ethnicity. Variation in payments associated with these characteristics may indicate differences in the care provided to vulnerable populations, and adjusting for these factors would obscure these disparities. The measure does not adjust for hospital characteristics either (for example, teaching status), since this would hold different types of hospitals to different standards, and because such characteristics may exist on a causal pathway to the outcome rather than act as confounders. This approach was consistent with NQF guidance at the time of measure development.[15] Complications of Index Hospitalization

> Complications occurring during index hospitalization are not comorbid illnesses and may reflect hospital care; therefore, they should not be used for risk adjustment. Although adverse events during hospitalization may increase the payments for a THA/TKA episode of care, including them as covariates in a risk-adjusted model could obscure payment differentials related to the quality of care delivered by hospitals. CORE previously reviewed every CMS-CC and identified those which, if they only occur during the index hospitalization and not in the 12 months prior, would be considered potential complications rather than comorbidities. For example, fluid, electrolyte or base disorders; sepsis; and acute liver failure are CMS-CCs that could potentially be complications of care (Appendix A).

2.7.2. Case Mix Adjustment: Candidate Comorbid Risk Variables

> Our goal was to develop a parsimonious model that accounted for differences in patient case mix at the time of index admission that were strongly associated with total payment for a THA/TKA 90-day episode of care. The candidate variables for the model were derived from secondary diagnoses of the index hospital stay (excluding potential complications), inpatient data, outpatient hospital data, and carrier files for physician, radiology and laboratory services during the 12 months prior to the index hospital stay.

> To select candidate variables, we started with the 189 CCs. Additionally, several specific isolated ICD-9 diagnosis codes, such as morbid obesity, that were felt to be important predictors of the outcome were selected independently of their CCs as candidate comorbid risk variables based on feedback from members of our TEP. We used the ICD-9 diagnosis code to CC assignment map, which is maintained by CMS and posted on QualityNet. A team of clinicians reviewed all 189 CCs and excluded those that were not relevant to the Medicare population or not clinically relevant to the THA/TKA payment outcome (for example, attention deficit disorder and female infertility). Some of these CCs were combined into clinically coherent groups. The remaining clinically relevant CCs were selected as candidate comorbid risk variables, while age, gender, location of procedure (hip or knee replacement), and procedure type (single, simultaneous bilateral, or staged across two hospitalizations) were forced into risk adjustment model. A complete list of candidate variables is presented in Table 4.

Table 4. THA/TKA Payment Model Candidate Risk 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 (versus TKA)	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
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

Category	Variable	ICD-9/CC
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
Other Comorbidity	Cellulitis, Local Skin Infection	CC 152
Other Comorbidity	Other Dermatological Disorders	CC 153

Category	Variable	ICD-9/CC
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

2.7.3.   Case Mix Adjustment: Choice of Functional Form

As is typical with data for healthcare payments, our dependent variable – total payment for a THA/TKA 90-day episode of care – is both right-skewed and leptokurtotic (skewness = 2.5; kurtosis = 13.1). This remains the case after Winsorization of patient-level 90-day payments at the 99.9% of the full distribution. This is illustrated in Figure 5. To address estimation problems that can arise with non-normally distributed data, we employed the algorithm suggested by Manning & Mullahy.[16] Using this algorithm and Sample A1, we compared several alternative models in order to determine the best estimation approach. Based on these assessments, we chose to estimate a generalized linear model with a log link and an inverse Gaussian distribution.

Figure 5. Distribution of Unadjusted Patient-Level Total Payments for a THA/TKA 90-Day Episode of Care (July 2011-June 2012 Sample A1; N=142,361 Patients)
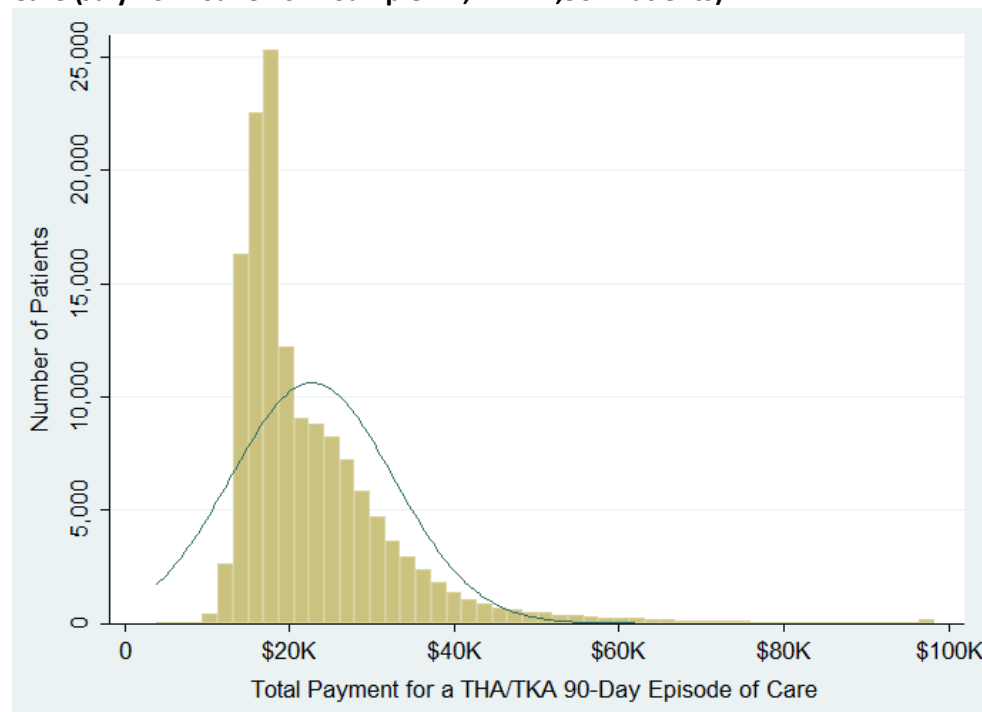
2.7.4. Final Variable Selection

To inform variable selection, we performed a modified approach to stepwise generalized linear model regression. We used Sample A1 to create 1,000 bootstrap samples. For each sample, we ran a generalized linear model that included all candidate variables. Specifically, let Y_{ij} denote the outcome (total payment for a THA/TKA 90-day episode of care) for the jth patient admitted to the ith hospital; and $\mathbf{Z}_{ij}$ denotes the candidate risk factors where $\mathbf{Z}_{ij} = (Z_{1ij}, Z_{2ij}, ..., Z_{pij})$ is a set of p patient-specific variables (for example, age, comorbid conditions). 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 risk factors via a known link function, $h(\cdot)$, as follows:

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

In our case, $h(\cdot)$ is the log link and we assumed an inverse Gaussian distribution for the outcome. We estimated these generalized linear models using the SAS software system (SAS 9.3 GENMOD procedure).

The results were summarized to show the percentage of times that each of the candidate variables was significantly associated with THA/TKA payment (at the $p<0.05$ level) in the 1,000 bootstrap samples (for example, 90% would mean that the candidate variable was significant at $p<0.05$ in 90% of the bootstrap samples). We also assessed the direction and magnitude of the regression coefficients.

The working group reviewed these results and decided to retain all risk-adjustment variables at or above a 90% cutoff (in other words, to retain variables that were significant at the 0.05 level in at least 90% of the bootstrap samples). We chose the 90% cutoff because variables at or above this threshold demonstrated a relatively robust association with THA/TKA payment and were clinically relevant. The final risk-adjusted THA/TKA payment model included 56 variables (Table 5).

Table 5. THA/TKA Payment Model Final Risk Variables, July 2010-June 2012

Risk-Adjustment Category	Variable	ICD-9/CC
Demographics	Mean Age Minus 65 (SD)	N/A
Demographics	Male	N/A
Procedure	Index Admission with an Elective THA Procedure (versus TKA)	ICD-9 81.51
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	Congestive Heart Failure	CC 80
Other Comorbidity	Acute Coronary Syndrome	CC 81-82
Other Comorbidity	Valvular or Rheumatic Heart Disease	CC 86
Other Comorbidity	Hypertension and Hypertension Complications	CC 89-91
Other Comorbidity	History of Infection	CC 1, 3-6
Other Comorbidity	Metastatic Cancer and Acute Leukemia	CC 7
Other Comorbidity	Cancer	CC 8-12
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	Obesity/Disorders of Thyroid, Cholesterol, Lipids	CC 24, excluding ICD-9 278.01
Other Comorbidity	Appendicitis	CC 35
Other Comorbidity	Bone/Joint/Muscle Infections/Necrosis	CC 37
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	Other Musculoskeletal and Connective Tissue Disorders	CC 43
Other Comorbidity	Severe Hematological Disorders	CC 44
Other Comorbidity	Coagulation Defects and Other Specified Hematological Disorders	CC 46
Other Comorbidity	Delirium and Encephalopathy	CC 48
Other Comorbidity	Dementia and Senility	CC 49-50
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	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	Arrhythmias	CC 92-93
Other Comorbidity	Stroke	CC 95-96
Other Comorbidity	Vascular or Circulatory Disease	CC 104-106

Risk-Adjustment Category	Variable	ICD-9/CC
Other Comorbidity	Chronic Obstructive Pulmonary Disease (COPD)	CC 108
Other Comorbidity	Pleural Effusion/Pneumothorax	CC 114
Other Comorbidity	Other Lung Disorders	CC 115
Other Comorbidity	Legally Blind	CC 116
Other Comorbidity	End-stage Renal Disease or Dialysis	CC 130
Other Comorbidity	Renal Failure	CC 131
Other Comorbidity	Incontinence	CC 134
Other Comorbidity	Urinary Tract Infection	CC 135
Other Comorbidity	Other Urinary Tract Disorders	CC 136
Other Comorbidity	Decubitus Ulcer or Chronic Skin Ulcer	CC 148-149
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	Major Symptoms, Abnormalities	CC 166
Other Comorbidity	Minor Symptoms, Signs, Findings	CC 167

2.8.   Statistical Approach to RSP

To calculate hospital-specific RSPs, we estimate hierarchical generalized linear models using Samples A and B. This strategy accounts for within-hospital correlation of the observed outcomes and accommodates the assumption that underlying differences in quality across hospitals lead to systematic differences in outcomes. We model the total payment as a function of patient age, gender, location of procedure (THA or TKA), procedure type (single, bilateral, or staged), and select comorbidities, with a hospital-specific random effect.

We use the following strategy to calculate the hospital-specific RSPs. We calculate these payments as the ratio of "predicted" THA/TKA payment to "expected" THA/TKA payment, and multiply by the national unadjusted average THA/TKA payment. The predicted THA/TKA payment for each hospital is estimated using its patient mix and an estimated hospital-specific intercept. The expected THA/TKA payment for each hospital is estimated given the same patient mix but the average intercept among all hospitals in the sample.

Operationally, the expected THA/TKA payment for each hospital is obtained by summing the expected THA/TKA payments for all patients in the hospital. The expected THA/TKA payment for each patient is calculated via the hierarchical model by applying the estimated regression coefficients to the observed patient characteristics and adding the average intercept. The predicted THA/TKA payment for each hospital is calculated by summing the predicted THA/TKA payments for all patients in the hospital. The predicted THA/TKA payment 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.

More specifically, we use a hierarchical generalized linear model to account for the natural clustering of observations within hospitals and adjust for the selected risk factors. The model employs a log link and an inverse Gaussian distribution with a hospital-specific random effect as follows:

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

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

where α_i represents the hospital-specific intercept, $\mathbf{Z}_{ij}$ is defined the same as in equation (1), μ is the average intercept across all hospitals in the sample, and τ^2 is the between-hospital variance component.[13] This model separates within-hospital variation from between-hospital variation. The hierarchical generalized linear models are estimated using the SAS software system (SAS 9.3 GLIMMIX procedure).

2.8.1 Hospital Performance Reporting

Using the selected set of risk factors, we fit the hierarchical generalized linear model defined by Equations (2) - (3) and estimate the parameters, $\hat{\mu}$, $\{\alpha_i, \alpha_2, ..., \alpha_I\}$, $\hat{\beta}$, and $\hat{\tau}^2$. We calculate a standardized outcome measure, RSP_i, for each hospital by computing the ratio of the predicted THA/TKA payment to the expected THA/TKA payment, and multiplying by the national unadjusted average THA/TKA payment, $\bar{Y}$. Specifically, we calculate

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

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

$$\widehat{RSP}_i(\mathbf{Z}_{ij}) = \frac{\sum_{j=1}^{n_i} \hat{y}_{ij}(Z)}{\sum_{j=1}^{n_i} \hat{e}_{ij}(Z)} \times \bar{y} \tag{6}$$

Again, i indexes hospitals, j indexes patients within hospitals, and n_i is the number of patients within hospital i. If "predicted" total payment is higher (or lower) than "expected" total payment for a given hospital, then its $\widehat{RSP}_i$ will be higher (or lower) than the national unadjusted average payment. For each hospital, we can compute an interval estimate of RSP_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 (for example, higher than expected, as expected, or lower than expected). See Figure 6 for our overall analysis steps.

2.8.2 Creating Interval Estimates

Because the statistic described in Equation 6 (Section 2.8.1), $\widehat{RSP}_i$, is a complex function of parameter estimates, we use the re-sampling technique – bootstrapping – to derive an interval estimate. Bootstrapping has the advantage of avoiding unnecessary distributional assumptions.

Algorithm:

Let *I* denote the total number of hospitals in the sample. We repeat steps 1-4 below for B times, where *B* is the number of bootstrap samples desired (with b indexes the *b*th bootstrap sample):

1. Sample *I* hospitals with replacement.

2. Fit the hierarchical generalized linear model using all patients within each sampled hospital. 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. $\hat{\beta}^{(b)}$ (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, $\{\hat{\alpha}_i^{(b)}, \widehat{var}(\alpha_i^{(b)}); i = 1, 2, \dots, I\}$

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

4. Within each unique hospital *i* sampled in Step 1, and for each patient *j* in that hospital, we calculate $\hat{y}_{ij}^{(b)}$, $\hat{e}_{ij}^{(b)}$, and $\widehat{RSP}_i(Z)^{(b)}$ 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).[17]

Figure 6. Analysis Steps

Compute Bivariate and Univariate summaries

Z & Y

Generalized Linear Model

$$h(Y_{ij}) = \alpha^A + \beta^A Z_{ij}$$

Obtain residuals, etc.

Hierarchical Generalized Linear Model

$$h(Y_{ij}) = \alpha_i^A + \beta^A Z_{ij}$$

$$\alpha_i^{(A)} \sim N(\mu_A, \tau^2{}_A)$$

Hospital-Specific Predicted Outcomes

$$\hat{y}_i^A(\mathbf{Z}) = \frac{1}{n_i} \sum_{j=1}^{n_i} h^{-1}(\hat{a}_i^A + \hat{\beta}^A Z_{ij})$$

Hospital-Specific Expected Outcomes

$$\hat{e}_i^A(\mathbf{Z}) = \frac{1}{n_i} \sum_{j=1}^{n_i} h^{-1}(\hat{\mu}_A + \hat{\beta}^A Z_{ij})$$

Hospital-Specific Risk-Standardized Outcomes

$$\hat{r}_i^A(Z) = \frac{\hat{y}_i^A(Z)}{\hat{e}_i^A(Z)}$$

$$\widehat{RSP}_i^A(Z) = \frac{\hat{y}_i^A(Z)}{\hat{e}_i^A(Z)} \times \bar{y}$$

3. RESULTS

3.1. Model Development and Validation Results

Table 6 shows the number of index admissions and number of hospitals associated with each of the samples used for measure development and validation, as outlined in [Section 2.6](#).

Table 6. Description of July 2010-June 2012 THA/TKA Payment Model Development and Validation Samples*

Sample	% of Total Sample	Purpose	Number of Index Admissions	Number of Hospitals
Sample A (Full Sample)	100% July 2011-June 2012	Development (cohort; outcome definition)	284,721	3,341
Sample A1 (Development)	50% July 2011- June 2012 (randomly selected)	Development (variable selection, determination of functional form of risk-adjustment model, and validity testing)	142,361	3,257
Sample A2 (Validation)	50% July 2011- June 2012 (remaining 50%)	Development (validity testing)	142,360	3,246
Sample B (Validation)	100% July 2010- June 2011	Development (cohort, outcome definition, and validity testing)	286,750	3,318

*2010 and 2011 payments were inflation adjusted to 2012 dollars.

The frequencies of final selected risk factors for all samples, as shown in Table 7, were consistent across the development and validation samples.

Table 7. July 2010-June 2012 THA/TKA Payment Model Risk Factor Frequencies in Development and Validation Samples

Variable	ICD-9/CC	July 2011-June 2012 Development Sample A1 (%)	July 2011-June 2012 Validation Sample A2 (%)	July 2010-June 2011 Validation Sample B (%)
Age Minus 65, mean (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

Variable	ICD-9/CC	July 2011-June 2012 Development Sample A1 (%)	July 2011-June 2012 Validation Sample A2 (%)	July 2010-June 2011 Validation Sample B (%)
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
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

Variable	ICD-9/CC	July 2011-June 2012 Development Sample A1 (%)	July 2011-June 2012 Validation Sample A2 (%)	July 2010-June 2011 Validation Sample B (%)
Minor Symptoms, Signs, Findings	CC 167	79.97	79.71	78.58

3.1.1. Results of Risk-Adjustment Model in Development and Validation Samples

Table 8 reports the estimated coefficients, standard errors, payment ratios (PRs) (exponentiated coefficient estimate), and 95% confidence intervals for the PRs associated with each risk factor generated from the July 2011-June 2012 development sample (Sample A1). Table 9 and Table 10 present the same information for the July 2011-June 2012 (Sample A2) and July 2010-June 2011 (Sample B) validation samples. PRs are similar across samples.

Table 8. Generalized Linear Model Results for Development Sample A1, July 2011-June 2012 (N=142,361 at 3,257 hospitals)

Risk-Adjustment Category	Risk-Adjustment Variable	Estimate	Standard Error	Payment Ratio (PR)	95% Confidence Interval for PR
Intercept	N/A	9.624	0.005	-	-
Demographics	Age-65 (years above 65, continuous)	0.015	0.000	1.015	(1.015-1.016)
Demographics	Male	-0.080	0.002	0.923	(0.920-0.926)
Procedure	Index Admission with an Elective THA Procedure (versus TKA)	0.019	0.002	1.019	(1.015-1.023)
Procedure	Procedure Type (Single Joint Replacement)	0.000	-	1.000	-
Procedure	Procedure Type (Bilateral Joint Replacement)	0.568	0.007	1.764	(1.742-1.787)
Procedure	Procedure Type (Staged Joint Replacement)	0.539	0.012	1.714	(1.675-1.755)
Other Comorbidity	Morbid Obesity	0.127	0.004	1.135	(1.126-1.144)
Other Comorbidity	Congestive Heart Failure	0.049	0.003	1.050	(1.044-1.057)
Other Comorbidity	Acute Coronary Syndrome	0.030	0.002	1.030	(1.026-1.034)
Other Comorbidity	Valvular or Rheumatic Heart Disease	0.016	0.002	1.016	(1.011-1.021)
Other Comorbidity	Hypertension and Hypertension Complications	0.039	0.002	1.040	(1.035-1.044)
Other Comorbidity	History of Infection	0.051	0.002	1.053	(1.048-1.057)
Other Comorbidity	Metastatic Cancer and Acute Leukemia	0.031	0.012	1.031	(1.008-1.055)
Other Comorbidity	Cancer	-0.003	0.002	0.997	(0.993-1.001)
Other Comorbidity	Benign Neoplasms of Skin, Breast, Eye	-0.010	0.002	0.990	(0.985-0.994)
Other Comorbidity	Diabetes and Diabetes Complications	0.060	0.002	1.062	(1.058-1.066)

Risk-Adjustment Category	Risk-Adjustment Variable	Estimate	Standard Error	Payment Ratio (PR)	95% Confidence Interval for PR
Other Comorbidity	Protein-Calorie Malnutrition	0.187	0.011	1.206	(1.179-1.233)
Other Comorbidity	Other Significant Endocrine and Metabolic Disorders	0.021	0.004	1.021	(1.012-1.030)
Other Comorbidity	Obesity/Disorders of Thyroid, Cholesterol, Lipids	-0.013	0.002	0.987	(0.984-0.991)
Other Comorbidity	Appendicitis	-0.097	0.024	0.908	(0.866-0.952)
Other Comorbidity	Bone/Joint/Muscle Infections/Necrosis	0.038	0.005	1.039	(1.028-1.050)
Other Comorbidity	Rheumatoid Arthritis and Inflammatory Connective Tissue Disease	0.025	0.003	1.025	(1.020-1.031)
Other Comorbidity	Disorders of the Vertebrae and Spinal Discs	0.011	0.002	1.011	(1.008-1.015)
Other Comorbidity	Osteoarthritis of Hip or Knee	0.056	0.004	1.057	(1.049-1.066)
Other Comorbidity	Other Musculoskeletal and Connective Tissue Disorders	0.031	0.003	1.032	(1.026-1.037)
Other Comorbidity	Severe Hematological Disorders	0.084	0.012	1.088	(1.064-1.113)
Other Comorbidity	Coagulation Defects and Other Specified Hematological Disorders	0.026	0.004	1.027	(1.019-1.035)
Other Comorbidity	Delirium and Encephalopathy	0.046	0.010	1.047	(1.027-1.068)
Other Comorbidity	Dementia and Senility	0.086	0.005	1.090	(1.080-1.100)
Other Comorbidity	Major Psychiatric Disorders	0.096	0.004	1.101	(1.091-1.110)
Other Comorbidity	Depression/Anxiety	0.035	0.002	1.035	(1.030-1.040)
Other Comorbidity	Other Psychiatric Disorders	0.013	0.003	1.013	(1.007-1.018)
Other Comorbidity	Mental Retardation or Developmental Disability	0.307	0.027	1.359	(1.288-1.434)
Other Comorbidity	Hemiplegia, Paraplegia, Paralysis, Functional Disability	0.069	0.007	1.071	(1.057-1.086)
Other Comorbidity	Polyneuropathy	0.040	0.003	1.041	(1.034-1.048)
Other Comorbidity	Multiple Sclerosis	0.128	0.020	1.137	(1.094-1.181)
Other Comorbidity	Parkinson's and Huntington's Diseases	0.172	0.009	1.188	(1.167-1.209)
Other Comorbidity	Seizure Disorders and Convulsions	0.067	0.007	1.069	(1.054-1.085)
Other Comorbidity	Arrhythmias	0.010	0.002	1.010	(1.006-1.014)
Other Comorbidity	Stroke	0.051	0.006	1.052	(1.039-1.065)
Other Comorbidity	Vascular or Circulatory Disease	0.028	0.002	1.028	(1.024-1.032)

Risk-Adjustment Category	Risk-Adjustment Variable	Estimate	Standard Error	Payment Ratio (PR)	95% Confidence Interval for PR
Other Comorbidity	Chronic Obstructive Pulmonary Disease (COPD)	0.043	0.003	1.044	(1.039-1.050)
Other Comorbidity	Pleural Effusion/Pneumothorax	-0.030	0.007	0.971	(0.957-0.985)
Other Comorbidity	Other Lung Disorders	0.018	0.002	1.018	(1.013-1.022)
Other Comorbidity	Legally Blind	0.097	0.020	1.102	(1.061-1.145)
Other Comorbidity	End-stage Renal Disease or Dialysis	0.343	0.025	1.410	(1.342-1.481)
Other Comorbidity	Renal Failure	0.040	0.003	1.040	(1.034-1.047)
Other Comorbidity	Incontinence	0.047	0.004	1.048	(1.040-1.056)
Other Comorbidity	Urinary Tract Infection	0.012	0.002	1.012	(1.007-1.016)
Other Comorbidity	Other Urinary Tract Disorders	0.011	0.003	1.011	(1.006-1.016)
Other Comorbidity	Decubitus Ulcer or Chronic Skin Ulcer	0.077	0.006	1.080	(1.068-1.093)
Other Comorbidity	Cellulitis, Local Skin Infection	0.030	0.003	1.030	(1.024-1.037)
Other Comorbidity	Other Dermatological Disorders	-0.019	0.002	0.981	(0.978-0.985)
Other Comorbidity	Trauma	0.050	0.004	1.051	(1.043-1.060)
Other Comorbidity	Vertebral Fractures	0.046	0.008	1.047	(1.030-1.064)
Other Comorbidity	Other Injuries	0.014	0.002	1.014	(1.010-1.018)
Other Comorbidity	Major Symptoms, Abnormalities	0.039	0.002	1.040	(1.037-1.044)
Other Comorbidity	Minor Symptoms, Signs, Findings	0.018	0.002	1.018	(1.014-1.022)

Table 9. Generalized Linear Model Results for Validation Sample A2, July 2011-June 2012 (N=142,360 at 3,246 hospitals)

Risk-Adjustment Category	Risk-Adjustment Variable	Estimate	Standard Error	Payment Ratio (PR)	95% Confidence Interval for PR
Intercept	N/A	9.617	0.005	-	-
Demographics	Age-65 (years above 65, continuous)	0.015	0.000	1.015	(1.015-1.015)
Demographics	Male	-0.078	0.002	0.925	(0.922-0.928)
Procedure	Index Admission with an Elective THA Procedure (versus TKA)	0.023	0.002	1.024	(1.020-1.027)
Procedure	Procedure Type (Single Joint Replacement)	0.000	-	1.000	-
Procedure	Procedure Type (Bilateral Joint Replacement)	0.563	0.007	1.755	(1.732-1.778)
Procedure	Procedure Type (Staged Joint Replacement)	0.518	0.012	1.679	(1.640-1.720)
Other Comorbidity	Morbid Obesity	0.127	0.004	1.135	(1.126-1.144)
Other Comorbidity	Congestive Heart Failure	0.057	0.003	1.058	(1.051-1.065)
Other Comorbidity	Acute Coronary Syndrome	0.027	0.002	1.027	(1.023-1.031)
Other Comorbidity	Valvular or Rheumatic Heart Disease	0.020	0.002	1.020	(1.015-1.025)
Other Comorbidity	Hypertension and Hypertension Complications	0.038	0.002	1.039	(1.035-1.044)
Other Comorbidity	History of Infection	0.053	0.002	1.054	(1.050-1.059)
Other Comorbidity	Metastatic Cancer and Acute Leukemia	0.044	0.012	1.045	(1.022-1.069)
Other Comorbidity	Cancer	-0.004	0.002	0.996	(0.992-1.000)
Other Comorbidity	Benign Neoplasms of Skin, Breast, Eye	-0.015	0.002	0.985	(0.981-0.990)
Other Comorbidity	Diabetes and Diabetes Complications	0.058	0.002	1.059	(1.055-1.063)
Other Comorbidity	Protein-Calorie Malnutrition	0.182	0.011	1.199	(1.173-1.226)
Other Comorbidity	Other Significant Endocrine and Metabolic Disorders	0.030	0.004	1.031	(1.022-1.040)
Other Comorbidity	Obesity/Disorders of Thyroid, Cholesterol, Lipids	-0.017	0.002	0.983	(0.980-0.987)
Other Comorbidity	Appendicitis	-0.083	0.025	0.921	(0.877-0.966)
Other Comorbidity	Bone/Joint/Muscle Infections/Necrosis	0.043	0.005	1.044	(1.033-1.055)
Other Comorbidity	Rheumatoid Arthritis and Inflammatory Connective Tissue Disease	0.021	0.003	1.021	(1.015-1.027)
Other Comorbidity	Disorders of the Vertebrae and Spinal Discs	0.010	0.002	1.010	(1.006-1.014)
Other Comorbidity	Osteoarthritis of Hip or Knee	0.066	0.004	1.068	(1.060-1.077)
Other Comorbidity	Other Musculoskeletal and Connective Tissue Disorders	0.037	0.003	1.038	(1.033-1.043)

Risk-Adjustment Category	Risk-Adjustment Variable	Estimate	Standard Error	Payment Ratio (PR)	95% Confidence Interval for PR
Other Comorbidity	Severe Hematological Disorders	0.063	0.011	1.065	(1.041-1.089)
Other Comorbidity	Coagulation Defects and Other Specified Hematological Disorders	0.025	0.004	1.025	(1.017-1.033)
Other Comorbidity	Delirium and Encephalopathy	0.046	0.010	1.047	(1.026-1.068)
Other Comorbidity	Dementia and Senility	0.105	0.005	1.111	(1.101-1.121)
Other Comorbidity	Major Psychiatric Disorders	0.094	0.004	1.099	(1.090-1.109)
Other Comorbidity	Depression/Anxiety	0.028	0.002	1.028	(1.023-1.033)
Other Comorbidity	Other Psychiatric Disorders	0.022	0.003	1.022	(1.016-1.028)
Other Comorbidity	Mental Retardation or Developmental Disability	0.270	0.031	1.310	(1.233-1.392)
Other Comorbidity	Hemiplegia, Paraplegia, Paralysis, Functional Disability	0.058	0.007	1.060	(1.045-1.074)
Other Comorbidity	Polyneuropathy	0.040	0.004	1.041	(1.033-1.048)
Other Comorbidity	Multiple Sclerosis	0.127	0.020	1.136	(1.093-1.180)
Other Comorbidity	Parkinson's and Huntington's Diseases	0.163	0.009	1.177	(1.156-1.197)
Other Comorbidity	Seizure Disorders and Convulsions	0.058	0.007	1.060	(1.045-1.075)
Other Comorbidity	Arrhythmias	0.010	0.002	1.010	(1.006-1.014)
Other Comorbidity	Stroke	0.045	0.006	1.046	(1.034-1.059)
Other Comorbidity	Vascular or Circulatory Disease	0.027	0.002	1.027	(1.023-1.031)
Other Comorbidity	Chronic Obstructive Pulmonary Disease (COPD)	0.047	0.003	1.048	(1.043-1.053)
Other Comorbidity	Pleural Effusion/Pneumothorax	-0.041	0.007	0.960	(0.946-0.974)
Other Comorbidity	Other Lung Disorders	0.022	0.002	1.022	(1.018-1.027)
Other Comorbidity	Legally Blind	0.104	0.020	1.110	(1.067-1.154)
Other Comorbidity	End-stage Renal Disease or Dialysis	0.309	0.028	1.363	(1.289-1.440)
Other Comorbidity	Renal Failure	0.040	0.003	1.041	(1.034-1.048)
Other Comorbidity	Incontinence	0.049	0.004	1.050	(1.042-1.058)
Other Comorbidity	Urinary Tract Infection	0.010	0.002	1.010	(1.005-1.015)
Other Comorbidity	Other Urinary Tract Disorders	0.012	0.003	1.013	(1.007-1.018)
Other Comorbidity	Decubitus Ulcer or Chronic Skin Ulcer	0.074	0.006	1.077	(1.064-1.089)

Risk-Adjustment Category	Risk-Adjustment Variable	Estimate	Standard Error	Payment Ratio (PR)	95% Confidence Interval for PR
Other Comorbidity	Cellulitis, Local Skin Infection	0.034	0.003	1.034	(1.028-1.041)
Other Comorbidity	Other Dermatological Disorders	-0.017	0.002	0.983	(0.980-0.987)
Other Comorbidity	Trauma	0.052	0.004	1.054	(1.045-1.063)
Other Comorbidity	Vertebral Fractures	0.050	0.008	1.052	(1.035-1.069)
Other Comorbidity	Other Injuries	0.009	0.002	1.009	(1.005-1.012)
Other Comorbidity	Major Symptoms, Abnormalities	0.040	0.002	1.041	(1.037-1.044)
Other Comorbidity	Minor Symptoms, Signs, Findings	0.014	0.002	1.014	(1.010-1.018)

Table 10. Generalized Linear Model Results for Validation Sample B, July 2010-June 2011 (N=286,750 at 3,318 hospitals)

Risk-Adjustment Category	Risk-Adjustment Variable	Estimate	Standard Error	Payment Ratio (PR)	95% Confidence Interval for PR
Intercept	N/A	9.657	0.004	-	-
Demographics	Age-65 (years above 65, continuous)	0.015	0.000	1.015	(1.015-1.015)
Demographics	Male	-0.086	0.001	0.918	(0.915-0.920)
Procedure	Index Admission with an Elective THA Procedure (versus TKA)	0.024	0.001	1.024	(1.022-1.027)
Procedure	Procedure Type (Single Joint Replacement)	0.000	-	1.000	-
Procedure	Procedure Type (Bilateral Joint Replacement)	0.553	0.004	1.739	(1.724-1.755)
Procedure	Procedure Type (Staged Joint Replacement)	0.548	0.009	1.730	(1.701-1.759)
Other Comorbidity	Morbid Obesity	0.112	0.003	1.118	(1.112-1.125)
Other Comorbidity	Congestive Heart Failure	0.061	0.002	1.063	(1.058-1.068)
Other Comorbidity	Acute Coronary Syndrome	0.028	0.001	1.028	(1.025-1.031)
Other Comorbidity	Valvular or Rheumatic Heart Disease	0.015	0.002	1.016	(1.012-1.019)
Other Comorbidity	Hypertension and Hypertension Complications	0.036	0.002	1.037	(1.034-1.040)
Other Comorbidity	History of Infection	0.052	0.002	1.054	(1.050-1.057)
Other Comorbidity	Metastatic Cancer and Acute Leukemia	0.032	0.008	1.032	(1.016-1.049)
Other Comorbidity	Cancer	-0.003	0.002	0.997	(0.994-1.000)
Other Comorbidity	Benign Neoplasms of Skin, Breast, Eye	-0.013	0.002	0.987	(0.984-0.990)
Other Comorbidity	Diabetes and Diabetes Complications	0.064	0.001	1.066	(1.064-1.069)
Other Comorbidity	Protein-Calorie Malnutrition	0.188	0.008	1.207	(1.187-1.227)

Risk-Adjustment Category	Risk-Adjustment Variable	Estimate	Standard Error	Payment Ratio (PR)	95% Confidence Interval for PR
Other Comorbidity	Other Significant Endocrine and Metabolic Disorders	0.025	0.003	1.026	(1.019-1.032)
Other Comorbidity	Obesity/Disorders of Thyroid, Cholesterol, Lipids	-0.010	0.001	0.990	(0.988-0.993)
Other Comorbidity	Appendicitis	-0.020	0.018	0.980	(0.946-1.015)
Other Comorbidity	Bone/Joint/Muscle Infections/Necrosis	0.038	0.004	1.038	(1.031-1.046)
Other Comorbidity	Rheumatoid Arthritis and Inflammatory Connective Tissue Disease	0.025	0.002	1.026	(1.021-1.030)
Other Comorbidity	Disorders of the Vertebrae and Spinal Discs	0.011	0.001	1.011	(1.008-1.013)
Other Comorbidity	Osteoarthritis of Hip or Knee	0.063	0.003	1.065	(1.059-1.071)
Other Comorbidity	Other Musculoskeletal and Connective Tissue Disorders	0.036	0.002	1.037	(1.033-1.040)
Other Comorbidity	Severe Hematological Disorders	0.053	0.008	1.055	(1.039-1.071)
Other Comorbidity	Coagulation Defects and Other Specified Hematological Disorders	0.020	0.003	1.020	(1.015-1.026)
Other Comorbidity	Delirium and Encephalopathy	0.033	0.007	1.034	(1.020-1.048)
Other Comorbidity	Dementia and Senility	0.107	0.003	1.113	(1.106-1.121)
Other Comorbidity	Major Psychiatric Disorders	0.099	0.003	1.104	(1.098-1.111)
Other Comorbidity	Depression/Anxiety	0.030	0.002	1.031	(1.027-1.035)
Other Comorbidity	Other Psychiatric Disorders	0.020	0.002	1.020	(1.015-1.024)
Other Comorbidity	Mental Retardation or Developmental Disability	0.243	0.021	1.275	(1.223-1.328)
Other Comorbidity	Hemiplegia, Paraplegia, Paralysis, Functional Disability	0.068	0.005	1.071	(1.060-1.081)
Other Comorbidity	Polyneuropathy	0.036	0.003	1.037	(1.032-1.042)
Other Comorbidity	Multiple Sclerosis	0.134	0.014	1.143	(1.113-1.174)
Other Comorbidity	Parkinson's and Huntington's Diseases	0.178	0.006	1.195	(1.180-1.210)
Other Comorbidity	Seizure Disorders and Convulsions	0.077	0.005	1.080	(1.069-1.091)
Other Comorbidity	Arrhythmias	0.011	0.001	1.011	(1.008-1.014)
Other Comorbidity	Stroke	0.046	0.004	1.047	(1.038-1.056)
Other Comorbidity	Vascular or Circulatory Disease	0.033	0.001	1.034	(1.031-1.037)
Other Comorbidity	Chronic Obstructive Pulmonary Disease (COPD)	0.049	0.002	1.050	(1.046-1.054)

Risk-Adjustment Category	Risk-Adjustment Variable	Estimate	Standard Error	Payment Ratio (PR)	95% Confidence Interval for PR
Other Comorbidity	Pleural Effusion/Pneumothorax	-0.014	0.005	0.986	(0.976-0.997)
Other Comorbidity	Other Lung Disorders	0.019	0.002	1.019	(1.016-1.022)
Other Comorbidity	Legally Blind	0.083	0.014	1.087	(1.057-1.118)
Other Comorbidity	End-stage Renal Disease or Dialysis	0.280	0.020	1.323	(1.272-1.375)
Other Comorbidity	Renal Failure	0.050	0.002	1.051	(1.046-1.056)
Other Comorbidity	Incontinence	0.043	0.003	1.044	(1.039-1.050)
Other Comorbidity	Urinary Tract Infection	0.009	0.002	1.009	(1.006-1.013)
Other Comorbidity	Other Urinary Tract Disorders	0.012	0.002	1.012	(1.008-1.015
Other Comorbidity	Decubitus Ulcer or Chronic Skin Ulcer	0.082	0.004	1.086	(1.077-1.095)
Other Comorbidity	Cellulitis, Local Skin Infection	0.029	0.002	1.030	(1.025-1.034)
Other Comorbidity	Other Dermatological Disorders	-0.015	0.001	0.985	(0.983-0.988)
Other Comorbidity	Trauma	0.051	0.003	1.053	(1.046-1.059)
Other Comorbidity	Vertebral Fractures	0.048	0.006	1.050	(1.038-1.062)
Other Comorbidity	Other Injuries	0.009	0.001	1.009	(1.006-1.012)
Other Comorbidity	Major Symptoms, Abnormalities	0.040	0.001	1.041	(1.039-1.044)
Other Comorbidity	Minor Symptoms, Signs, Findings	0.014	0.001	1.014	(1.011-1.016)

For each generalized linear model, we compute six summary statistics to assess model performance: calibration (a measure of over-fitting), predictive ratios by deciles and bottom and top 1% of predicted payment, distribution of residuals, mean absolute prediction error (MAPE), root mean square error (RMSE), and model chi-square. We also estimated a 'quasi-R2' by regressing the total payment outcome on the predicted outcome.[18] Specifically, we regressed the unadjusted total payment on the payment estimated by the patient-level risk-adjustment model. Model performance results are summarized in Table 11.

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

A predictive ratio is an estimator's ratio of predicted outcome to observed outcome.[19] A predictive ratio of 1.0 indicates an accurate prediction. A ratio greater than 1.0 indicates overprediction, and a ratio less than 1.0 indicates underprediction.

Standardized Pearson residuals also assess model fit. If a substantial number of standardized Pearson residuals exceed 2 in absolute value, lack of fit may be indicated.

The MAPE is a measure of the model's predictive accuracy.[18] It is calculated by taking the mean of the absolute values of prediction errors.

The RMSE is another measure of model predictive accuracy.[18] It is calculated by taking the square root of the mean of squared prediction errors.

The model chi-square provides evidence of a global test of goodness of fit of the model, where the null hypothesis is that all the parameters of covariates are 0s. Take the deviance from the model with intercept only and minus the deviance in the full model with all covariates. It gives us a chi-square statistics with the degree of freedom equal the number of variables tested.

Taking together, results from all these model diagnostics suggest that the model performs well across all samples.

Table 11. Generalized Linear Model Performance for Development and Validation Samples

Indices	July 2011-June 2012 Development Sample A1 (%)	July 2011-June 2012 Validation Sample A2 (%)	July 2010-June 2011 Validation Sample B (%)
Number of hospital stays	142,361	142,360	286,750
Number of hospitals	3,257	3,246	3,318
Unadjusted mean payment	$22,743	$22,774	$23,770
Calibration (γ0, γ1)	(0,1)	(0.03,1.00)	(-0.11,1.02)
Discrimination – Predictive Ratios Bottom 1% (lowest)	0.96	0.97	0.97
Discrimination – Predictive Ratios First Decile	0.99	0.99	0.99
Discrimination – Predictive Ratios Second Decile	1.00	1.00	1.00
Discrimination – Predictive Ratios Third Decile	1.01	1.01	1.01
Discrimination – Predictive Ratios Fourth Decile	1.01	1.01	1.01
Discrimination – Predictive Ratios Fifth Decile	1.01	1.01	1.01
Discrimination – Predictive Ratios Sixth Decile	1.01	1.01	1.01
Discrimination – Predictive Ratios Seventh Decile	1.00	1.01	1.00
Discrimination – Predictive Ratios Eighth Decile	0.99	0.99	0.99
Discrimination – Predictive Ratios Ninth Decile	0.98	0.98	0.99
Discrimination – Predictive Ratios Tenth Decile	1.01	1.00	1.01
Discrimination – Predictive Ratios Top 1% (highest)	1.10	1.09	1.08
Residuals Lack of Fit (Pearson Residual Fall %) <-2	0.01%	0.02%	0.02%
Residuals Lack of Fit (Pearson Residual Fall %) [-2, 0)	62.75%	62.72%	62.17%
Residuals Lack of Fit (Pearson Residual Fall %) [0, 2)	32.02%	32.06%	32.65%
Residuals Lack of Fit (Pearson Residual Fall %) [2+	5.21%	5.20%	5.16%
MAPE	$5,781	$5,829	$6,089
RMSE	$8,711	$8,780	$9,123
R^2	0.223	0.222	0.226
Model χ^2 [DF] (p-value)	45374 [57] (p<0.001)	44638 [57] (p<0.001)	91325 [57] (p<0.001)

3.2. Final Model Results

The results presented below for the final hierarchical generalized linear model are for the full July 2010-June 2012 combined sample (Samples A and B combined). The list of covariates and coefficients, standard errors, PR, and 95% confidence intervals for the PR associated with each risk factor are shown in Table 12.

Table 12. Hierarchical Generalized Linear Model Results for Full July 2010-June 2012 Sample

Risk-Adjustment Category	Risk-Adjustment Variable	Estimate	Standard Error	Payment Ratio (PR)	95% Confidence Interval for PRs
Intercept	N/A	9.663	0.004	-	-
Demographics	Age-65 (years above 65, continuous)	0.015	0.000	1.015	(1.015-1.015)
Demographics	Male	-0.075	0.001	0.928	(0.926-0.929)
Procedure	Index Admission with an Elective THA Procedure (versus TKA)	0.022	0.001	1.022	(1.020-1.024)
Procedure	Procedure Type (Bilateral Joint Replacement)	0.553	0.004	1.738	(1.726-1.751)
Procedure	Procedure Type(Staged Joint Replacement)	0.559	0.007	1.749	(1.726-1.773)
Procedure	Procedure Type (Single Joint Replacement)	0.000	-	1.000	-
Other Comorbidity	Morbid Obesity	0.118	0.002	1.125	(1.120-1.130)
Other Comorbidity	Congestive Heart Failure	0.058	0.002	1.060	(1.056-1.064)
Other Comorbidity	Acute Coronary Syndrome	0.021	0.001	1.021	(1.019-1.023)
Other Comorbidity	Valvular or Rheumatic Heart Disease	0.007	0.001	1.007	(1.004-1.009)
Other Comorbidity	Hypertension and Hypertension Complications	0.030	0.001	1.030	(1.028-1.033)
Other Comorbidity	History of Infection	0.044	0.001	1.045	(1.042-1.048)
Other Comorbidity	Metastatic Cancer and Acute Leukemia	0.033	0.007	1.034	(1.020-1.047)
Other Comorbidity	Cancer	-0.007	0.001	0.993	(0.991-0.995)
Other Comorbidity	Benign Neoplasms of Skin, Breast, Eye	-0.019	0.001	0.981	(0.979-0.984)
Other Comorbidity	Diabetes and Diabetes Complications	0.056	0.001	1.058	(1.056-1.060)
Other Comorbidity	Protein-Calorie Malnutrition	0.175	0.007	1.191	(1.175-1.206)
Other Comorbidity	Other Significant Endocrine and Metabolic Disorders	0.023	0.003	1.024	(1.019-1.029)
Other Comorbidity	Obesity/Disorders of Thyroid, Cholesterol, Lipids	-0.011	0.001	0.990	(0.988-0.992)
Other Comorbidity	Appendicitis	-0.053	0.014	0.948	(0.923-0.975)
Other Comorbidity	Bone/Joint/Muscle Infections/Necrosis	0.038	0.003	1.038	(1.032-1.045)
Other Comorbidity	Rheumatoid Arthritis and Inflammatory Connective Tissue Disease	0.022	0.002	1.022	(1.019-1.026)
Other Comorbidity	Disorders of the Vertebrae and Spinal Discs	0.008	0.001	1.008	(1.006-1.010)
Other Comorbidity	Osteoarthritis of Hip or Knee	0.069	0.002	1.072	(1.067-1.076)
Other Comorbidity	Other Musculoskeletal and Connective Tissue Disorders	0.033	0.001	1.034	(1.031-1.037)
Other Comorbidity	Severe Hematological Disorders	0.062	0.006	1.064	(1.051-1.077)
Other Comorbidity	Coagulation Defects and Other Specified Hematological Disorders	0.020	0.002	1.020	(1.016-1.025)
Other Comorbidity	Delirium and Encephalopathy	0.040	0.006	1.041	(1.029-1.052)
Other Comorbidity	Dementia and Senility	0.100	0.003	1.105	(1.100-1.111)
Other Comorbidity	Major Psychiatric Disorders	0.091	0.003	1.095	(1.089-1.100)
Other Comorbidity	Depression/Anxiety	0.036	0.001	1.037	(1.034-1.040)
Other Comorbidity	Other Psychiatric Disorders	0.015	0.002	1.016	(1.012-1.019)
Other Comorbidity	Mental Retardation or Developmental Disability	0.272	0.017	1.313	(1.270-1.356)
Other Comorbidity	Hemiplegia, Paraplegia, Paralysis, Functional Disability	0.067	0.004	1.070	(1.061-1.078)
Other Comorbidity	Polyneuropathy	0.039	0.002	1.039	(1.035-1.043)
Other Comorbidity	Multiple Sclerosis	0.125	0.011	1.133	(1.109-1.158)
Other Comorbidity	Parkinson's and Huntington's Diseases	0.172	0.005	1.188	(1.176-1.200)
Other Comorbidity	Seizure Disorders and Convulsions	0.067	0.004	1.070	(1.061-1.079)
Other Comorbidity	Arrhythmias	0.013	0.001	1.013	(1.011-1.016)
Other Comorbidity	Stroke	0.045	0.004	1.047	(1.039-1.054)
Other Comorbidity	Vascular or Circulatory Disease	0.025	0.001	1.025	(1.023-1.027)
Other Comorbidity	Chronic Obstructive Pulmonary Disease (COPD)	0.044	0.001	1.045	(1.042-1.048)
Other Comorbidity	Pleural Effusion/Pneumothorax	-0.018	0.004	0.982	(0.974-0.990)

Risk-Adjustment Category	Risk-Adjustment Variable	Estimate	Standard Error	Payment Ratio (PR)	95% Confidence Interval for PRs
Other Comorbidity	Other Lung Disorders	0.017	0.001	1.017	(1.015-1.020)
Other Comorbidity	Legally Blind	0.089	0.011	1.093	(1.069-1.117)
Other Comorbidity	End-stage Renal Disease or Dialysis	0.296	0.015	1.345	(1.305-1.386)
Other Comorbidity	Renal Failure	0.048	0.002	1.049	(1.045-1.053)
Other Comorbidity	Incontinence	0.051	0.002	1.053	(1.048-1.057)
Other Comorbidity	Urinary Tract Infection	0.011	0.001	1.011	(1.009-1.014)
Other Comorbidity	Other Urinary Tract Disorders	0.010	0.001	1.010	(1.007-1.013)
Other Comorbidity	Decubitus Ulcer or Chronic Skin Ulcer	0.077	0.003	1.080	(1.073-1.087)
Other Comorbidity	Cellulitis, Local Skin Infection	0.028	0.002	1.028	(1.024-1.032)
Other Comorbidity	Other Dermatological Disorders	-0.013	0.001	0.987	(0.985-0.989)
Other Comorbidity	Trauma	0.048	0.002	1.049	(1.044-1.055)
Other Comorbidity	Vertebral Fractures	0.052	0.005	1.054	(1.044-1.063)
Other Comorbidity	Other Injuries	0.008	0.001	1.008	(1.006-1.010)
Other Comorbidity	Major Symptoms, Abnormalities	0.032	0.001	1.033	(1.031-1.035)
Other Comorbidity	Minor Symptoms, Signs, Findings	0.018	0.001	1.018	(1.016-1.021)

3.2.1. Distribution of Unadjusted and Adjusted Hospital-Specific THA/TKA 90-Day Episode-of-Care Payment

The estimated between-hospital variance from the hierarchical generalized linear model is 0.014 (SE = 0.0004). The THA/TKA payment for a hospital with one standard deviation above average was 1.27 times that of a hospital with one standard deviation below average.

Both unadjusted (Figure 7) and adjusted (Figure 8) payments from THA/TKA admission to 90 days post-admission vary considerably across hospitals (Table 13). For hospitals with at least 25 cases, the hospital unadjusted THA/TKA 90-day episode-of-care payment ranges from $15,137 to $41,673 across 2,614 hospitals with a median (interquartile range) of $23,397 ($21,502, $25,702). The mean ± SD hospital unadjusted payment is $23,772 ± $3,377. After adjusting for patient case mix, the RSP at the hospital level has a median (interquartile range) of $23,120 ($21,473, $24,885). The mean ± SD risk-standardized hospital payment is $23,248 ± $2,535, ranging from $16,421 to $35,123 across 2,614 hospitals.

While we included all hospitals when estimating the risk-adjustment model, we excluded hospitals with fewer than 25 total cases from the summary statistics below, since estimates for hospitals with fewer cases are less reliable, and CMS's past approach to public reporting has been not to report these results. The volume of THA/TKA hospitalizations among the included hospitals ranges from 25 to 5,569 index THA/TKA admissions, with a mean of 215 index admissions and a median of 136 index admissions.
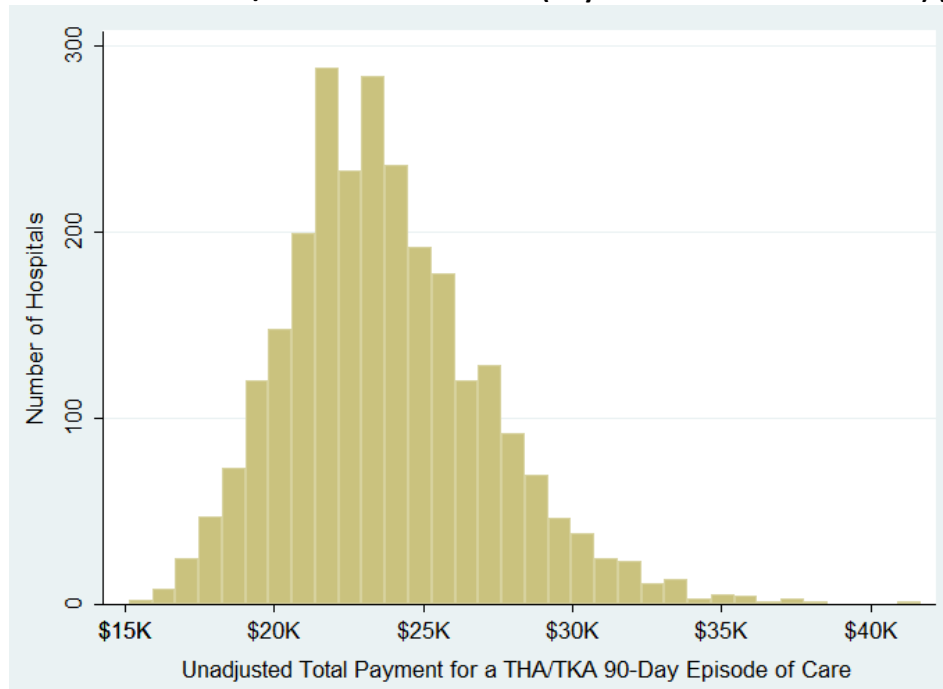
Table 13. Distribution of Unadjusted and Risk-Standardized Payments for Hospitals with a Minimum of 25 THA/TKA Index Admissions (July 2010-June 2012 combined) (N=2,614 hospitals)*

| Summary Statistic	THA/TKA Episode-of-Care Payment (Unadjusted)	THA/TKA Episode-of-Care Payment (Risk-Standardized)
Mean	$23,772	$23,248
SD	$3,377	$2,535
Min	$15,137	$16,421
10th Percentile	$19,774	$20,127
25th Percentile	$21,502	$21,473
Median	$23,397	$23,120
75th Percentile	$25,702	$24,885
90th Percentile	$28,256	$26,550
Max	$41,673	$35,123

*2010 and 2011 payments were inflation adjusted to 2012 dollars.

Figure 7. Distribution of THA/TKA 90-Day Episode-of-Care Unadjusted Payments for Hospitals with a Minimum of 25 THA/TKA Index Admissions (July 2010-June 2012 combined) (N=2,614 hospitals)**

**2010 and 2011 payments were inflation adjusted to 2012 dollars.

Figure 8. Distribution of THA/TKA Episode-of-Care RSPs for Hospitals with a Minimum of 25 THA/TKA Index Admissions (July 2010-June 2012 combined) (N=2,614 hospitals)
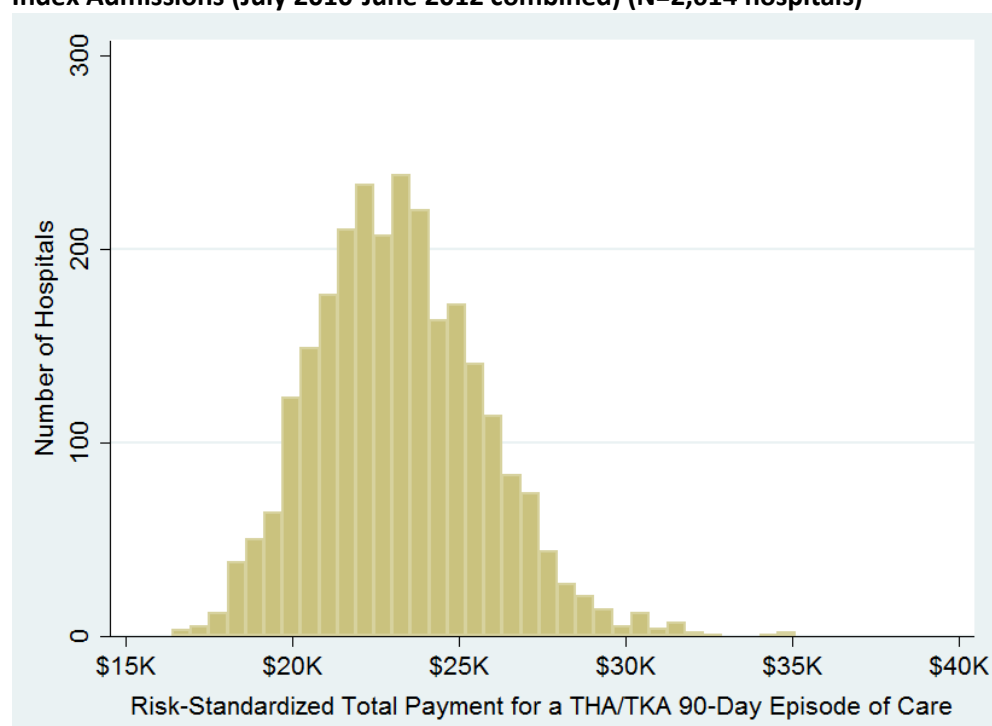
3.3. Measure Testing

3.3.1. Reliability Testing

We calculated the Intraclass Correlation Coefficient (ICC) in order to assess the reliability of the measure. The ICC score can be used to determine the extent to which assessments of a hospital using different but randomly selected subsets of patients produces similar measures of hospital performance. We calculated the RSP using a split-sample of the combined July 2010-June 2012 data. Thus, we obtained two RSPs for each hospital, using an entirely distinct set of patients from the same time period. To the extent that the calculated measures of these two subsets agree, we have evidence that the measure assesses an attribute of the hospital, not of the patients. As a metric of agreement we calculated the ICC (2,1) as defined by Shrout and Fleiss.[20]

The agreement between the two independent assessments of each hospital was 0.955, which, according to the conventional interpretation, is "almost perfect".[21]

3.3.1.1. Data Element Reliability

In constructing the THA/TKA payment measure, we aimed to utilize only those data elements from the claims data that have both face validity and reliability. We avoided the use of fields that are coded inconsistently across hospitals or providers. Additionally, CMS has several hospital auditing programs in place to assess overall claims code

accuracy, to ensure appropriate billing, and to recoup overpayment. CMS routinely conducts data analyses to identify potential problem areas and detect fraud, and audits important data fields used in our measures, including diagnosis and procedure codes, and other elements that are consequential to payment.[22]

3.3.2. Validity Testing

3.3.2.1. Validity of Claims-Based Measures

Our team has demonstrated the validity of claims-based measures for profiling hospitals for a number of prior measures by comparing either the measure results or the individual data elements against medical records. CMS validated the six NQF-endorsed claims-based measures currently in public reporting (mortality and readmission measures for AMI, heart failure, and pneumonia) with models that used medical record-abstracted data for risk adjustment. Specifically, claims model validation was conducted by building comparable models using abstracted medical record data for risk adjustment for heart failure patients (National Heart Failure data), AMI patients (Cooperative Cardiovascular Project data), and pneumonia patients (National Pneumonia Project dataset). When both models were applied to the same patient population, the hospital risk-standardized mortality and readmission rates estimated using the claims-based risk-adjustment models had a high level of agreement with the results based on the medical record model, thus supporting the use of the claims-based models for public reporting. In addition, CMS's THA/TKA complication measure outcome definition was validated through a medical record review which produced 99% (635/644) agreement between the current claims-based definition of complications and medical record data.[23]

3.3.2.2. Validity of Development Process

We are developing this measure in consultation with national guidelines for publicly reported outcomes measures, outside experts, and the public. The measure is consistent with the technical approach to outcomes measurement set forth in National Quality Forum (NQF) guidance for outcomes measures,[8] 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."[10]

In order to examine the face validity of our methods for estimating payments for a THA/TKA episode of care, we compared our approach with one other measure that estimate payments for episodes of care and is endorsed by NQF for public reporting. Specifically, we compared our methods with the:

- **CMS Medicare Spending per Beneficiary (MSPB) measure**, which estimates the cost of an episode of care for all inpatient diagnoses at the hospital-level from three days prior to admission through 30 days post-discharge for Medicare FFS beneficiaries 18 years and older. Their cost outcome includes patient copayments and excludes geographic and policy adjustments. Risk adjustment

includes age, hierarchical condition categories, enrollment status, long-term care variables, variable interaction terms, and MS-DRGs present 90 days prior to index admission. The hospital is the unit of reporting.

Although our measure is being developed independently of the CMS MSPB measure above, we share several key decisions:

1. *Isolate resource utilization:* Like ours, the CMS MSPB measure attempts to isolate payment differentials due to resource utilization by removing payment adjustments that do not reflect the clinical care delivered, such as geographic factors and policy adjustments.
2. *Perform risk adjustment*: Like ours, the CMS MSPB measure employs a thorough and transparent approach to risk adjustment, although the specific risk-adjustment strategies differ technically.

In addition, we surveyed the TEP and asked each member to assess the preliminary face validity of our measure by rating the following statement using a six-point scale (1=Strongly Disagree, 2=Moderately Disagree, 3=Somewhat Disagree, 4=Somewhat Agree, 5=Moderately Agree, and 6=Strongly Agree):

> "The Hip/Knee Payment measure as specified will provide a valid assessment of the relative costs of a 90-day hip/knee arthroplasty episode of care for Medicare patients admitted to a given hospital."

Among the thirteen TEP members who provided a response, two responded "Somewhat Agree," six responded "Moderately Agree," and five reported "Strongly Agree".

4. MAIN FINDINGS / SUMMARY

We present a hierarchical generalized linear regression model for assessing hospital-level, risk-standardized payments for a 90-day episode of care associated with an index admission for elective primary THA/TKA. Our approach to model development and risk adjustment is consistent with quality measure methods recommendations for publicly reported outcomes measures from NQF, CMS, and the American Heart Association scientific statement.[9-11] This proposed measure is based on administrative claims data for FFS Medicare beneficiaries 65 years and older, and is being developed with extensive input from clinical and methodological experts with knowledge and experience relevant to quality measurement.

The study sample is appropriately defined, consisting of patients having an inpatient stay with a primary discharge diagnosis of elective primary THA/TKA. The outcome is measured using stripped or standardized payments for Medicare patients starting with the index admission and continuing 90 days post-admission across all care settings, services, and supplies (except Part D). The risk-adjustment process accounts for patient age and comorbid conditions identified from: secondary diagnoses of the index hospital stay (excluding potential complications), inpatient data, outpatient hospital data, and carrier files for physician, radiology, and laboratory services during the 12 months prior to the index admission. The hierarchical generalized linear model accounts for hospital case mix and the clustering of patients within hospitals, thereby making the measure suitable for public reporting.

We find substantial variation in risk-standardized payments for a THA/TKA episode of care across hospitals. Implementation of this measure in conjunction with CMS's 90-day THA/TKA risk-standardized complication measure has the potential to improve the efficiency of care for patients with THA/TKA.

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6. APPENDICES

Appendix A. Potential Complications in the Index Admission for THA/TKA Payment Model

CC #	Description	Potential Complication in Index Admission
CC 1	HIV/AIDS	No
CC 2	Septicemia/Shock	Yes
CC 3	Central Nervous System Infection	No
CC 4	Tuberculosis	No
CC 5	Opportunistic Infections	No
CC 6	Other Infectious Diseases	Yes
CC 7	Metastatic Cancer and Acute Leukemia	No
CC 8	Lung, Upper Digestive Tract, and Other Severe Cancers	No
CC 9	Lymphatic, Head and Neck, Brain, and Other Major Cancers	No
CC 10	Breast, Prostate, Colorectal and Other Cancers and Tumors	No
CC 11	Other Respiratory and Heart Neoplasms	No
CC 12	Other Digestive and Urinary Neoplasms	No
CC 13	Other Neoplasms	No
CC 14	Benign Neoplasms of Skin, Breast, Eye	No
CC 15	Diabetes with Renal Manifestation	No
CC 16	Diabetes with Neurologic or Peripheral Circulatory Manifestation	No
CC 17	Diabetes with Acute Complications	Yes
CC 18	Diabetes with Ophthalmologic Manifestation	No
CC 19	Diabetes with No or Unspecified Complications	No
CC 20	Type I Diabetes Mellitus	No
CC 21	Protein-Calorie Malnutrition	No
CC 22	Other Significant Endocrine and Metabolic Disorders	No
CC 23	Disorders of Fluid/Electrolyte/Acid-Base	Yes
CC 24	Other Endocrine/Metabolic/Nutritional Disorders	No
CC 25	End-Stage Liver Disease	No
CC 26	Cirrhosis of Liver	No
CC 27	Chronic Hepatitis	No
CC 28	Acute Liver Failure/Disease	Yes
CC 29	Other Hepatitis and Liver Disease	No
CC 30	Gallbladder and Biliary Tract Disorders	No
CC 31	Intestinal Obstruction/Perforation	Yes
CC 32	Pancreatic Disease	No
CC 33	Inflammatory Bowel Disease	No
CC 34	Peptic Ulcer, Hemorrhage, Other Specified Gastrointestinal Disorders	Yes
CC 35	Appendicitis	No
CC 36	Other Gastrointestinal Disorders	No
CC 37	Bone/Joint/Muscle Infections/Necrosis	No
CC 38	Rheumatoid Arthritis and Inflammatory Connective Tissue Disease	No
CC 39	Disorders of the Vertebrae and Spinal Discs	No
CC 40	Osteoarthritis of Hip or Knee	No
CC 41	Osteoporosis and Other Bone/Cartilage Disorders	No
CC 42	Congenital/Developmental Skeletal and Connective Tissue Disorders	No
CC 43	Other Musculoskeletal and Connective Tissue Disorders	No
CC 44	Severe Hematological Disorders	No
CC 45	Disorders of Immunity	No
CC 46	Coagulation Defects and Other Specified Hematological Disorders	Yes

CC #	Description	Potential Complication in Index Admission
CC 47	Iron Deficiency and Other/Unspecified Anemias and Blood Disease	No
CC 48	Delirium and Encephalopathy	Yes
CC 49	Dementia	No
CC 50	Senility, Nonpsychotic Organic Brain Syndromes/Conditions	No
CC 51	Drug/Alcohol Psychosis	No
CC 52	Drug/Alcohol Dependence	No
CC 53	Drug/Alcohol Abuse, Without Dependence	No
CC 54	Schizophrenia	No
CC 55	Major Depressive, Bipolar, and Paranoid Disorders	No
CC 56	Reactive and Unspecified Psychosis	No
CC 57	Personality Disorders	No
CC 58	Depression	No
CC 59	Anxiety Disorders	No
CC 60	Other Psychiatric Disorders	No
CC 61	Profound Mental Retardation/Developmental Disability	No
CC 62	Severe Mental Retardation/Developmental Disability	No
CC 63	Moderate Mental Retardation/Developmental Disability	No
CC 64	Mild/Unspecified Mental Retardation/Developmental Disability	No
CC 65	Other Developmental Disability	No
CC 66	Attention Deficit Disorder	No
CC 67	Quadriplegia, Other Extensive Paralysis	No
CC 68	Paraplegia	No
CC 69	Spinal Cord Disorders/Injuries	No
CC 70	Muscular Dystrophy	No
CC 71	Polyneuropathy	No
CC 72	Multiple Sclerosis	No
CC 73	Parkinson's and Huntington's Diseases	No
CC 74	Seizure Disorders and Convulsions	No
CC 75	Coma, Brain Compression/Anoxic Damage	Yes
CC 76	Mononeuropathy, Other Neurological Conditions/Injuries	No
CC 77	Respirator Dependence/Tracheostomy Status	Yes
CC 78	Respiratory Arrest	Yes
CC 79	Cardio-Respiratory Failure and Shock	Yes
CC 80	Congestive Heart Failure	Yes
CC 81	Acute Myocardial Infarction	Yes
CC 82	Unstable Angina and Other Acute Ischemic Heart Disease	Yes
CC 83	Angina Pectoris/Old Myocardial Infarction	No
CC 84	Coronary Atherosclerosis/Other Chronic Ischemic Heart Disease	No
CC 85	Heart Infection/Inflammation, Except Rheumatic	No
CC 86	Valvular and Rheumatic Heart Disease	No
CC 87	Major Congenital Cardiac/Circulatory Defect	No
CC 88	Other Congenital Heart/Circulatory Disease	No
CC 89	Hypertensive Heart and Renal Disease or Encephalopathy	No
CC 90	Hypertensive Heart Disease	No
CC 91	Hypertension	No
CC 92	Specified Heart Arrhythmias	Yes
CC 93	Other Heart Rhythm and Conduction Disorders	Yes
CC 94	Other and Unspecified Heart Disease	Yes
CC 95	Cerebral Hemorrhage	Yes
CC 96	Ischemic or Unspecified Stroke	Yes
CC 97	Precerebral Arterial Occlusion and Transient Cerebral Ischemia	Yes

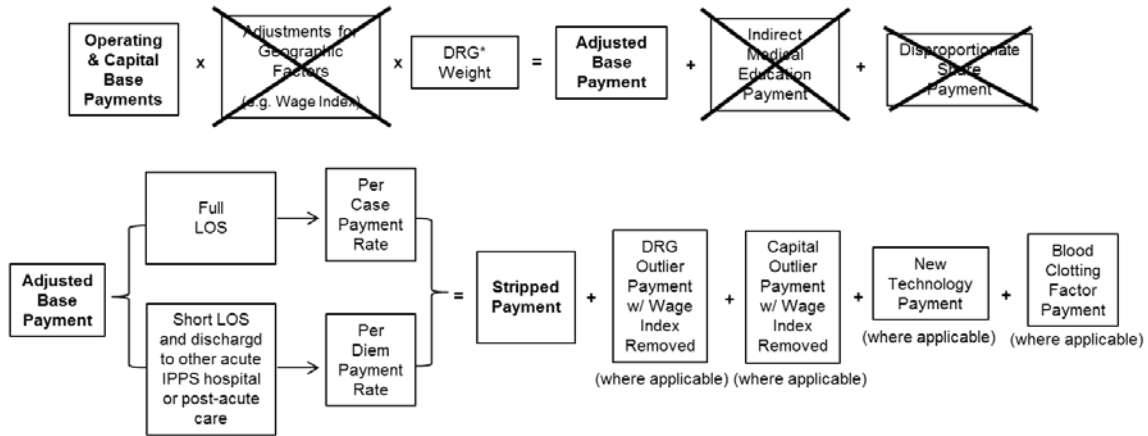| CC #	Description	Potential Complication in Index Admission
CC 98	Cerebral Atherosclerosis and Aneurysm	No
CC 99	Cerebrovascular Disease, Unspecified	No
CC 100	Hemiplegia/Hemiparesis	Yes
CC 101	Diplegia (Upper), Monoplegia, and Other Paralytic Syndromes	Yes
CC 102	Speech, Language, Cognitive, Perceptual	Yes
CC 103	Cerebrovascular Disease Late Effects, Unspecified	No
CC 104	Vascular Disease with Complications	Yes
CC 105	Vascular Disease	Yes
CC 106	Other Circulatory Disease	Yes
CC 107	Cystic Fibrosis	No
CC 108	Chronic Obstructive Pulmonary Disease	No
CC 109	Fibrosis of Lung and Other Chronic Lung Disorders	No
CC 110	Asthma	No
CC 111	Aspiration and Specified Bacterial Pneumonias	Yes
CC 112	Pneumococcal Pneumonia, Emphysema, Lung Abscess	Yes
CC 113	Viral and Unspecified Pneumonia, Pleurisy	No
CC 114	Pleural Effusion/Pneumothorax	Yes
CC 115	Other Lung Disorders	No
CC 116	Legally Blind	No
CC 117	Major Eye Infections/Inflammations	No
CC 118	Retinal Detachment	No
CC 119	Proliferative Diabetic Retinopathy and Vitreous Hemorrhage	No
CC 120	Diabetic and Other Vascular Retinopathies	No
CC 121	Retinal Disorders, Except Detachment and Vascular Retinopathies	No
CC 122	Glaucoma	No
CC 123	Cataract	No
CC 124	Other Eye Disorders	No
CC 125	Significant Ear, Nose, and Throat Disorders	No
CC 126	Hearing Loss	No
CC 127	Other Ear, Nose, Throat, and Mouth Disorders	No
CC 128	Kidney Transplant Status	No
CC 129	End Stage Renal Disease	Yes
CC 130	Dialysis Status	Yes
CC 131	Renal Failure	Yes
CC 132	Nephritis	Yes
CC 133	Urinary Obstruction and Retention	Yes
CC 134	Incontinence	No
CC 135	Urinary Tract Infection	Yes
CC 136	Other Urinary Tract Disorders	No
CC 137	Female Infertility	No
CC 138	Pelvic Inflammatory Disease and Other Specified Female Genital Disorders	No
CC 139	Other Female Genital Disorders	No
CC 140	Male Genital Disorders	No
CC 141	Ectopic Pregnancy	No
CC 142	Miscarriage/Abortion	No
CC 143	Completed Pregnancy With Major Complications	No
CC 144	Completed Pregnancy With Complications	No
CC 145	Completed Pregnancy Without Complication	No
CC 146	Uncompleted Pregnancy With Complications	No
CC 147	Uncompleted Pregnancy With No or Minor Complications	No
CC 148	Decubitus Ulcer of Skin	Yes

CC #	Description	Potential Complication in Index Admission
CC 149	Chronic Ulcer of Skin, Except Decubitus	No
CC 150	Extensive Third-Degree Burns	No
CC 151	Other Third-Degree and Extensive Burns	No
CC 152	Cellulitis, Local Skin Infection	Yes
CC 153	Other Dermatological Disorders	No
CC 154	Severe Head Injury	Yes
CC 155	Major Head Injury	Yes
CC 156	Concussion or Unspecified Head Injury	Yes
CC 157	Vertebral Fractures	No
CC 158	Hip Fracture/Dislocation	Yes
CC 159	Major Fracture, Except of Skull, Vertebrae, or Hip	Yes
CC 160	Internal Injuries	No
CC 161	Traumatic Amputation	No
CC 162	Other Injuries	No
CC 163	Poisonings and Allergic Reactions	Yes
CC 164	Major Complications of Medical Care and Trauma	No
CC 165	Other Complications of Medical Care	Yes
CC 166	Major Symptoms, Abnormalities	No
CC 167	Minor Symptoms, Signs, Findings	No
CC 168	Extremely Low Birth weight Neonates	No
CC 169	Very Low Birth weight Neonates	No
CC 170	Serious Perinatal Problem Affecting Newborn	No
CC 171	Other Perinatal Problems Affecting Newborn	No
CC 172	Normal, Single Birth	No
CC 173	Major Organ Transplant	No
CC 174	Major Organ Transplant Status	Yes
CC 175	Other Organ Transplant/Replacement	Yes
CC 176	Artificial Openings for Feeding or Elimination	Yes
CC 177	Amputation Status, Lower Limb/Amputation	Yes
CC 178	Amputation Status, Upper Limb	Yes
CC 179	Post-Surgical States/Aftercare/Elective	Yes
CC 180	Radiation Therapy	No
CC 181	Chemotherapy	No
CC 182	Rehabilitation	No
CC 183	Screening/Observation/Special Exams	No
CC 184	History of Disease	No
CC 185	Oxygen	No
CC 186	CPAP/IPPB/Nebulizers	No
CC 187	Patient Lifts, Power Operated Vehicles, Beds	No
CC 188	Wheelchairs, Commodes	No
CC 189	Walkers	No

Appendix B. Example of Included and Excluded Payments When Counting the 90-Day Episode of Care for a Patient with an Index Admission on May 3 and Discharged on May 8

Claim Type	Provider ID	Claim Date	Admission Type	Primary ICD-9	Payment	Included in Model?	Payment Included in Model	Comments
Carrier	123456	30 Apr-30 Apr	N/A		$255.61	N	$0.00	Started prior to the index admission.
Inpatient	234567	3 May-4 May	Admission	81.51	$1,109.49	Y	$1,109.49	This inpatient THA (81.51) admission defines the index admission date (5/3).
Inpatient	345678	4 May-8 May	Transfer	81.51	$8,008.15	Y	$8,008.15	This inpatient THA (81.51) discharge defines the discharge date (5/8).
Physician	567891	3 May-3 May	N/A		$367.20	Y	$367.20	Physician payments during the index stay
Physician	678910	3 May-3 May	N/A		$6.59	Y	$6.59	Physician payments during the index stay
Physician	789101	3 May-8 May	N/A		$350.52	Y	$350.52	Physician payments during the index stay
Physician	456789	5 May-5 May	N/A		$225.75	Y	$225.75	Physician payments during the index stay
Physician	345678	7 May-7 May	N/A		$148.39	Y	$148.39	Physician payments during the index stay
Inpatient	910112	28 July - 2 Aug	Readmission		$4,262.13	Y (pro-rated)	$3,409.70	Payment is prorated, based only on the days which fall into the 90-day post-admission period. The amount included in the payment model would be: ($4262.13/5)*4 = $3409.70.
Skilled Nursing Facility	891011	1 Aug-21 Aug	Transfer		$1,652.28	N	$0.00	Started after the 90-day post-admission period.
				TOTAL	$16,386.11		$13,625.79	

Appendix C. Stripped/Standardized Payment Diagrams

Acute Inpatient Hospital: Stripped Payment

Operating & Capital Base Payments × ~~Adjustments for Geographic Factors (e.g. Wage Index)~~ × DRG* Weight = Adjusted Base Payment + ~~Indirect Medical Education Payment~~ + ~~Disproportionate Share Payment~~

Adjusted Base Payment →
- Full LOS → Per Case Payment Rate
- Short LOS and dischargd to other acute IPPS hospital or post-acute care → Per Diem Payment Rate

= Stripped Payment + DRG Outlier Payment w/ Wage Index Removed (where applicable) + Capital Outlier Payment w/ Wage Index Removed (where applicable) + New Technology Payment (where applicable) + Blood Clotting Factor Payment (where applicable)

Stripped Payment Formula:

$$\left(\begin{array}{c}\text{Operating Base Payment} + \text{Capital Base Payment}\end{array}\right) \times \text{DRG* Weight} + \frac{\text{DRG Outlier Payment}}{\left(\text{Labor Ratio} \times \text{Wage Index}\right) + \text{Nonlabor Ratio}} + \frac{\text{Capital Outlier Payment}}{(\text{Wage Index})^{0.6846}} + \text{New Technology Payment} + \text{Blood Clotting Factor Payment}$$
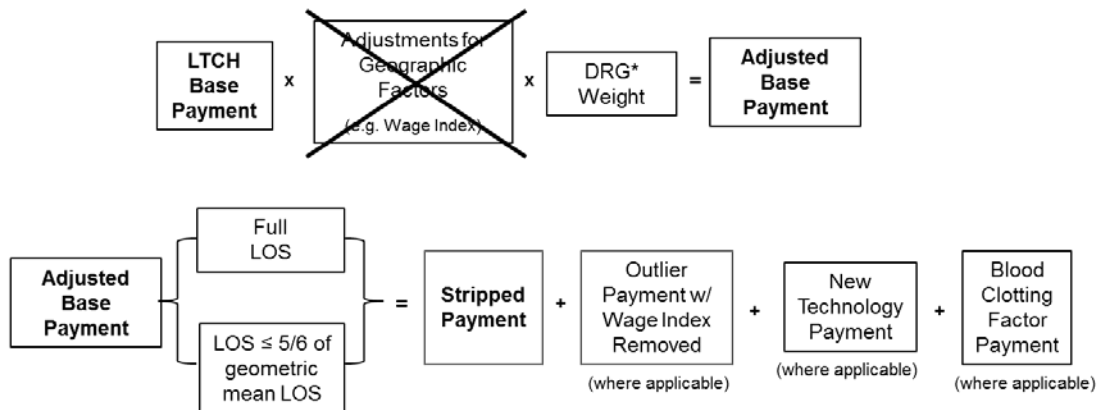
(where applicable) (where applicable) (where applicable) (where applicable)

*DRG (Diagnosis Related Group): Includes principal diagnosis, procedure, complications, and comorbidities
Note: Payments to critical access hospitals (CAHs) were calculated using the IPPS stripped payment formula.
Note: The payment diagrams are adapted from the MedPAC Payment Basics series, October 2011

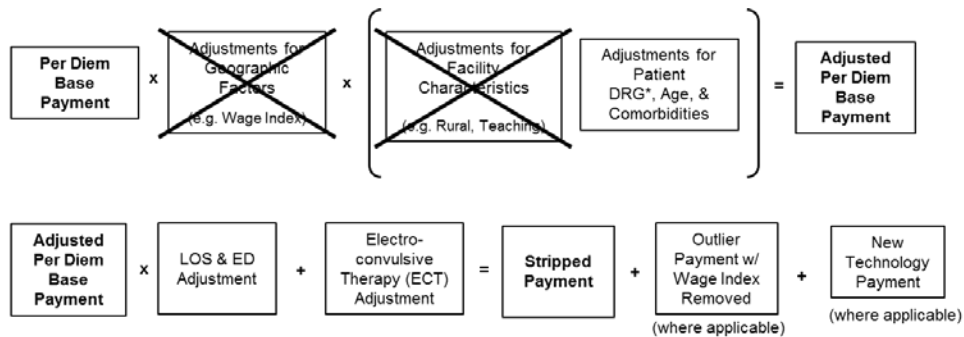## Long Term Care Hospitals: Stripped Payment

Stripped Payment Formula:

$$\left(\begin{array}{c} \text{Base} \\ \text{Payment} \end{array} \times \begin{array}{c} \text{DRG*} \\ \text{Weight} \end{array} \times \text{LOS Adjustment} \right) + \cfrac{\text{Outlier Payment}}{\left(\begin{array}{c} \text{Labor} \\ \text{Ratio} \end{array} \times \begin{array}{c} \text{Wage} \\ \text{Index} \end{array} \right) + \begin{array}{c} \text{Nonlabor} \\ \text{Ratio} \end{array}} + \begin{array}{c} \text{New Technology} \\ \text{Payment} \end{array} + \begin{array}{c} \text{Blood Clotting} \\ \text{Factor Payment} \end{array}$$

(where applicable)   (where applicable)   (where applicable)

* DRG (Diagnosis Related Group): Includes principal & secondary diagnoses, procedures, age, sex, discharge status
Note: The payment diagrams are adapted from the MedPAC Payment Basics series, October 2011

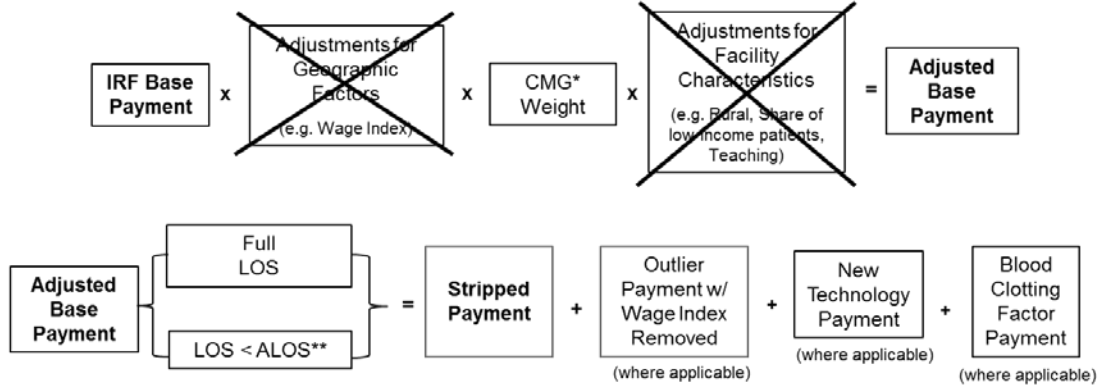## Inpatient Psychiatric Facility: Stripped Payment

Stripped Payment Formula:

$$\left(\begin{array}{c} \text{Per Diem} \\ \text{Base} \\ \text{Payment} \end{array} \times \begin{array}{c} \text{DRG*} \\ \text{Weight} \end{array} \times \begin{array}{c} \text{Age} \\ \text{Adjustment} \end{array} \times \begin{array}{c} \text{Comorbidity} \\ \text{Adjustment} \end{array} \times \begin{array}{c} \text{LOS \& ED} \\ \text{Adjustment} \end{array} \right) + \begin{array}{c} \text{ECT} \\ \text{Adjustment} \end{array} + \cfrac{\text{Outlier Payment}}{\left(\begin{array}{c} \text{Labor} \\ \text{Ratio} \end{array} \times \begin{array}{c} \text{Wage} \\ \text{Index} \end{array} \right) + \begin{array}{c} \text{Nonlabor} \\ \text{Ratio} \end{array}} + \begin{array}{c} \text{New} \\ \text{Technology} \\ \text{Payment} \end{array}$$

(where applicable)   (where applicable)

*DRG (Diagnosis Related Group): Includes principal diagnoses
Note: The payment diagrams are adapted from the MedPAC Payment Basics series, October 2011

Inpatient Rehabilitation Facility: Stripped Payment

Stripped Payment Formula:

$$\left(\begin{array}{c} \text{IRF Base} \\ \text{Payment} \end{array} \times \begin{array}{c} \text{CMG*} \\ \text{Weight} \end{array} \times \begin{array}{c} \text{LOS} \\ \text{Adjustment} \end{array} \right) + \frac{\text{Outlier Payment}}{\left(\begin{array}{c} \text{Labor} \\ \text{Ratio} \end{array} \times \begin{array}{c} \text{Wage} \\ \text{Index} \end{array} \right) + \begin{array}{c} \text{Nonlabor} \\ \text{Ratio} \end{array}} + \begin{array}{c} \text{New} \\ \text{Technology} \\ \text{Payment} \end{array} + \begin{array}{c} \text{Blood Clotting} \\ \text{Factor Payment} \end{array}$$

(where applicable)   (where applicable)   (where applicable)

* CMG (Case-Mix Group): Includes diagnosis requiring rehabilitation, functional status, cognitive status, age, and comorbidities
** ALOS = Average Length of Stay for CMG
Note: The payment diagrams are adapted from the MedPAC Payment Basics series, October 2011

Hospital Outpatient and Community Mental Health Centers (CMHCs): Stripped Payment

Stripped Payment Formula:

$$\left(\begin{array}{c} \text{Conversion} \\ \text{Factor} \end{array} \times \begin{array}{c} \text{APC} \\ \text{Weight*} \end{array} \times \text{Units} \right)^{\dagger} + \frac{\text{Outlier Payment}}{\left(\begin{array}{c} \text{Labor} \\ \text{Ratio} \end{array} \times \begin{array}{c} \text{Wage} \\ \text{Index} \end{array} \right) + \begin{array}{c} \text{Nonlabor} \\ \text{Ratio} \end{array}}$$

(where applicable)

* APC (Ambulatory Payment Classification): Measures resource requirements of services
** SCH = Sole Community Hospital
*** Hold Harmless: Additional payments to hospitals (i.e. cancer, children's, non-SCH rural with <100 beds) that experience losses under OPPS system compared to cost-based system
† This amount is adjusted for any modifiers such as reduced or discontinued procedures
Note: Outpatient hospital claims can include services paid under the clinical lab, ambulance, physician, DME/POS/PEN, and Part B drugs fee schedules as well. Payments for those services are calculated according to the applicable payment formula.
Note: The payment diagrams are adapted from the MedPAC Payment Basics series, October 2011

Comprehensive Outpatient Rehabilitation Facilities (CORFs) and Outpatient Rehabilitation Facilities (ORFs): Stripped Payment
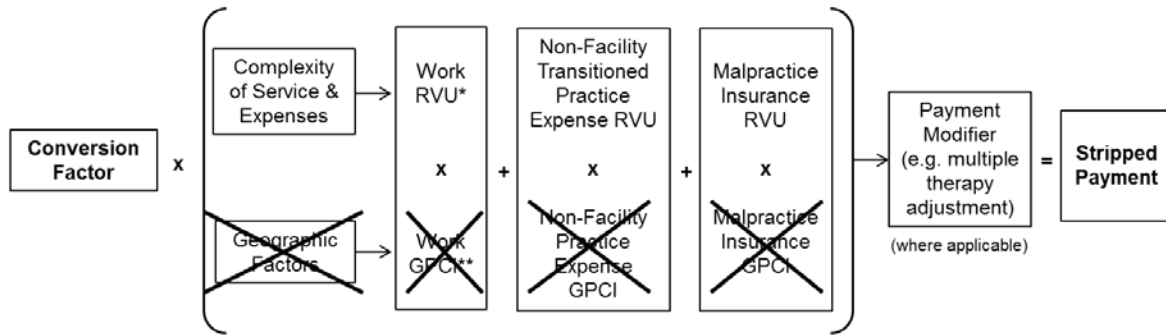
Stripped Payment Formula:

$$\left[\text{Conversion Factor} \times \left(\text{Work RVU*} + \text{Non-Facility Transitioned Practice Expense RVU} + \text{Malpractice Insurance RVU} \right) \right]^{***} \times \text{Units}$$

* RVU (Relative Value Units): Account for the relative costliness of the inputs used to provide services: clinician's work, practice expenses, and professional liability insurance (PLI) expenses
** GPCI = Geographic Practice Cost Index
*** Subject to a payment modifier (e.g. multiple therapy adjustment) where applicable
Note: The payment diagrams are adapted from the MedPAC Payment Basics series, October 2011

PPS SNF Claims: Standardized Payment
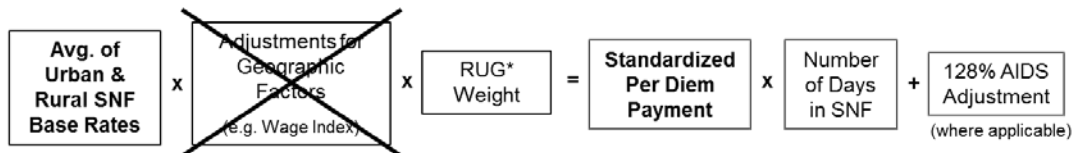
Standardized Payment Formula:

$$\text{Avg. of Urban and Rural Rates} \times \text{RUG Weight*} \times \text{Days in SNF} + \text{AIDS Adjustment (where applicable)}$$

* RUG (Resource Utilization Group): Includes therapy and service use, presence of certain medical conditions, and activity of daily living score
Note: The payment diagrams are adapted from the MedPAC Payment Basics series, October 2011.
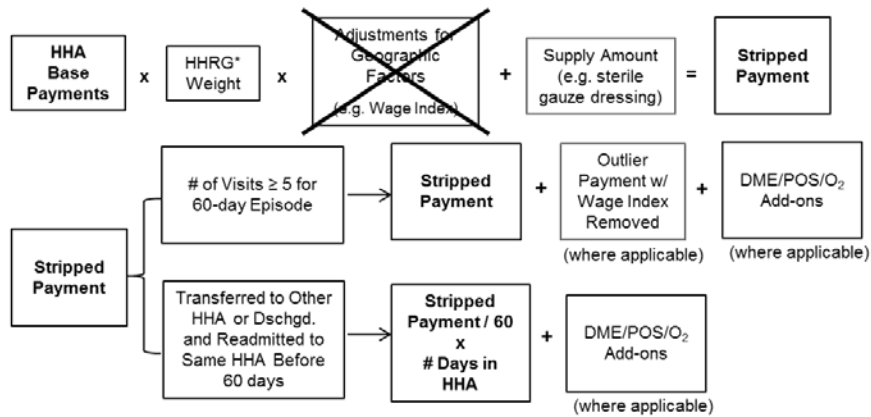
CAH Swing-Bed SNF Claims: Standardized Payment

Standardized Payment Formula†:

$$\frac{\text{Actual Payment} + \text{Co-Insurance}}{\left(\frac{\text{SNF Labor}}{\text{Ratio}} \times \frac{\text{Wage}}{\text{Index}}\right) + \left(1 - \frac{\text{SNF Labor}}{\text{Ratio}}\right)}$$

† CAH-Swing Bed SNF Claims are not given a RUG weight
Note: The payment diagrams are adapted from the MedPAC Payment Basics series, October 2011.

Home Health Agency (HHA): Stripped Payment

Low Utilization Payment Adjustment (LUPA) HHA Claims:

If HHA Claim has 4 or less visits in entire 60-day episode, the standardized LUPA per visit payment rate is applied. Standardized LUPA payment rate is published each year in the HHA PPS Final Rule.

Stripped Payment Formula:

$$\begin{aligned}&\frac{\text{HHA Base}}{\text{Payment}} \times \frac{\text{HHRG}}{\text{Weight*}} + \frac{\text{Supply}}{\text{Amount}} + \frac{\text{Outlier Payment}}{\left(\frac{\text{Labor}}{\text{Ratio}} \times \frac{\text{Wage}}{\text{Index}}\right) + \frac{\text{Nonlabor}}{\text{Ratio}}} + \frac{\text{DME/POS/O}_2}{\text{Add-ons}}\\&\qquad\qquad\qquad\qquad\qquad\qquad\text{(where applicable)}\qquad\quad\text{(where applicable)}\end{aligned}$$
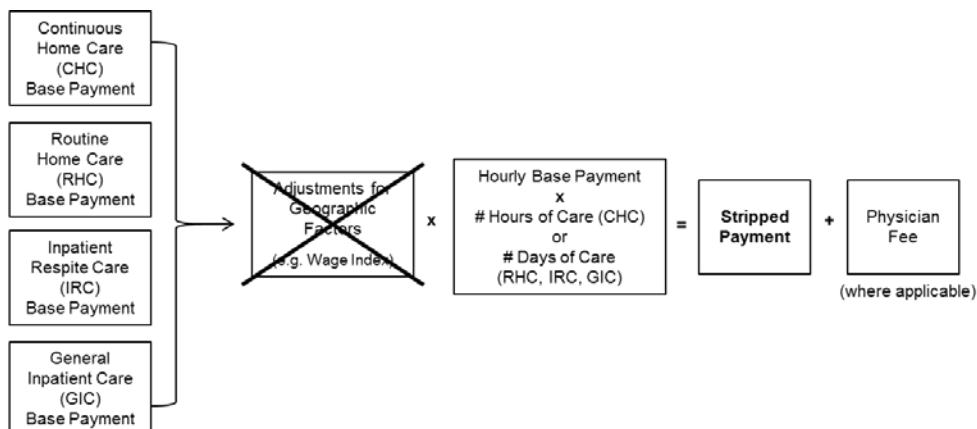
* HHRG (Home Health Resource Group): Comprised of clinical, functional, and service utilization scores based on patient characteristics.
Note: HHA claims can include DME/Prosthetics/O$_2$ as well. Payment for those claim lines are calculated according to the DME/POS payment formula.
Note: The payment diagrams are adapted from the MedPAC Payment Basics series, October 2011.

Hospice: Stripped Payment

Note: The payment diagrams are adapted from the MedPAC Payment Basics series, October 2011

Durable Medical Equipment (DME)/Prosthetics, Orthotics, and Surgical Supplies (POS)/Parenteral and Enteral Nutrition (PEN) Claims: Standardized Payment

DME/POS Claims:
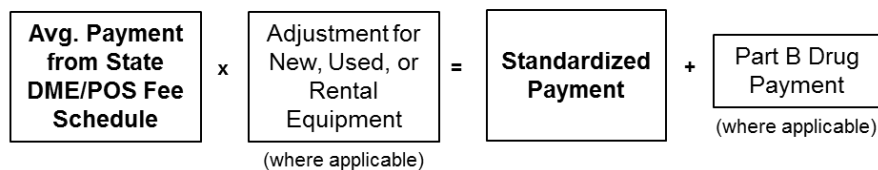
DME/POS Standardized Payment Formula:

PEN Claims:

The PEN fee schedule is a national fee schedule (i.e. there is no variation from state to state). Thus, all PEN claims were assigned the PEN fee schedule amount.

Note: Where applicable, Part B Drugs associated with DME claims were assigned the DME infusion limit amount from the Part B Drugs fee schedule.

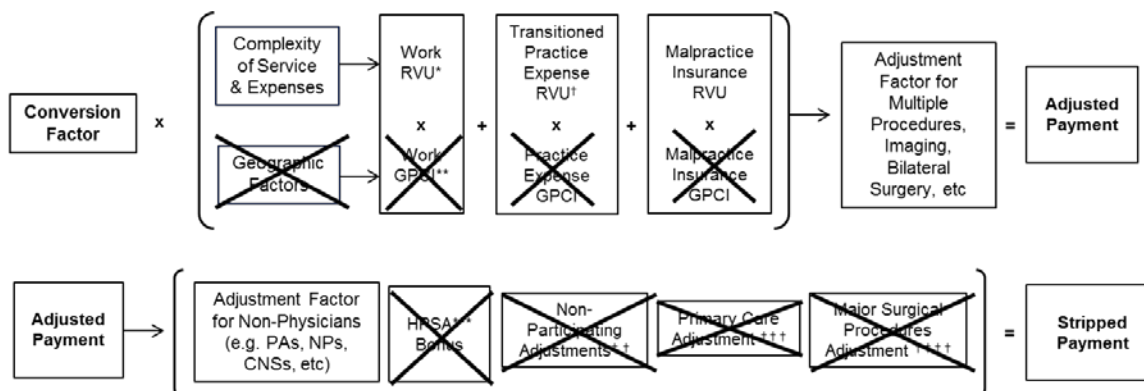## Ambulatory Surgical Center (ASC): Stripped Payment
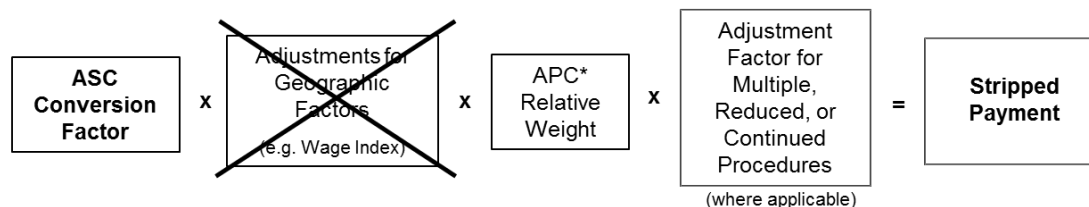
Stripped Payment Formula:

$$\left(\begin{array}{c} \text{ASC Conversion} \\ \text{Factor} \end{array} \times \begin{array}{c} \text{APC Relative} \\ \text{Weight*} \end{array} \right)^{\dagger} \times \begin{array}{c} \text{Unit} \\ \text{Count} \end{array} \times \begin{array}{c} \text{Adjustment Factor for Multiple,} \\ \text{Reduced, or Continued Procedures} \end{array}$$
(where applicable)

* APC = Ambulatory Payment Classification
† The amount equal to (ASC Conversion Factor x APC Relative Weight) is given on the ASC fee schedule.
Note: The payment diagrams are adapted from the MedPAC Payment Basics series, October 2011

Physician Services: Stripped Payment

Stripped Payment Formula:

$$\left[\begin{array}{c} \text{Conversion} \\ \text{Factor} \end{array} \times \left(\begin{array}{c} \text{Work} \\ \text{RVU*} \end{array} + \begin{array}{c} \text{Transitioned} \\ \text{Practice} \\ \text{Expense RVU}^{\dagger} \end{array} + \begin{array}{c} \text{Malpractice} \\ \text{Insurance} \\ \text{RVU} \end{array} \right) \right]^{\ddagger} \times \text{Units}$$

* RVU (Relative Value Units): Account for the relative costliness of the inputs used to provide services: clinician's work, practice expenses, and professional liability insurance (PLI) expenses
** GPCI = Geographic Practice Cost Index
*** HPSA = Health Professional Shortage Area
† The physician fee schedule lists separate PE RVUs for facility and non-facility settings.
†† Adjustment for physicians who are not in Medicare's participating physician and supplier program
††† Primary care incentive payment for primary care services furnished by eligible practitioner.
†††† Major surgical procedures incentive payment for qualifying services when furnished by eligible surgeon in an HPSA.
‡ Subject to: (1) Adjustment Factor for Non-Physicians, (2) HPSA Bonus, (3) Non-participating Adjustments, (4) Primary Care Adjustment, (5) Major Surgical Procedures Adjustment
Note: The payment diagrams are adapted from the MedPAC Payment Basics series, October 2011

Clinical Labs: Standardized Payment

Avg. Payment from Clinical Diagnostic Laboratory Fee Schedule	=	Standardized Payment

Standardized Payment Formula:

Avg. Payment from Clinical Diagnostic Laboratory Fee Schedule **x** Unit Count

Labs Under the Automated Multi-Channel Chemistry Code (AMCC) Payment Algorithm Standardized Payment Formula:

Actual Payment **+** Coinsurance **+** Deductible

Part B Drugs: Standardized Payment

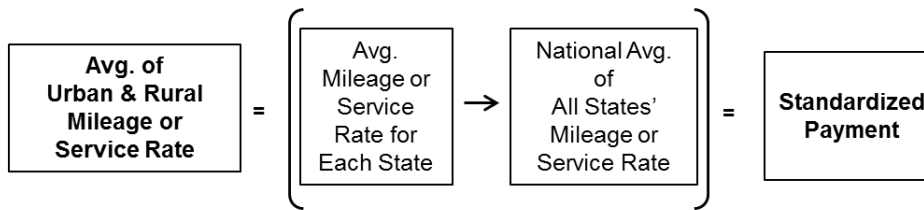| Part B Drugs National Fee Schedule Amount	=	Standardized Payment

Part B Drug Claims:

The Part B Drug fee schedule is a national fee schedule (i.e. there is no variation from state to state).
Thus, all Part B Drug claims were assigned the national fee schedule amount.

Standardized Payment Formula:

Part B Drugs National Fee Schedule Amount **x** Unit Count

Note: Where applicable, Part B Drugs associated with DME claims were assigned the DME infusion limit amount from the Part B Drugs fee schedule.

Ambulance: Standardized Payment

Avg. of Urban & Rural Mileage or Service Rate	=	Avg. Mileage or Service Rate for Each State	→	National Avg. of All States' Mileage or Service Rate	=	Standardized Payment

Standardized Payment Formula:

Step 1:

$$\frac{\text{Urban + Rural Mileage or Service Rates}}{2} = \text{Avg. Mileage or Service Rate for Each State}$$

Step 2:

$$\frac{\sum \text{Avg. Mileage or Service Rate for Each State}}{\text{\# of States}} = \text{National Avg. Mileage or Service Rate}$$

Step 3:

$$\text{National Average Mileage or Service Rate} \quad \times \quad \text{Unit Count}$$

Rural Health Clinics (RHCs) and Federally Qualified Health Clinics (FQHCs): Standardized Payment

RHCs:

Each year Congress determines a RHC per visit payment limit. We remove the portion of the payment likely attributable to wages using the SNF state rural wage index.

Stripped Payment Formula:

$$\frac{\text{Actual Payment + Coinsurance + Deductible}}{\left(\text{Outpatient Labor Ratio} \times \text{Wage Index}\right) + \left(1 - \text{Outpatient Labor Ratio}\right)}$$

FQHCs:

FQHC payments are an all-inclusive per visit amount based on reasonable costs. Given the resources necessary to determine whether the FQHC is located in a rural or urban area, we did not adjust for wages in the current data.

Standardized Payment Formula:

$$\text{Actual Payment + Coinsurance}$$

Note: A FQHC PPS is schedule to be implemented in October 2014.

Renal Dialysis Facilities (RDFs): Stripped Payment

Dialysis Payments:

Though a Renal Dialysis PPS was implemented in 2011, we do not have all partient-specific variables in our data to create a stripped payment based on that algorithm. Thus, we calculate all renal dialysis payments as the total amount paid to the provider with the portion of payment attributable to the wage index removed. We also add an outlier payment, where applicable, for payments in 2011 and 2012.

Stripped Payment Formula:

$$\frac{\text{Actual Payment} + \text{Coinsurance} + \text{Deductible}}{\left(\frac{\text{Labor}}{\text{Ratio}} \times \frac{\text{Wage}}{\text{Index}}\right) + \frac{\text{Nonlabor}}{\text{Ratio}}} + \frac{\text{Outlier Payment}}{\left(\frac{\text{Labor}}{\text{Ratio}} \times \frac{\text{Wage}}{\text{Index}}\right) + \frac{\text{Nonlabor}}{\text{Ratio}}}$$

(where applicable)

Note: For 2010, payments for clinical labs and Part B drugs associated with dialysis treatments were calculated according to their payment formulas.

Appendix D. Technical Expert Panel Member Roster

Name	Title	Organization	Area of Expertise
AJ Yates, MD	Associate Professor of Medicine	University of Pittsburgh School of Medicine: Department of Orthopedic Surgery	Topic Knowledge
Amita Rastogi, MD, MHA, CHE, MS	Chief Medical Officer	Health Care Incentives Improvement Institute	Purchaser Perspective, Topic Knowledge, Performance Measurement
Blair Biase, MMSc, PA-C, MBA	Product Director	Global Knee Reconstruction, OrthoSensor, Inc.	Topic Knowledge
Brian McCardel, MD	Chief of Orthopedics	Sparrow Health System, Orthopedic Surgery Section	Topic Knowledge, Quality Improvement, Health Care Disparities
Cheryl Crumpton, MS, RN, CEN	Orthopedic/ Neurosurgery Service Line Coordinator	Cheyenne Regional Medical Center	Performance Measurement
Cheryl Fahlman, PhD, MBA, BSP	Principal Research Scientist	Premier Healthcare Solutions, Inc.	Topic Knowledge, Purchaser Perspective, Performance Measurement, Quality Improvement
Cynthia Jacelon, PhD, RN, CRRN, FAAN	Associate Professor	University of Massachusetts School of Nursing	Topic Knowledge
Kate Chenok (May 2014– July 2014)	Director of New Initiatives	Pacific Business Group on Health	Topic Knowledge, Performance Measurement, Quality Improvement
David Hopkins, PhD, MS (July 2014 – December 2014)	Senior Advisor	Pacific Business Group on Health	Topic Knowledge, Performance Measurement, Quality Improvement, and Purchaser Perspective
Derek Nordman, MPT, ATC	Vice President, Specialty Operations	Gentiva Health Services	Topic Knowledge and Quality Improvement
John Birkmeyer, MD	George D. Zuidema Professor and Chair of Health Services Research; Attending General Surgeon	University of Michigan: Department of Surgery	Topic Knowledge, Performance Measurement, Quality Improvement and Health Care Disparities
Jonathan Schaffer, MD, MBA	Managing Director, Information Technology Division	The Cleveland Clinic Foundation: Department of Orthopedic Surgery	Topic Knowledge, Performance Measurement, Quality Improvement, and Coding and Informatics

Kathleen Willhite, MS	Director of Payor Contracting	BayCare Health Systems	Topic Knowledge, Performance Perspective, Quality Improvement
Vinod Dasa, MD	Associate Professor, Department of Orthopedic Surgery	Louisiana State University Health Sciences Center, Oschsner Kenner Medical Center	Topic Knowledge and Health Care Disparities
Vivian Ho, PhD	James A. Baker III Institute Chair in Health Economics	Rice University: Department of Economics	Topic Knowledge, Performance Measurement, and Quality Improvement
Patient, Anonymous			Topic Knowledge