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Evaluation of a Centers of Excellence Program for Knee and Hip Replacement

Ateev Mehrotra, MD^{1,2}, Elizabeth M. Sloss, PhD¹, Peter S. Hussey, PhD¹, John L. Adams, PhD¹, Susan Lovejoy, MS¹, and Nelson F. SooHoo, MD³

¹ RAND Corporation

² University of Pittsburgh School of Medicine, Department of Medicine

³ David Geffen School of Medicine at UCLA, Department of Orthopaedic Surgery

Abstract

Background—Medicare and private plans are encouraging individuals to seek care at hospitals which are designated as centers of excellence. Few evaluations of such programs have been conducted. The Blue Cross Blue Shield Association, whose member plans insure one in three Americans, has established an initiative to designate hospitals as centers of excellence for knee and hip replacement.

Objective—Comparison of outcomes and costs associated with knee and hip replacement at designated hospitals **and** other hospitals.

Research design—Retrospective claims analysis of approximately 54 million enrollees.

Study population—Individuals with Blue Cross Blue Shield insurance who underwent a primary knee or hip replacement in 2007–2009.

Outcomes—Primary outcomes were any complication within 30 days of discharge and costs within 90 days following the procedure.

Results—80,931 patients had a knee replacement and 39,532 patients had a hip replacement of which 52.2% and 56.5%, respectively, were performed at a designated hospital. Designated hospitals had a larger number of beds and were more likely to be an academic center. Patients with a knee replacement at designated hospitals did not have a statistically significantly lower overall complication rate with an odds ratio of 0.90 ($p=0.08$). Patients with a hip replacement treated at designated hospitals had a statistically significantly lower risk of complications with an odds ratio of 0.80 ($p=0.002$). There was no significant difference in 90-day costs for either procedure.

Conclusions—Hospitals designated as joint replacement centers of excellence had lower rates of complications for hip replacement, but there was no statistically significant difference for knee replacement. It is important to validate the criteria used to designate centers of excellence.

Corresponding author and address for reprints: Ateev Mehrotra, 4570 Fifth Avenue, Suite 600, Pittsburgh, PA, 15213. 412-683-2300x4894, 412-802-4972 (fax), mehrotra@rand.org.

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Keywords

Orthopedic surgery; centers of excellence; outcomes; cost analysis; knee arthroplasty; knee replacement; hip arthroplasty; hip replacement

Background

Driven by rising health care costs and variation in the quality of medical care observed across providers and regions,(1–3) private and government payers are searching for approaches to improve value, defined as health outcomes per dollar spent.(4) One approach is to encourage patients to seek care at centers of excellence(5) - hospitals that are expected to provide higher-value care. The Centers of Medicare and Medicaid Services (CMS) recently enacted a policy to only cover bariatric surgery cases performed at a center of excellence.(6) Cigna, Aetna, and other health plans as well as professional organizations are also designating centers of excellence for a broad range of conditions and procedures.(7–9) The goal of such programs is to drive quality improvement by encouraging patients to obtain their care at these centers, thereby yielding better overall outcomes, lower costs, and thus greater value.

A variety of methods are used to designate centers of excellence. One commonly used criterion is volume of cases, because a large number of studies have demonstrated better outcomes in higher-volume hospitals.(2, 10) However, volume explains only some of the variation in outcomes.(11) Recent centers of excellence programs require that hospitals meet a broader set of evidence-based criteria,(12) including volume, training of providers,(13) availability of computerized physician order entry,(14, 15) performance on process quality metrics,(16) discharge planning,(17) and nursing-patient ratios.(18, 19) While evidence exists to support each of the individual criteria used to select centers of excellence, there remains a need to systematically evaluate whether centers of excellence have better outcomes and costs.(20) Recent evaluations of CMS's bariatric surgery centers of excellence program found no clinically significant differences in outcomes or costs.(21, 22)

The purpose of this study is to evaluate a centers of excellence program established in 2008 by the Blue Cross and Blue Shield Association for knee and hip replacement. The Blue Cross Blue Shield Association (BCBSA) is a national federation of 39 independent Blue Cross and Blue Shield companies that collectively provide healthcare coverage for nearly 100 million – one in three – Americans. Knee and hip replacement are an important focus for centers of excellence programs because they are elective inpatient procedures that are performed frequently and outcomes vary across hospitals.(23–25) To be designated as a center of excellence in the BCBSA program, hospitals complete an application form that includes selection criteria such as surgeon and hospital volume, use of multidisciplinary care pathways and teams, electronic medical records and patient data management and tracking, and length of stay (Table 1). In this study, we compare the outcomes and costs associated with knee and hip replacement in 43 states between 647 hospitals designated as centers of excellence and 2,149 other hospitals.

Methods

Data Sources

We analyzed all inpatient and outpatient health insurance claims for the years 2007–2009 of approximately 54 million members from 19 Blue Cross and Blue Shield Plans. We matched hospitals with at least one knee or hip replacement in the claims to the 2008 American Hospital Association (AHA) database which contains data on hospital characteristics. Based

on Medicare hospital identifiers in the AHA data, we extracted 2008 hospital-level data on patient experience (Hospital Consumer Assessment of Healthcare Providers and Systems [HCAHPS])(26) and surgical quality measures (Surgical Care Improvement Project [SCIP]) (27) from the Medicare Hospital Compare database.

Patient sample

We identified all patients in the claims database with an inpatient hospitalization for a primary total knee or hip replacement during a 27-month period between July 1, 2007 and September 30, 2009. This 27-month study period allows for a 180-day “clean period” before each initial procedure and a 90-day follow-up period after each procedure. We used ICD-9-CM procedure codes 81.54 to identify primary knee replacement and 81.51 for primary hip replacement. **We excluded the** following patients: age <18 or ≥65 years; living outside the United States; not continuously enrolled in the health plan for 6 months before and 3 months after the procedure (except those who died); patients for whom Blue Cross Blue Shield was not the primary insurer; revision knee or hip replacement (respectively); bilateral or multiple procedures; hip hemiarthroplasty (hip analysis); another knee or hip replacement in the 6 months before procedure (respectively); pathologic fracture, bone cancer, metastatic cancer, joint infection, knee fracture (knee analysis); pelvic or femoral fracture (hip analysis); and those who left the hospital against medical advice. The justification for these criteria (including prior studies who have used the same criteria), number of cases excluded, and diagnosis codes used to identify patients are provided in the Appendix.

Hospital Sample and Analysis of Hospital Characteristics

We identified all hospitals in the AHA database with at least one knee or hip replacement patient in our sample. Among these, we identified all hospitals designated as a BCBSA center of excellence for knee and hip replacement surgery (designation process was started in 2009 and completed in 2010). All other hospitals were classified as “other hospitals.” We excluded *all* hospitals in 7 states (Alaska, Delaware, Mississippi, Oklahoma, Vermont, West Virginia, and Wyoming), in which none of the hospitals applied to the designation program. Twenty-two hospitals that applied to the program met the criteria in Table 1 to be designated, but did not meet certain business requirements (for example, provider network participation). In our analyses, we classified these hospitals as designated, but they are not listed on the BCBSA website.

Outcome Measures

We used two main clinical outcome measures: a composite complications rate and an all-cause readmission rate. These measures were developed recently for the CMS by researchers at Yale University. Details and specifications are published elsewhere.(28) These measures were validated by comparing the complication rate as measured by claims vs. medical charts for 644 patients. The overall agreement was 93%. In addition to the composite complications rate, we also calculated separate rates of nine individual complications that make up the composite (acute myocardial infarction, pneumonia, sepsis/septicemia, pulmonary embolism, wound infection, surgical site bleeding, death, periprosthetic joint infection, or mechanical complication).

We identified complications in the initial hospitalization or a readmission to *any hospital* using specific diagnosis and procedure codes within a specified time period, which varies by complication (detailed in Appendix). Consistent with prior work,(29, 30) we restricted complications to those associated with a hospitalization, because the expert panel who developed the measures felt they represent more serious complications and therefore less likely to be biased by differences in coding. A patient rehospitalized could have been at home or at a rehabilitation facility. Mortality was identified based on the discharge status of

the initial admission and of other admissions occurring within 30 days of discharge, because information on mortality after discharge was not available from another data source. This differs from the CMS measure which specifies a 30-day mortality rate following the admission date.(31) The readmission rate includes all hospitalizations for any reason within 30 days of the discharge date for the initial stay. However, planned readmissions for another knee or hip replacement (contralateral procedure), and admissions or transfers to an acute rehabilitation hospital or skilled nursing facility were excluded from the readmission rate. Transfer to another acute care hospital was considered a “readmission” (Appendix includes detailed specifications).

Our other outcome was 90-day *total* costs for knee and hip replacement. This 90-day cost measure included the costs for *every service* (e.g. rehabilitation services, follow-up hospitalizations, home health) from the initial procedure admission date to 90 days after that date. Pharmacy costs were not included because pharmacy claims data were not available for all patients. The 90-day period, used in prior joint replacement studies,(32) has face validity because the majority of costs in this period are related to the joint replacement and follow-up care. The costs for each service used was the “allowed amount”, which is the sum of health plan reimbursement and any patient copayment or deductible. Explicit payments for graduate or indirect medical education are not made by the health plans. To address the concern that costs unrelated to the joint replacement might bias any observed differences, sensitivity analyses on the cost measure were conducted using the publicly-available Prometheus Payment algorithm.(33–36) Based on diagnosis and procedure codes in claims data, this algorithm classifies claims as “related to” and “not related to” the joint replacement. Details on the Prometheus algorithm are available in the Appendix.

Covariates

We adjusted for differences in patient characteristics that might impact the comparison of the two sets of hospitals using risk adjustment models based on the specifications for the CMS complication measures for knee and hip replacement.(28) Patient covariates included in all models were age, gender, and 26 comorbidities (listed in the Appendix). We identified patients as having a comorbidity based on diagnoses coded on inpatient and outpatient hospital and physician claims during the 6 months prior to the knee or hip replacement. We chose a 6-month period, instead of the 12-month period specified in the Yale measures, because we were limited by the time period of the claims data available. The comorbidities were classified using Condition Categories from the CMS Hierarchical Condition Category Model (see the Appendix).

Statistical Analysis

We conducted all statistical analyses using SAS Enterprise Guide Version 4.2 (SAS Institute, Cary, NC, 2010). For all descriptive analyses, we tested for differences between designated hospitals and other hospitals using chi-square tests for categorical data and *t* tests for continuous data.

To examine the association between complication or readmission rates and designated hospital status, we used multivariate logistic regression models. The unit of the analysis was a hospitalization for knee or hip replacement. The main predictor variable was whether the hospital was designated by BCBSA as a center of excellence. Each model adjusts for the patient covariates described above. For models that did not converge, an abbreviated list of comorbidities was substituted for the list of 26 comorbidities in the model (listed in the Appendix). Clustering of cases within hospitals was addressed using the Taylor series linearization method. Because of the low complication and readmission rates, use of hospital random effects in those models was not feasible.

To examine the relationship between the costs and designated hospital status, we used multivariate models with a gamma distribution and log link. A gamma model was used because costs were not normally distributed.(37) The outcome variable for the model was the 90- day treatment cost, which is inclusive of costs during the initial hospitalization and the subsequent 90 days post-procedure. The main predictor variable was whether the hospital was a designated hospital. Each model also includes the patient covariates described above (i.e., age, gender, and 26 comorbidities). To address clustering of cases we used a hierarchical model with a random effect for each hospital.(11, 38) To account for regional variation in factors associated with costs, we included a fixed effect for each state. Coefficients in log link models can be interpreted as the percentage difference in costs associated with a unit change in the independent variable. To assess how well covariates in the model control for differences in patient characteristics between the two sets of hospitals, we conducted sensitivity analyses in which we added 6-month baseline costs as an independent variable to the model. Because high and low cost outliers could represent cases with erroneous data, we conducted sensitivity analyses eliminating outliers. Details on these sensitivity analyses are available in the Appendix. Approval for this study was obtained from the RAND Human Subjects Protection Committee.

Results

Hospital Characteristics

Of the 2,796 hospitals with a knee or hip replacement, 647 (23%) were designated by BCBSA as centers of excellence for knee and hip replacement. Compared to other hospitals, these designated hospitals were more likely to be larger, academic, urban, located in the Midwest and Northeast, and had more surgical cases per year (Table 2). Compared to other hospitals, designated hospitals generally performed better on the Surgical Care Improvement Project measures (Table 2). For example, patients at designated hospitals were more likely to receive deep vein thrombosis prophylaxis (average percentage at designated hospitals and other hospitals, 94.0% and 90.4%, $p<0.01$). In contrast, designated hospitals had generally the same or lower results on patient experience measures. For example, the fraction of patients at designated hospitals who would definitely recommend the hospital was lower than at the other hospitals (24.3% and 26.4%, $p<0.01$).

Patient Characteristics

Of 80,931 patients with a knee replacement, 42,255 (52.2%) had their surgery at a designated hospital. Of the 39,532 patients with a hip replacement, 22,329 (56.5%) had their surgery at a designated hospital. Comparing knee and hip replacement patients in designated hospitals with those in other hospitals, a slightly lower percentage had hypertension and a slightly higher percentage had vascular disease coded on claims in the 6 months preceding the surgery (Table 3). Patients at designated hospitals were slightly younger (e.g., percentage of patient with hip replacement 18–44, 9.5% designated hospitals vs. 8.7% at other hospitals).

Complication and Readmission Rates

After a total knee replacement, patients at designated hospitals had a lower aggregate complication rate compared to those treated at other hospitals (unadjusted: 2.17% vs. 2.45%). After controlling for patient characteristics, the chance of having a complication was not significantly lower at a designated hospital (OR 0.90, $p=0.08$) (Table 4 and Figure 1). For specific complications following total knee replacement, there was a lower rate of surgical site bleeding (OR 0.41, $p<0.001$). There were no significant differences between designated hospitals and other hospitals in the other individual complications.

After a hip replacement, fewer patients had complications at designated hospitals than at other hospitals (unadjusted rates: 2.46% vs. 3.12%). After controlling for patient characteristics, the chance of having a complication was significantly lower at a designated hospital (OR 0.80, $p=0.002$) (Table 4 and Figure 1). For specific complications following total hip replacement, patients at designated hospitals experienced significantly lower rates of sepsis/septicemia (OR 0.50, $p=0.003$), and wound infection (OR 0.54, $p=0.001$). At designated hospitals, there was a significantly lower 30-day readmission rate than at other hospitals (OR 0.82, $p=0.003$).

90-day Costs

Patients at designated hospitals and other hospitals had similar mean unadjusted 90-day costs for knee replacement (\$28,456 and \$27,845, respectively) and hip replacement (\$27,884 and \$28,377, respectively). After controlling for differences in patient characteristics, mean 90-day costs did not differ significantly between designated hospitals and other hospitals for knee replacement (percentage difference 1.1%, $p=0.37$) or for hip replacement (percentage difference -0.5% , $p=0.71$). In sensitivity analyses, there were no notable differences in the results (Appendix).

Discussion

Centers of excellence programs are being developed by CMS and individual health plans to improve the value of care received in the health care system. In one of the first evaluations of such a program, we found that there was a 10–20% reduction in overall complication rates following knee and hip replacement at the hospitals designated as centers of excellence with no difference in costs compared to other hospitals.(39) The difference in complication rates for knee replacement was not statistically significant.

The findings of this study confirm the potential of designating centers of excellence, but suggest that further validation of the selection criteria is warranted. Specifically, our findings for hip replacement support the premise underlying centers of excellence programs: using structural characteristics, it is possible to identify a set of hospitals that on average provide higher quality care. This is in contrast to a prior evaluation of bariatric surgery centers of excellence, which did not observe differences in outcomes.(21)

Our results highlight some of the difficulties of developing valid and clinically significant criteria for centers of excellence. For joint replacement, the observed complication rates were low and therefore the differences in complication rates were low. For example, the difference in hip replacement complication rate between designated hospitals and other hospitals was approximately half a percentage point. Encouraging patients to switch to designated hospitals may be viewed as premature until the selection criteria can identify hospitals with clearly superior outcomes.

Hospitals were designated as centers of excellence based on a long list of criteria (e.g., volume, nursing-patient ratios of hospitals). Given the prior literature on the association between outcomes and these criteria, the relatively modest differences we observed are surprising. Recognizing that a panel of experts helped develop the designation criteria,(40) it is possible that the associations between the designation criteria and outcomes in previous studies are weak or spurious. For example, one of the designation criteria is higher performance on the publicly-reported CMS Surgical Care Improvement Project measures, yet recent work showed little relationship between performance on these measures and outcomes.(41) One could attempt to refine the selection criteria to maximize the differences in outcomes between designated and other hospitals. Another option is to designate hospitals based on their complication rate. For example, hospitals with a statistically significant lower

complication rate would be designated as a center of excellence. Unfortunately, given the volume of cases and low complication rate we observe, few, if any, hospitals would meet this criteria for hip or knee replacement in our data. We must acknowledge that it may be impossible to identify a set of criteria that identifies hospitals that provide clearly superior care.

One of our hypotheses was that the higher-quality care at designated hospitals would result in fewer complications and, therefore, lower costs. Designated hospitals did exhibit lower complication rates for hip replacement patients, but we did not observe a difference in costs. This finding is consistent with prior studies that have found no association between outcomes and costs.(42) One possible explanation is that complications make only a minor contribution to costs. Because complications were rare events in our data, even if complications increase the costs for an individual patient significantly, the added costs have a small effect on *average* costs. Therefore, cost differences between hospitals are likely driven by other factors such as geographic variation in utilization(43) or variation in reimbursement(44). In our analyses, we look at costs from the payer's perspective, which encompasses the provider reimbursement and patient co-payments. Therefore, if designated hospitals, which are often academic medical centers, negotiate higher reimbursement, this would mask any cost difference due to a lower complication rate. Future work could use standardized costs for each service to control for these reimbursement differences.

This study is limited by the data available in administrative claims and how we measure costs. Specifically, mortality rates are based on the discharge status of the initial admission and of other admissions occurring within 30 days of discharge. This may result in the overall mortality rate being underestimated. In addition, we did not examine other complications such as deep venous thrombosis. These were not included in the CMS complication measure because this complication is frequently managed as an outpatient and experts felt it may be biased by differences in coding. We measure costs from the payer's perspective and do not address the hospital's costs in providing care or quality improvement initiatives. Information is also not available on variations in negotiated implant costs among providers.

We do not assess the potential impact of this program on many key outcomes including access to care (e.g., fraction of patients who have access to a designated hospital), disparities (e.g., fraction of low-income patients who choose a designated hospital), or functional outcomes (e.g. do patients at designated hospitals have greater improvements in their joint pain).(12) The impact on functional outcomes is important because that is typically why patients have a hip or knee replacement. Given only three years of data were available, we were also unable to assess another possible outcome - mean time to reoperation. Further, we cannot assess whether there are differences between the two sets of hospitals in whether the surgeries performed are appropriate.(45)

To the degree that the percentage of patients with more severe or complex illnesses differs between the two sets of hospitals and that our inclusions, exclusions, and risk-adjustment do not address these differences, our results could be biased. One limitation of claims analyses is that we cannot measure socioeconomic status (e.g., income) or important clinical factors (e.g., obesity) that might be unmeasured confounders. However, the differences in the patient variables we can capture (e.g. age, co-morbidities) between the two sets of hospitals is relatively small. Claims data are subject to variation in the accuracy and specificity of reporting of complications, which may differ between designated and other hospitals. Some hospitals that would qualify for the designated hospital program may not have submitted an application to become a designated hospital under this program. However, the designation program conducted a follow-up with hospitals that did not respond to the initial call, so there should be few "eligible but not designated" hospitals. While we analyzed the care of a large

and diverse population, our focus is only on patients under 65 years of age with commercial insurance and does not generalize to older patients with Medicare or those with Medicaid.

There are a growing number of health plans and other payers developing centers of excellence, yet there have been few evaluations of the impact of these programs. In our evaluation of one program, we found lower complication rates in designated hospitals but similar costs between the two sets of hospitals. Such evaluations can help highlight the strengths and weaknesses of the center of excellence approach compared to other approaches to improve health care value, including public reporting of risk-adjusted outcomes(46) and costs(47, 48) and quality improvement initiatives that strive to improve care at all hospitals.(49, 50)

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Technical Appendix

Mehrotra et al., “Evaluation of a Center of Excellence Program for Knee and Hip Replacement”

The purpose of this technical appendix is to provide detail about the methods and results that could not be included in the manuscript. The appendix includes the following tables:

Table 1

Full list of criteria used to determine whether a hospital can achieve designated status for knee and hip replacement^a

Required Criteria	
Comprehensive Inpatient Facility (ED, ICU and other specialized services)	Required
Accreditation (full accreditation by a CMS-deemed national accreditation organization)	Required
Duration of surgery service (>12 months)	Required
Surgeons must be Board Certified	Required
Volume (100 knee and hip replacement surgeries annually with 25 TKR and 25 THR replacements; Average and median surgeon volume 50 primary or revision TKR or THR)	Required
Facility is provider in local health plan's network	Required
All identified surgeons have active provider contracts with health plan	Required

Other Criteria (need 60 out of 100 points)	
Structure – Total Possible 63 points	Points
Participation in IHI (formal commitment to ≥ 6 improvement maps)	2
Reports to Leapfrog or comparable local initiative	1
Accepts AAMC principles for conduct and reporting of clinical trials	1
Health Information Technology (certified EMR, e-prescribing, medication reconciliation)	3

Other Criteria (need 60 out of 100 points)	
Structure – Total Possible 63 points	Points
Nursing Excellence (Magnet designation or reports to NDNQI)	1
Participates in HCAHPS survey and makes data available on Hospital Compare	1
National Quality Improvement Initiatives (Universal Protocol/WHO Safety Checklist)	1
Participates in SCIP (Points for performance and tracking and reporting results)	9
Disclosure Policies (e.g., conflict of interest, relationship to device manufacturers)	4
Pain Management (protocols based on national guidelines for peri-operative surgical patients)	4
Dedicated Unit (for orthopedic/spine surgery)	2
Multidisciplinary Clinical Pathways and Teams	20
Fellowship Training in Adult Reconstructive Orthopedics (50% of surgeons)	1
Continuous Quality Improvement (e.g., collection of data, development of improvement goals and demonstrated improvement, ongoing physician learning)	2
Data Management and Patient Tracking (Internal registry for treatment and outcomes, process to track complications and revisions, evaluates patient satisfaction)	9
Data Reporting to a national or international database (e.g., NSQIP)	2

Process – Possible 20 points	Points
Patient Selection Criteria (written criteria, depression and anxiety screening)	4
Preoperative Patient Education (classes, materials, protocol informing of risks)	5
Medical Management (utilize established guidelines, such as ADA Standards of Diabetes Care)	2
Thromboprophylaxis protocol (specific for knee/hip)	1
Anesthesia practices (evaluated for use of regional anesthesia, normothermia protocol)	1
Physical Therapy and Rehabilitation Services (protocols for assessment and treatment)	1
Functional Assessments (standardized indexes for pre- and post-op assessments)	3
Transitions of Care (case management, discharge planning, monitoring of transitions)	3

Outcomes and Volume—Total Possible 17 points	Points
Facility Volume for TKR and THR combined (250 surgeries during reported 12-month period)	3
Facility Volume for TKR and THR combined (500 surgeries during reported 12-month period)	2 (add'l)
Revisions (Performs 50 net revisions for TKR and THR)	2
Average length of stay (TKR 3.5, THR 4)	6
30-Day Readmission Rate for TKR and THR patients (10%)	4

Abbreviations: TKR – total knee replacement, THR – total hip replacement, ADA – American Diabetes Association, NSQIP – National Surgical Quality Improvement Program, NDNQI - National Database of Nursing Quality Indicators, WHO – World Health Association, CMS – Centers for Medicare and Medicaid Services, ICU – Intensive Care Unit, ED – Emergency Department, IHI – Institute for Healthcare Improvement, AAMC –Association of American Medical Colleges

^aTo be designated hospital for knee and hip replacement, hospitals must have met the required criteria and also achieve a score of at least 60 points out of 100 on the rest of the criteria. Hospitals are designated for both knee and hip replacement. The selection criteria shown in this table are specific to the 2009 cycle of designation.

Table 2**Knee Replacement: Patient Categories Excluded from Analytic Sample, Time Periods, and Rationale**

Exclusion Category	Time Period	Rationale
Enrollee's address out of country: Exclude other countries and US territories (GU-Guam, PR-Puerto Rico, and VI-Virgin Islands)	<ul style="list-style-type: none"> Initial stay¹ 	This requirement ensures all claims and costs are captured. Care outside of the US might be fundamentally different.
Address of the initial hospital is in a state in which the Plans did not participate in the program: Alaska (AK), Delaware (DE), Mississippi (MS), Oklahoma (OK), Vermont (VT), West Virginia (WV), and Wyoming (WY).	<ul style="list-style-type: none"> Initial stay 	Because no hospitals in these states applied for participation in the designated hospital program, all hospitals in these states were excluded.
Bilateral procedures: The CPT modifier code, 50, when used in conjunction with a knee replacement CPT code indicates that the bilateral procedures were performed during the same operative session.	<ul style="list-style-type: none"> Professional claim for initial stay 	These are excluded because the cost and outcomes of the procedure might differ substantially from unilateral Knee replacements.
Multiple procedures performed: The CPT modifier code, 51, indicates multiple procedures were performed at the same session by the same provider	<ul style="list-style-type: none"> Professional claim for initial stay 	These are excluded because the cost and outcomes of the procedure might differ substantially from single Knee replacements.
Repeat procedure: The CPT modifier codes, 76 (repeat procedure by same physician) and 77 (repeat procedure by another physician), indicate the procedure was repeated.	<ul style="list-style-type: none"> Professional claim for initial stay 	As with revision procedures, repeat procedures are much less common and more heterogeneous with regard to the indication and type of procedure, making adequate control in the analysis difficult.
Another primary or revision knee surgery in prior six months	<ul style="list-style-type: none"> 6 months before initial procedure date 	Patients with another primary or revision Knee surgery in prior six months would be likely to have different complication and readmission rates.
Revision knee replacement listed as a secondary procedure on stay file	<ul style="list-style-type: none"> Initial stay 	Patients with a revision Knee replacement listed as a secondary procedure would be likely to have different complication and readmission rates.
Patient <18 years of age at time of initial procedure	<ul style="list-style-type: none"> Initial stay 	Knee replacements in cases <18 years of age are rare and have different clinical indications.
Pathologic fracture, bone cancer, metastatic cancer, trauma patients who were diagnosed with knee fractures	<ul style="list-style-type: none"> 6 months before initial procedure date Initial stay 	Cases with these conditions were excluded to eliminate non-elective procedures. These are very different types of cases from a clinical perspective. These exclusions are consistent with prior literature. ²
Joint infection or mechanical complications	<ul style="list-style-type: none"> 6 months before initial procedure date 	Cases with these conditions were excluded to eliminate non-elective procedures. Clinically these are very different types of cases and these exclusions are consistent with prior literature. ³
Hospitalizations in which patient left against medical advice	<ul style="list-style-type: none"> Initial stay 	Although rare, the costs and outcomes of these

Exclusion Category	Time Period	Rationale
(discharge_status_code =07)		hospitalizations are likely very different.
Place of service not inpatient hospital	<ul style="list-style-type: none"> Initial stay 	These cases were excluded because acute care inpatient hospitals are the focus of this study.
Selected types of non-community hospitals	<ul style="list-style-type: none"> Initial stay 	Patients having the procedure in selected types of non-community hospitals were excluded.
Not continuously enrolled from 6 months before procedure to 3 months after: Patients who die within 3 months after the procedure were not excluded.	<ul style="list-style-type: none"> From 6 months before to 3 months after initial procedure 	This requirement ensures all claims and costs are captured.
Primary insurance is with other health plan	<ul style="list-style-type: none"> At time of initial procedure 	These patients were excluded because it might not be possible to capture all of their claims and costs.
Age 65 years or older	<ul style="list-style-type: none"> At time of initial procedure 	These patients were excluded because it might not be possible to capture all of their claims and costs.

¹ An initial stay refers to the hospital stay during which the initial procedure (i.e., knee replacement) was performed.

² Previous studies of outcomes and complications following knee replacement procedures have excluded patients with knee fractures (Browne 2010; Farmer 2006; Khatod 2008; Kurtz 2010; Manley 2009; Ong 2008; Ong 2009), pathological fractures. (Browne 2010; Marchant 2009; SooHoo 2006), and malignancies (Katz 2008; Khatod 2008; Krishnan 2007; Losina 2006; Manley 2009; Marchant 2009; Ong 2008; Ong 2009),.

³ Previous studies of outcomes and complications following knee replacement procedures have excluded patients with infection (Browne 2010; Katz 2008; Krishnan 2007; Losina 2006; Manley 2009; Marchant 2009; Ong 2009; SooHoo 2006) and mechanical complications (Hervey 2003; Khatod 2008).

Table 3

Knee replacement: ICD-9-CM Diagnosis and Procedure Codes Used to Identify Patient Categories Excluded from Analytic Sample

Exclusion Category and Code	Type of Code
Knee Replacement, revision	
81.55	ICD-9-CM Procedure
0.80	ICD-9-CM Procedure
0.81	ICD-9-CM Procedure
0.82	ICD-9-CM Procedure
0.83	ICD-9-CM Procedure
0.84	ICD-9-CM Procedure
Previous complications (including mechanical complications)	
996.66	ICD-9-CM Diagnosis
996.67	ICD-9-CM Diagnosis
996.7	ICD-9-CM Diagnosis
996.70	ICD-9-CM Diagnosis
996.77	ICD-9-CM Diagnosis
996.78	ICD-9-CM Diagnosis

Exclusion Category and Code	Type of Code
996.79	ICD-9-CM Diagnosis
996.4	ICD-9-CM Diagnosis
996.40	ICD-9-CM Diagnosis
996.41	ICD-9-CM Diagnosis
996.42	ICD-9-CM Diagnosis
996.43	ICD-9-CM Diagnosis
996.44	ICD-9-CM Diagnosis
996.45	ICD-9-CM Diagnosis
996.46	ICD-9-CM Diagnosis
996.47	ICD-9-CM Diagnosis
996.48	ICD-9-CM Diagnosis
996.49	ICD-9-CM Diagnosis
infection of knee or thigh (including osteomyelitis and pyogenic arthritis)	
711.05	ICD-9-CM Diagnosis
711.06	ICD-9-CM Diagnosis
730.0	ICD-9-CM Diagnosis
730.1	ICD-9-CM Diagnosis
730.00	ICD-9-CM Diagnosis
730.05	ICD-9-CM Diagnosis
730.06	ICD-9-CM Diagnosis
730.10	ICD-9-CM Diagnosis
731.05	ICD-9-CM Diagnosis
731.06	ICD-9-CM Diagnosis
730.2	ICD-9-CM Diagnosis
730.20	ICD-9-CM Diagnosis
730.25	ICD-9-CM Diagnosis
730.26	ICD-9-CM Diagnosis
730.9	ICD-9-CM Diagnosis
730.90	ICD-9-CM Diagnosis
730.95	ICD-9-CM Diagnosis
730.96	ICD-9-CM Diagnosis
996.60	ICD-9-CM Diagnosis
996.66	ICD-9-CM Diagnosis
996.67	ICD-9-CM Diagnosis
Pathological fractures, malignant neoplasms, bone cancer, metastatic cancer	
170	ICD-9-CM Diagnosis
170.7	ICD-9-CM Diagnosis

Exclusion Category and Code	Type of Code
170.8	ICD-9-CM Diagnosis
170.9	ICD-9-CM Diagnosis
198	ICD-9-CM Diagnosis
198.5	ICD-9-CM Diagnosis
196.5	ICD-9-CM Diagnosis
238.9	ICD-9-CM Diagnosis
239.9	ICD-9-CM Diagnosis
733.1	ICD-9-CM Diagnosis
733.15	ICD-9-CM Diagnosis
733.16	ICD-9-CM Diagnosis
Fracture/injury of knee	
733.93	ICD-9-CM Diagnosis
821.2	ICD-9-CM Diagnosis
821.20	ICD-9-CM Diagnosis
821.21	ICD-9-CM Diagnosis
821.22	ICD-9-CM Diagnosis
821.23	ICD-9-CM Diagnosis
821.29	ICD-9-CM Diagnosis
821.3	ICD-9-CM Diagnosis
821.30	ICD-9-CM Diagnosis
821.31	ICD-9-CM Diagnosis
821.32	ICD-9-CM Diagnosis
821.33	ICD-9-CM Diagnosis
821.39	ICD-9-CM Diagnosis
822	ICD-9-CM Diagnosis
822.0	ICD-9-CM Diagnosis
822.1	ICD-9-CM Diagnosis
823.0	ICD-9-CM Diagnosis
823.00	ICD-9-CM Diagnosis
823.01	ICD-9-CM Diagnosis
823.02	ICD-9-CM Diagnosis
823.1	ICD-9-CM Diagnosis
823.10	ICD-9-CM Diagnosis
823.11	ICD-9-CM Diagnosis
823.12	ICD-9-CM Diagnosis
928.11	ICD-9-CM Diagnosis

Table 4

Knee replacement: Number of Patients in Analytic Sample after Each Exclusion, by Designated Hospital Status, July 2007 – September 2009

	Designated hospitals			Other Hospitals			Total		
	Number Excluded	Sample Size After Exclusion	% of Initial Sample Size	Number Excluded	Sample Size After Exclusion	% of Initial Sample Size	Number Excluded	Sample Size After Exclusion	% of Initial Sample Size
Initial sample size		72,438	100.0%		71,980	100.0%		144,418	100.0%
Enrollee's address out of country	21	72,417	100.0%	18	71,962	100.0%	39	144,379	100.0%
Bilateral procedure	2,249	70,168	96.9%	1,568	70,394	97.8%	3817	140,562	97.3%
Multiple procedures	161	70,007	96.6%	177	70,217	97.6%	338	140,224	97.1%
Repeat procedures	12	69,995	96.6%	26	70,191	97.5%	38	140,186	97.1%
Another primary or revision knee surgery in prior six months	484	69,511	96.0%	437	69,754	96.9%	921	139,265	96.4%
Revision knee replacement listed as a secondary procedure on stay file	53	69,458	95.9%	52	69,702	96.8%	105	139,160	96.4%
Patient <18 at time of initial procedure	11	69,447	95.9%	23	69,679	96.8%	34	139,126	96.3%
Fractures	58	69,389	95.8%	62	69,617	96.7%	120	139,006	96.3%
Pathological fractures and malignancies	53	69,336	95.7%	31	69,586	96.7%	84	138,922	96.2%
Pre-existing infection of knee or thigh	36	69,300	95.7%	29	69,557	96.6%	65	138,857	96.1%
Previous complications (including mechanical complications)	62	69,238	95.6%	48	69,509	96.6%	110	138,747	96.1%
Place of service not inpatient hospital	30	69,208	95.5%	60	69,449	96.5%	90	138,657	96.0%
Left against medical advice	12	69,196	95.5%	17	69,432	96.5%	29	138,628	96.0%
Not continuously enrolled from 6 months before procedure to 3 months after	3,432	65,764	90.8%	3,042	66,390	92.2%	6474	132,154	91.5%
Primary insurance is with other health plan	18,926	46,838	64.7%	23,137	43,253	60.1%	42,063	90,091	62.4%
Age 65 years or older	4,583	42,255	58.3%	4,577	38,676	53.7%	9,160	80,931	56.0%
Final sample size (after all exclusions)		42,255	58.3%		38,676	53.7%		80,931	56.0%

Table 5**Hip replacement: Patient Categories Excluded from Analytic Sample, Time Periods, and Rationale**

Exclusion Category	Time Period	Rationale
Enrollee's address out of country: Exclude other countries and US territories (GU-Guam, PR-Puerto Rico, and VI-Virgin Islands)	• Initial stay ⁴	This requirement ensures all claims and costs are captured. Care outside of the US might be fundamentally different.
Address of the initial hospital is in a state in which the Plans did not participate in the program: Alaska (AK), Delaware (DE), Mississippi (MS), Oklahoma (OK), Vermont (VT), West Virginia (WV), and Wyoming (WY).	• Initial stay	Because hospitals in these states were not invited to participate in the Designated hospital program for Knee and Hip, all hospitals in these states were excluded.
Bilateral procedures: The CPT modifier code, 50, when used in conjunction with a knee or hip replacement CPT code indicates that the bilateral procedures were performed during the same operative session.	• Professional claim for initial stay	These are excluded because the cost and outcomes of the procedure might differ substantially from single hip replacements.
Multiple procedures performed: The CPT modifier code, 51, indicates multiple procedures were performed at the same session by the same provider	• Professional claim for initial stay	These are excluded because the cost and outcomes of the procedure might differ substantially from single hip replacements.
Repeat procedure: The CPT modifier codes, 76 (repeat procedure by same physician) and 77 (repeat procedure by another physician), indicate the procedure was repeated.	• Professional claim for initial stay	As with revision procedures, repeat procedures are much less common and more heterogeneous with regard to the indication and type of procedure, making adequate control in the analysis difficult.
Another primary or revision hip surgery in prior six months	• 6 months before initial procedure date	Patients with another primary or revision hip surgery in prior six months would be likely to have different complication and readmission rates.
Revision hip replacement listed as a secondary procedure on stay file	• Initial stay	Patients with a revision hip replacement listed as a secondary procedure would be likely to have different complication and readmission rates.
Hip resurfacing	• Initial stay	Hip resurfacing is usually performed on a different type of patient (i.e., younger, healthier) (YNHHSC/CORE, 2010).
Partial hip replacement	• Initial stay	Partial hip replacements are typically performed when older patients fall and have fractures. They are usually performed on patients who are older, more frail and have more co-morbidities than patients having a hip replacement (YNHHSC/CORE, 2010). Excluding these cases is consistent with prior literature.
Patient <18 years of age at time of initial procedure	• Initial stay	Hip replacements in cases <18 years of age are rare and have different clinical indications.

Exclusion Category	Time Period	Rationale
Pathologic fracture, bone cancer, metastatic cancer, trauma patients who were diagnosed with pelvic or femoral fractures (for hip), or hip dislocation	<ul style="list-style-type: none"> 6 months before initial procedure date Initial stay 	Cases with these conditions were excluded to eliminate non-elective procedures. These are very different types of cases from a clinical perspective. These exclusions are consistent with prior literature. ⁵
Joint infection or mechanical complications	<ul style="list-style-type: none"> 6 months before initial procedure date 	Cases with these conditions were excluded to eliminate non-elective procedures. Clinically these are very different types of cases and these exclusions are consistent with prior literature. ⁶
Hospitalizations in which patient left against medical advice (discharge status code =07)	<ul style="list-style-type: none"> Initial stay 	Although rare, the costs and outcomes of these hospitalizations are likely very different.
Place of service not inpatient hospital	<ul style="list-style-type: none"> Initial stay 	These cases were excluded because acute care inpatient hospitals are the focus of this study.
Selected types of non-community hospitals	<ul style="list-style-type: none"> Initial stay 	Patients having the procedure in selected types of non-community hospitals were excluded.
Not continuously enrolled from 6 months before procedure to 3 months after: Patients who die within 3 months after the procedure were not excluded.	<ul style="list-style-type: none"> From 6 months before to 3 months after initial procedure 	This requirement ensures all claims and costs are captured.
Primary insurance is with other health plan	<ul style="list-style-type: none"> At time of initial procedure 	These patients were excluded because it might not be possible to capture all of their claims and costs.
Age 65 years or older	<ul style="list-style-type: none"> At time of initial procedure 	These patients were excluded because it might not be possible to capture all of their claims and costs.

⁴ An initial stay refers to the hospital stay during which the initial procedure (i.e., hip replacement) was performed.

⁵ Previous studies of outcomes and complications following hip replacement procedures have excluded patients with hip fractures (Doro 2006; Farmer 2007; Manley 2008; Ong 2008; Ong, Lau 2009), pathological fractures. (Doro 2006; Marchant 2009; SooHoo 2010), and malignancies (Doro 2006; Marchant 2009; Ong 2008; Ong, Lau 2009).

⁶ Previous studies of outcomes and complications following hip replacement procedures have excluded patients with infection (Doro 2006; Marchant 2009; Ong 2008; Ong, Lau 2009; SooHoo 2010) and mechanical complications (Doro 2006; Marchant 2009).

Table 6

Hip replacement: ICD-9-CM Diagnosis and Procedure Codes Used to Identify Patient Categories Excluded from Analytic Sample

Exclusion Category and Codes	Type of Code
Fractures	
820	ICD-9 Diagnosis
820.0	ICD-9 Diagnosis
820.00	ICD-9 Diagnosis
820.01	ICD-9 Diagnosis
820.02	ICD-9 Diagnosis

Exclusion Category and Codes	Type of Code
820.03	ICD-9 Diagnosis
820.09	ICD-9 Diagnosis
820.1	ICD-9 Diagnosis
820.10	ICD-9 Diagnosis
820.11	ICD-9 Diagnosis
820.12	ICD-9 Diagnosis
820.13	ICD-9 Diagnosis
820.19	ICD-9 Diagnosis
820.2	ICD-9 Diagnosis
820.20	ICD-9 Diagnosis
820.21	ICD-9 Diagnosis
820.22	ICD-9 Diagnosis
820.3	ICD-9 Diagnosis
820.30	ICD-9 Diagnosis
820.31	ICD-9 Diagnosis
820.32	ICD-9 Diagnosis
820.8	ICD-9 Diagnosis
820.9	ICD-9 Diagnosis
821	ICD-9 Diagnosis
821.0	ICD-9 Diagnosis
821.00	ICD-9 Diagnosis
821.01	ICD-9 Diagnosis
821.1	ICD-9 Diagnosis
821.1	ICD-9 Diagnosis
821.11	ICD-9 Diagnosis
808.0	ICD-9 Diagnosis
808.1	ICD-9 Diagnosis
808.2	ICD-9 Diagnosis
808.3	ICD-9 Diagnosis
808.41	ICD-9 Diagnosis
808.42	ICD-9 Diagnosis
808.43	ICD-9 Diagnosis
808.49	ICD-9 Diagnosis
808.51	ICD-9 Diagnosis
808.52	ICD-9 Diagnosis
808.53	ICD-9 Diagnosis
808.59	ICD-9 Diagnosis
808.8	ICD-9 Diagnosis
Infection	

Exclusion Category and Codes	Type of Code
711.05	ICD-9 Diagnosis
711.65	ICD-9 Diagnosis
711.95	ICD-9 Diagnosis
730.0	ICD-9 Diagnosis
730.00	ICD-9 Diagnosis
730.05	ICD-9 Diagnosis
730.1	ICD-9 Diagnosis
730.10	ICD-9 Diagnosis
730.15	ICD-9 Diagnosis
730.2	ICD-9 Diagnosis
730.20	ICD-9 Diagnosis
730.25	ICD-9 Diagnosis
730.9	ICD-9 Diagnosis
730.90	ICD-9 Diagnosis
730.95	ICD-9 Diagnosis
996.6	ICD-9 Diagnosis
996.60	ICD-9 Diagnosis
996.66	ICD-9 Diagnosis
996.67	ICD-9 Diagnosis
Malignancy or Pathologic Fracture	
170	ICD-9 Diagnosis
170.6	ICD-9 Diagnosis
170.7	ICD-9 Diagnosis
170.9	ICD-9 Diagnosis
195.3	ICD-9 Diagnosis
195.5	ICD-9 Diagnosis
198	ICD-9 Diagnosis
198.5	ICD-9 Diagnosis
199.0	ICD-9 Diagnosis
733.1	ICD-9 Diagnosis
733.14	ICD-9 Diagnosis
Complications of Previous Implant	
V54.0	ICD-9 Diagnosis
996.4	ICD-9 Diagnosis
996.4*	ICD-9 Diagnosis
996.7	ICD-9 Diagnosis
996.70	ICD-9 Diagnosis
996.77	ICD-9 Diagnosis

Exclusion Category and Codes	Type of Code
996.78	ICD-9 Diagnosis
Dislocations	
835.*	ICD-9 Diagnosis
Fractures	
79.05	ICD-9 Procedure
79.15	ICD-9 Procedure
79.25	ICD-9 Procedure
79.35	ICD-9 Procedure
Revision Hip Replacement	
81.53	ICD-9 Procedure
00.70	ICD-9 Procedure
00.71	ICD-9 Procedure
00.72	ICD-9 Procedure
00.73	ICD-9 Procedure
81.59	ICD-9 Procedure
Complications of previous THR	
78.6	ICD-9 Procedure
78.60	ICD-9 Procedure
78.65	ICD-9 Procedure
80.0	ICD-9 Procedure
80.00	ICD-9 Procedure
80.05	ICD-9 Procedure
Hip Resurfacing	
0.85	ICD-9 Procedure
0.86	ICD-9 Procedure
0.87	ICD-9 Procedure
Partial Hip Procedure	
81.52	ICD-9 Procedure
Fractures	
27230	CPT Procedure
27231	CPT Procedure
27232	CPT Procedure
27233	CPT Procedure
27234	CPT Procedure
27235	CPT Procedure
27236	CPT Procedure
27237	CPT Procedure

Exclusion Category and Codes	Type of Code
27238	CPT Procedure
27239	CPT Procedure
27240	CPT Procedure
27241	CPT Procedure
27242	CPT Procedure
27243	CPT Procedure
27244	CPT Procedure
27245	CPT Procedure
27246	CPT Procedure
27247	CPT Procedure
27248	CPT Procedure
27500	CPT Procedure
27501	CPT Procedure
27502	CPT Procedure
27503	CPT Procedure
27504	CPT Procedure
27505	CPT Procedure
27506	CPT Procedure
27507	CPT Procedure
Conversion of Previous Hip Surgery to THR	
27132	CPT Procedure
Infection-Arthrotomy	
27030	CPT Procedure
Radical Resection for Tumor or Infection	
27075	CPT Procedure
27076	CPT Procedure
27077	CPT Procedure
27078	CPT Procedure
27079	CPT Procedure
Complications of Previous THR	
20680	CPT Procedure
27090	CPT Procedure
27091	CPT Procedure
27134	CPT Procedure
27137	CPT Procedure
27138	CPT Procedure

Table 7

Hip replacement: Number of Patients in Analytic Sample after Each Exclusion, by Designated Hospital Status, July 2007 – September 2009

	Designated hospitals			Other Hospitals			Total		
	Number Excluded	Sample Size After Exclusion	% of Initial Sample Size	Number Excluded	Sample Size After Exclusion	% of Initial Sample Size	Number Excluded	Sample Size After Exclusion	% of Initial Sample Size
Initial sample size		41,799	100.0%		39,401	100.0%		81,200	100.0%
Enrollee's address out of country	7	41,792	100.0%	3	39,398	100.0%	10	81,190	100.0%
States not participating in DESIGNATED HOSPITAL program (AK, DE, MS, OK, VT, WV, WY)	0	41,792	100.0%	0	39,398	100.0%	0	81,190	100.0%
Bilateral procedure	190	41,602	99.5%	104	39,294	99.7%	294	80,896	99.6%
Multiple procedures	29	41,573	99.5%	19	39,275	99.7%	48	80,848	99.6%
Repeat procedures	1	41,572	99.5%	2	39,273	99.7%	3	80,845	99.6%
Another primary or revision hip surgery in prior six months	231	41,341	98.9%	170	39,103	99.2%	401	80,444	99.1%
Revision hip replacement listed as secondary procedure	27	41,314	98.8%	31	39,072	99.2%	58	80,386	99.0%
Hip resurfacing	1,910	39,404	94.3%	1,514	37,558	95.3%	3,424	76,962	94.8%
Partial hip replacement	4,154	35,250	84.3%	6,844	30,714	78.0%	10,998	65,964	81.2%
Patient <18 at time of initial procedure	26	35,224	84.3%	22	30,692	77.9%	48	65,916	81.2%
Fractures	728	34,496	82.5%	902	29,790	75.6%	1,630	64,286	79.2%
Dislocations	4	34,492	82.5%	2	29,788	75.6%	6	64,280	79.2%
Pathological fractures and malignancies	143	34,349	82.2%	116	29,672	75.3%	259	64,021	78.8%
Pre-existing infection	45	34,304	82.1%	30	29,642	75.2%	75	63,946	78.8%
Previous complications (including mechanical complications)	52	34,252	81.9%	37	29,605	75.1%	89	63,857	78.6%
Place of service not inpatient hospital	11	34,241	81.9%	24	29,581	75.1%	35	63,822	78.6%
Left against medical advice	4	34,237	81.9%	8	29,573	75.1%	12	63,810	78.6%
Not continuously enrolled from 6 months before procedure to 3 months after	1,691	32,546	77.9%	1,281	28,292	71.8%	2,972	60,838	74.9%
Primary insurance is with another health plan	8,202	24,344	58.2%	9,345	18,947	48.1%	17,547	43,291	53.3%
Age 65 years or older	2,015	22,329	53.4%	1,744	17,203	43.7%	3,759	39,532	48.7%

Table 8

Specifications for Identifying Complications Following Knee replacement or Hip replacement

Complication	ICD-9-CM Diagnosis and Procedure Codes	Time Period
Acute Myocardial Infarction	Presence of one of the following diagnosis codes in a primary or secondary diagnosis field on the record for the initial hospitalization OR in a primary diagnosis field only on a readmission record with an admission date that falls within the specified time period (see third column): <ul style="list-style-type: none"> 410.xx excluding 410.x2 	From admission date of initial hospitalization to 7 days after admission date
Pneumonia	Presence of one of the following diagnosis codes in a primary or secondary diagnosis field on the record for the initial hospitalization OR in a primary diagnosis field only on a readmission record with an admission date that falls within the specified time period (see third column): <ul style="list-style-type: none"> 480, 480.0, 480.1, 480.2, 480.3, 480.8, 480.9, 481, 482, 482.0, 482.1, 482.2, 482.3, 482.30, 482.31, 482.32, 482.39, 482.4, 482.40, 482.41, 482.42, 482.49, 482.81, 482.82, 482.83, 482.84, 482.89, 482.9, 483, 483.0, 483.1, 483.8, 485, 486, 487.0, 507.0 	From admission date of initial hospitalization to 7 days after admission date
Sepsis/Septicemia	Presence of one of the following diagnosis codes in a primary or secondary diagnosis field on the record for the initial hospitalization or in a primary or secondary diagnosis field on a readmission record with an admission date that falls within the specified time period (see third column): <ul style="list-style-type: none"> 038, 038.0, 038.1, 038.10, 038.11, 038.12, 038.19, 038.2, 038.3, 038.4, 038.40, 038.41, 038.42, 038.43, 038.44, 038.49, 038.8, 038.9, 785.52, 785.59, 790.7, 995.91, 995.92, 998.0, 998.59, 790.7, 998.59 	From admission date of initial hospitalization to 7 days after admission date
Pulmonary Embolism	Presence of one of the following diagnosis codes in a primary or secondary diagnosis field on the record for the initial hospitalization or in a primary or secondary diagnosis field on a readmission record with an admission date that falls within the specified time period (see third column): <ul style="list-style-type: none"> 415.1, 415.11, 415.19 	From admission date of initial hospitalization to 30 days after admission date
Wound Infection	Presence of one of the following diagnosis codes in a primary or secondary diagnosis field on the record for the initial hospitalization or in a primary or secondary diagnosis field on a readmission record with an admission date that falls within the specified time period (see third column): 998.6, 998.83, 998.3, 998.30, 998.31, 998.32, 998.33, 998.5, 998.51, 998.59, 996.67 AND at least one of the following procedure codes: Incision and Drainage: 86.22, 86.28, 86.04 <ul style="list-style-type: none"> Revision: 81.53, 81.55, 81.59, 00.70, 00.71, 00.72, 00.73, 00.80, 00.81, 00.82, 00.83, 00.84 Removal: 80.05, 80.06, 80.09 	From admission date of initial hospitalization to 30 days after admission date
Surgical Site Bleeding	Presence of one of the following diagnosis codes in a primary or secondary diagnosis field on the record for the initial hospitalization or in a primary or secondary diagnosis field on a readmission record with an admission date that falls within the specified time period (see third column): 998.1, 998.11, 998.12, 998.13, 286.5, 719.10, 719.16, 719.17 AND at least one of the following procedure code: Incision and Drainage: 86.22, 86.28, 86.04	From admission date of initial hospitalization to 30 days after admission date

Complication	ICD-9-CM Diagnosis and Procedure Codes	Time Period								
Death in an acute care hospital or other facility	<small>Presence of one of the following discharge status codes for the initial hospitalization:</small> <table><tr><td>40</td><td>Discharged to home</td></tr><tr><td>41</td><td>Discharged to home (long-term care)</td></tr><tr><td>42</td><td>Admitted to a medical facility (e.g., hospital, SNF, etc.) for continuing care</td></tr><tr><td>43</td><td>Discharged direct admission (long-term care)</td></tr></table>	40	Discharged to home	41	Discharged to home (long-term care)	42	Admitted to a medical facility (e.g., hospital, SNF, etc.) for continuing care	43	Discharged direct admission (long-term care)	From <u>admission date</u> of initial hospitalization to 30 days after admission date
40	Discharged to home									
41	Discharged to home (long-term care)									
42	Admitted to a medical facility (e.g., hospital, SNF, etc.) for continuing care									
43	Discharged direct admission (long-term care)									
Periprosthetic Joint Infection	Presence of one of the following diagnosis codes in a primary or secondary diagnosis field on the record for the initial hospitalization or in a primary or secondary diagnosis field on a readmission record with an admission date that falls within the specified time period (see third column): 996.66 AND at least one of the following procedure codes: Incision and Drainage: 86.22, 86.28, 86.04 • Revision: 81.53, 81.55, 81.59, 00.70, 00.71, 00.72, 00.73, 00.80, 00.81, 00.82, 00.83, 00.84 • Removal: 80.05, 80.06, 80.09	From <u>admission date</u> of initial hospitalization to 90 days after admission date								
Mechanical Complication	Presence of one of the following diagnosis codes in a primary or secondary diagnosis field on the record for the initial hospitalization or in a primary or secondary diagnosis field on a readmission record with an admission date that falls within the specified time period (see third column): • 996.4, 996.40, 996.41, 996.42, 996.44, 996.47, 996.49	From <u>admission date</u> of initial hospitalization to 90 days after admission date								
Any Complication	Presence of at least one of the nine complications (as defined above)	Time periods for the nine complications (as defined above)								

* Based on information from: Yale New Haven Health Services Corporation/Center for Outcomes Research and Evaluation (YNHHSC/CORE). Form 9.1: Measure Information Form, Hospital risk-standardized complications rate following elective primary knee replacement (THA) and/or knee replacement (TKA), Draft. July 15, 2010.

Table 9

Diagnosis and Procedure Codes and Time Period for Identifying Readmissions Following Knee replacement or Hip replacement*

Measure Element	ICD-9-CM Diagnosis and Procedure Codes	Time Period
Denominator	Patients aged 18 and older admitted to non-federal acute care hospitals for an elective, primary knee replacement (THA). Patients are eligible for inclusion in the denominator if they have had a THA, identified using the following ICD-9-CM procedure code: • 81.54 Knee replacement	Admission date of initial hospitalization from July 1, 2007 through September 30, 2009
Numerator: Inclusion	Include: Any readmission to an acute care hospital within 30 days	From discharge date of initial hospitalization to 30 days after discharge date
Numerator Exclusion 1: Planned Readmissions**	Exclude: Readmission to any acute care hospital within 30 days of the discharge date of initial hospitalization that is associated with a subsequent "planned" knee replacement. The criteria for identifying a subsequent planned knee replacement and/or knee replacement requires both of the following criteria be met: a. An admission to an acute care hospital within 30 days of discharge date of initial hospitalization with the following procedure code: • 81.54 - Knee replacement AND b. At least one of the following primary ICD-9 primary discharge diagnosis codes for osteoarthritis,	From discharge date of initial hospitalization to 30 days after discharge date

Measure Element	ICD-9-CM Diagnosis and Procedure Codes	Time Period
	<p>rheumatoid arthritis, or arthropathy must be coded for the same acute care hospitalization:</p> <ul style="list-style-type: none"> 713, 713.0, 713.1, 713.2, 713.3, 713.4, 713.5, 713.6, 713.7, 713.8, 714, 714.0, 714.1, 714.2, 714.3, 714.30, 714.31, 714.32, 714.33, 714.4, 714.8, 714.89, 714.9, 715, 715.0, 715.00, 715.09, 715.1, 715.10, 715.15, 715.16, 715.18, 715.2, 715.20, 715.25, 715.26, 715.28, 715.3, 715.30, 715.35, 715.36, 715.38, 715.8, 715.89, 715.9, 715.90, 715.95, 715.96, 715.98, 716, 716.0, 716.00, 716.05, 716.06, 716.08, 716.09, 716.1, 716.10, 716.15, 716.16, 716.18, 716.19, 716.2, 716.20, 716.25, 716.26, 716.28, 716.29, 716.3, 716.30, 716.35, 716.36, 716.38, 716.39, 716.4, 716.40, 716.45, 716.46, 716.48, 716.49, 716.5, 716.50, 716.55, 716.56, 716.58, 716.59, 716.6, 716.60, 716.65, 716.66, 716.68, 716.8, 716.80, 716.85, 716.86, 716.88, 716.89, 716.9, 716.90, 716.95, 716.96, 716.98, 716.99, 733.42 	
Numerator Exclusion 2: Likely rehab admissions [#]	<p>Exclude the following categories:</p> <p>Readmissions to a different hospital on the same day that are not a discharge or transfer to another short term hospital:</p> <ul style="list-style-type: none"> samehosp=0 and readmit interval 1=0 and initial discharge status code NE '02: DISCHARGE/TRANSFER TO ANOTHER SHORT TERM HOSPITAL' <p>Readmissions to a rehabilitation hospital:</p> <ul style="list-style-type: none"> PROVIDER SPECIALTY CODE = 'A1 SKILLED NURSING FACILITY' OR 'A3 NURSING FACILITY, OTHER OR '25 PHYSICAL MEDICINE AND REHABILITATION' <p>Readmissions with a principal diagnosis indicating rehabilitation:</p> <ul style="list-style-type: none"> V57.89 (Other specified rehabilitation procedure, Multiple training or therapy) or any other diagnosis that begins with a 'V' 	From discharge date of initial hospitalization to 30 days after discharge date

* Based on information from: Yale New Haven Health Services Corporation/Center for Outcomes Research and Evaluation (YNHHSC/CORE). Form 9.1: Measure Information Form, Hospital risk-standardized complications rate following elective primary knee replacement (THA) and/or knee replacement (TKA), Draft. July 15, 2010.

** This exclusion is based on the work of YNHHSC/CORE (see above footnote).

This exclusion was developed by the authors.

Table 10

Clinical Risk Factor Categories Used in Multivariate Models with Condition Category (CC) Numbers^{*}

Clinical Risk Factor Category [*]	Condition Category (CC) [#]
Infection	CC 1, 3–6
Metastatic Cancer and acute leukemia	CC 7
Cancer	CC 8–12
Diabetes and Diabetes Mellitus Complications	CC 15–20, 119, 120
Protein-calorie malnutrition	CC 21
Disorders of Fluid/Electrolyte/Acid-Base	CC 22, 23
Rheumatoid Arthritis and Inflammatory Connective Tissue Disease	CC 38
Severe Hematological Disorders	CC 44
Dementia and senility	CC 49, 50
Major psychiatric Disorders	CC 54–56

Clinical Risk Factor Category*	Condition Category (CC) [#]
Hemiplegia, paraplegia, paralysis, functional disability	CC 67–69, 100–102, 177–178
Polyneuropathy	CC 71
Congestive Heart Failure	CC 80
Chronic Atherosclerosis	CC 83–84
Hypertension	CC 89, 91
Arrhythmias	CC 92, 93
Stroke	CC 95, 96
Vascular or circulatory disease	CC 104–106
COPD	CC 108
Pneumonia	CC 111–113
End-stage renal disease or dialysis	CC 129 ^{**} , 130
Renal Failure	CC 131
Decubitus ulcer or chronic skin ulcer	CC 148, 149
Cellulites, local skin infection	CC 152
Other injuries	CC 162
Major symptoms, abnormalities	CC 166

* Based on information from: Yale New Haven Health Services Corporation/Center for Outcomes Research and Evaluation (YNHHC/CORE). Form 9.1: Measure Information Form, Hospital risk-standardized complications rate following elective primary hip replacement (TEA) and/or knee replacement (TKA), Draft. July 15, 2010.

[#] The “condition category” (CC) numbers were developed as part of the Centers for Medicare & Medicaid Services (CMS)-Hierarchical Condition Category (HCC) Model (Pope et al., 2004). Each “condition category” corresponds to a set of ICD-9-CM codes. The condition categories are defined in a “Condition Category-to-ICD-9-CM Crosswalk” which was available from the Quality Net website (www.qualitynet.org) on September 4, 2010. The crosswalk file name is 302_416_2010_ICD_9_Crosswalk.txt (exact URL not available).

^{**} The original article on the HCC model states, “CC 129, ESRD is defined by Medicare entitlement status” (Pope et al., 2004). However, because we are not analyzing Medicare claims, we were not able to assign CC 129 (End Stage Renal Disease (Medicare elig)) as originally specified. Therefore, our models contains only one indicator of ESRD, representing CC 130 (Dialysis Status).

Table 11

Comparison of Performance on H-CAHPS and SCIP Measures Between Designated Hospitals and Other Hospitals

Performance Measures	Designated hospitals ^a	Other hospitals ^a	p-value ^b
H-CAHPS measures (average percentage across all hospitals)			
Nurses “Always” communicated well	73.0	73.8	<0.01
Doctors “Always” communicated well	77.6	79.2	<0.01
Patient “Always” received help as soon as they wanted it	59.0	61.7	<0.01
Pain was “Always” well controlled	67.1	68.1	<0.01
Staff “Always” explained medicines before giving it to them	57.4	58.4	<0.01
Room and bathroom were “Always” clean	65.7	69.0	<0.01
Area around their room was “Always” quiet at night	51.9	55.8	<0.01

Performance Measures	Designated hospitals ^a	Other hospitals ^a	p-value ^b
Patients given information about what to do after discharge	81.5	80.7	<0.01
Rated hospital as 9 or 10 on a scale from 0 to 10 (highest)	65.1	64.4	0.09
Definitely would recommend the hospital	24.3	26.4	<0.01
Surgical Care Improvement Project (SCIP) Measures (average percentage across hospitals)			
Patients given antibiotic within one hour before surgery	95.0	92.5	<0.01
Antibiotics stopped within 24 hours	92.2	89.0	<0.01
Patients given appropriate antibiotic	97.6	95.8	<0.01
Patients received appropriate timing of DVT prophylaxis	91.7	87.9	<0.01
Patients received DVT prophylaxis	94.0	90.4	<0.01
Patients received appropriate glucose control	88.1	84.5	<0.01
Patients received appropriate hair removal	98.6	97.6	<0.01
Patients on beta blockers continued on beta blockers	89.3	87.7	<0.01

Table 12

Prevalence of Medical Conditions* Among Patients Having Knee replacement or Hip replacement by Designated Hospital Status

	Knee replacement		Hip replacement	
	Designated Hospitals N=35,675	Other Hospitals N=42,836	Designated Hospitals N=19,167	Other Hospitals N=42,836
Clinical Risk Factor Category	%	%		
Infection	2.1	2.1	2.5	
Metastatic cancer and acute leukemia	0.1	0.1	0.2	
Cancer	4.7	4.2 ^b	4.8	
Diabetes and diabetes mellitus complications	17.7	18.7 ^b	10.7	
Protein-calorie malnutrition	0.1	0.1	0.2	
Disorders of fluid/electrolyte/acid-base	7.6	7.7	7.2	
Rheumatoid arthritis and inflammatory connective tissue disease	4.5	4.3	4.5	
Severe hematological disorders	0.2	0.2	0.3	
Dementia and senility	0.3	0.2	0.3	
Major psychiatric disorders	1.6	1.3 ^b	1.4	
Hemiplegia, paraplegia, paralysis, functional disability	0.4	0.5	0.5	
Polyneuropathy	1.7	1.6	1.4	
Congestive heart failure	2.0	1.9	1.9	
Chronic atherosclerosis	8.0	8.0	6.9	
Hypertension	59.3	60.3 ^b	47.9	
Arrhythmias	6.7	6.5	6.5	

	Knee replacement		Hip replacement	
	Designated Hospitals N=35,675	Other Hospitals N=42,836	Designated Hospitals N=19,167	Other Hospitals N=42,836
Clinical Risk Factor Category	%	%		
Stroke	0.24	0.16 ^b	0.2	0.1
Vascular or circulatory disease	7.5	6.8 ^b	8.9	7.5
Chronic Obstructive Pulmonary Disease (COPD)	3.7	4.3 ^b	3.9	4.3
Pneumonia	0.6	0.6	0.5	0.5
End-stage renal disease or dialysis	0.0	0.0	0.1	0.1
Renal failure	2.1	2.1	2.0	2.0
Decubitus ulcer or chronic skin ulcer	0.3	0.3	0.3	0.3
Cellulites, local skin infection	1.2	1.2	0.9	0.9
Other injuries	8.6	9.3 ^b	5.7	5.7
Major symptoms, abnormalities	15.0	15.4	14.0	14.0

^aAll clinical risk factor categories, except pneumonia, are based on primary and secondary diagnoses from the initial stay and from inpatient and outpatient claims data during the six months preceding the initial procedure date. The pneumonia variable is based on primary and secondary diagnoses from inpatient and outpatient claims data during the six months preceding the initial procedure date, not on the initial stay.

^bSignificant difference between Designated hospitals and other hospitals based on a chi-square test ($p < .05$).

Table 13

Sensitivity Analyses: Comparison of Medical Costs (in Dollars) Using Different Methods

	Cost Category	Knee replacement			Designated hospitals N=42,212
		Designated hospitals N=42,212	Other hospitals N=38,652	Percentage difference between sets of hospitals	
Sensitivity analyses	Medical costs only during initial hospitalization	\$18,749	\$19,071	1.6% (0.28)	\$19,500
From manuscript	Total medical costs during 90 days following admission date	18,749	19,071	1.1% (0.37)	19,500
Modifications to multivariate model	Added to risk adjustment - 6 month baseline costs in risk adjustment [*]			1.0% (0.39)	
	Winsorizing outliers ^{**}			1.3% (0.25)	
Costs determined using Prometheus Algorithm	Medical costs during 90 days following admission date related to procedure	23,065 [^]	23,634 [^]	-0.5% (0.68)	22,500

^{*} Because of concerns that model used in paper might not sufficiently account for differences in baseline risk, we added to the models all costs in the 6 months prior to the procedure

^{**} Because of concerns that high and low cost outliers could represent mistakes in coding, we Winsorized outliers based on prior work.¹⁷ We examined the distribution of 90 day costs across all cases and identified the costs at the 2.5th and 97.5th percentile. All cases below the 2.5th percentile were given the costs at the 2.5th percentile and all cases with costs above the 97.5th percentile were given the costs at the 97.5th percentile.

^{***} We used a modified version of the Prometheus Payment model's analytical software to estimate the categories of costs represented in the table. We modified the standard method used by the Prometheus algorithm in several ways. First, we

used a longer list of exclusion criteria which to be consistent with the outcomes analysis. Second, we used a more restricted list of procedure codes to define a primary knee or hip replacement. For example, Prometheus includes hip resurfacing procedures which we excluded because we felt they were inappropriate for this project. Third, we only looked at costs during the 90 days post-procedure, instead of the 180 day follow-up period typically used in the Prometheus algorithm. We shortened it because the 90 day period is consistent with the follow-up period for our clinical outcome measures, and this period includes the vast majority of costs for these procedures.

^ Costs are higher because sample is different. Prometheus algorithm excluded a number of cases for other exclusion criteria that were not included in our specifications. These tended to be lower cost cases and therefore average costs are higher.

Table 14

Knee replacement: Parameters from Logistic Model with Any Complications as Dependent Variable

Effect	Analysis of Maximum Likelihood Estimates				Odds Ratio Estimates		
	Estimate	Standard Error	Wald Chi-Square	Pr>ChiSq	Point Estimate	95% Wald Confidence Limits	
Intercept	-4.1769	0.1695	607.0331	<.0001	--	--	--
male	0.0628	0.0481	1.7049	0.1916	1.065	0.969	1.170
age_minus18	0.00439	0.00430	1.0399	0.3078	1.004	0.996	1.013
cc_infection	-0.0158	0.1517	0.0108	0.9172	0.984	0.731	1.325
cc_metastatic	-10.6349	0.1717	3835.2634	<.0001	<0.001	<0.001	<0.001
cc_cancer	0.00377	0.1103	0.0012	0.9727	1.004	0.809	1.246
cc_diabetes	0.1160	0.0638	3.3101	0.0689	1.123	0.991	1.273
cc_protein	0.0457	0.5300	0.0074	0.9313	1.047	0.370	2.958
cc_fluid	0.5263	0.0739	50.7166	<.0001	1.693	1.464	1.957
cc_arthritis	0.2209	0.1047	4.4518	0.0349	1.247	1.016	1.531
cc_hematological	0.7138	0.4221	2.8596	0.0908	2.042	0.893	4.670
cc_dementia	0.2653	0.3844	0.4763	0.4901	1.304	0.614	2.770
cc_psych	0.2697	0.1763	2.3415	0.1260	1.310	0.927	1.850
cc_hemiplegia	0.3571	0.2518	2.0111	0.1562	1.429	0.872	2.341
cc_neuropathy	-0.1051	0.1605	0.4283	0.5128	0.900	0.657	1.233
cc_chf	0.6353	0.1175	29.2228	<.0001	1.888	1.499	2.377
cc_atherosclerosis	0.2530	0.0817	9.5798	0.0020	1.288	1.097	1.512
cc_hypertension	-0.0989	0.0526	3.5409	0.0599	0.906	0.817	1.004
cc_arrhythmias	0.4050	0.0836	23.4498	<.0001	1.499	1.273	1.766
cc_stroke	0.8019	0.3169	6.4027	0.0114	2.230	1.198	4.149
cc_vascular	0.5149	0.0755	46.5278	<.0001	1.674	1.443	1.940
cc_copd	0.3247	0.1015	10.2274	0.0014	1.384	1.134	1.688
cc_pneumonia	0.2107	0.2518	0.6998	0.4029	1.235	0.754	2.022
cc_esrd	-11.7283	0.6536	321.9827	<.0001	<0.001	<0.001	<0.001
cc_renal	0.4477	0.1202	13.8714	0.0002	1.565	1.236	1.980
cc_decubitus	-0.5710	0.4521	1.5947	0.2067	0.565	0.233	1.371
cc_cellulites	1.7357	0.1188	213.4581	<.0001	5.673	4.494	7.160
cc_other_injury	0.1663	0.0777	4.5791	0.0324	1.181	1.014	1.375
cc_major_symptoms	0.1289	0.0646	3.9855	0.0459	1.138	1.002	1.291

	Analysis of Maximum Likelihood Estimates				Odds Ratio Estimates		
Effect	Estimate	Standard Error	Wald Chi-Square	Pr>ChiSq	Point Estimate	95% Wald Confidence Limits	
designated hospital	-0.1053	0.0597	3.1121	0.0777	0.900	0.801	1.012

Table 15

Knee replacement: Parameters from Logistic Model with Readmission in 30 Days as Dependent Variable

	Analysis of Maximum Likelihood Estimates				Odds Ratio Estimates		
Effect	Estimate	Standard Error	Wald Chi-Square	Pr>ChiSq	Point Estimate	95% Wald Confidence Limits	
Intercept	-3.8610	0.1480	680.8451	<.0001	--	--	--
male	0.1816	0.0419	18.7728	<.0001	1.199	1.105	1.302
age_minus18	0.000920	0.00388	0.0564	0.8123	1.001	0.993	1.009
cc_infection	0.0801	0.1234	0.4215	0.5162	1.083	0.851	1.380
cc_metastatic	-10.9098	0.1807	3643.4424	<.0001	<0.001	<0.001	<0.001
cc_cancer	-0.00090	0.0906	0.0001	0.9921	0.999	0.836	1.193
cc_diabetes	0.2088	0.0477	19.1864	<.0001	1.232	1.122	1.353
cc_protein	0.6699	0.3617	3.4299	0.0640	1.954	0.962	3.971
cc_fluid	0.1930	0.0676	8.1404	0.0043	1.213	1.062	1.385
cc_arthritis	0.1596	0.0887	3.2363	0.0720	1.173	0.986	1.396
cc_hematological	0.6460	0.4147	2.4266	0.1193	1.908	0.846	4.301
cc_dementia	0.3826	0.3138	1.4859	0.2228	1.466	0.793	2.712
cc_psych	0.3295	0.1360	5.8739	0.0154	1.390	1.065	1.815
cc_hemiplegia	0.5292	0.2393	4.8897	0.0270	1.698	1.062	2.714
cc_neuropathy	-0.0323	0.1377	0.0551	0.8144	0.968	0.739	1.268
cc_chf	0.1995	0.1149	3.0140	0.0826	1.221	0.975	1.529
cc_atherosclerosis	0.2674	0.0640	17.4659	<.0001	1.307	1.153	1.481
cc_hypertension	0.1643	0.0428	14.7704	0.0001	1.179	1.084	1.282
cc_arrhythmias	0.2826	0.0683	17.1231	<.0001	1.327	1.160	1.517
cc_stroke	0.4131	0.3206	1.6605	0.1975	1.511	0.806	2.833
cc_vascular	0.2531	0.0666	14.4607	0.0001	1.288	1.130	1.468
cc_copd	0.3016	0.0869	12.0464	0.0005	1.352	1.140	1.603
cc_pneumonia	0.4430	0.1777	6.2175	0.0126	1.557	1.099	2.206
cc_esrd	-12.0000	0.3852	970.2993	<.0001	<0.001	<0.001	<0.001
cc_renal	0.6458	0.0925	48.7594	<.0001	1.907	1.591	2.286
cc_decubitus	0.1012	0.2821	0.1287	0.7197	1.107	0.637	1.924
cc_cellulites	0.6578	0.1292	25.9128	<.0001	1.930	1.499	2.487
cc_other_injury	0.1938	0.0689	7.9099	0.0049	1.214	1.060	1.389

Effect	Analysis of Maximum Likelihood Estimates				Odds Ratio Estimates		
	Estimate	Standard Error	Wald Chi-Square	Pr>ChiSq	Point Estimate	95% Wald Confidence Limits	
cc_major_symptoms	0.3284	0.0536	37.5324	<.0001	1.389	1.250	1.543
designated hospital	-0.0665	0.0498	1.7823	0.1819	0.936	0.849	1.032

Table 16

Hip replacement: Parameters from Logistic Model with Any Complications as Dependent Variable

Effect	Analysis of Maximum Likelihood Estimates				Odds Ratio Estimates		
	Estimate	Standard Error	Wald Chi-Square	Pr>ChiSq	Point Estimate	95% Wald Confidence Limits	
Intercept	-3.4693	0.1648	443.0017	<.0001	--	--	--
male	-0.1244	0.0653	3.6325	0.0567	0.883	0.777	1.004
age_minus18	-0.00400	0.00436	0.8450	0.3580	0.996	0.988	1.005
cc_infection	0.3327	0.1641	4.1080	0.0427	1.395	1.011	1.924
cc_metastatic	0.5698	0.4673	1.4864	0.2228	1.768	0.707	4.418
cc_cancer	-0.1142	0.1599	0.5095	0.4753	0.892	0.652	1.221
cc_diabetes	0.0737	0.0987	0.5571	0.4554	1.076	0.887	1.306
cc_protein	0.8077	0.4045	3.9885	0.0458	2.243	1.015	4.955
cc_fluid	0.3533	0.0989	12.7558	0.0004	1.424	1.173	1.728
cc_arthritis	0.2177	0.1345	2.6170	0.1057	1.243	0.955	1.618
cc_hematological	-0.4149	0.5724	0.5255	0.4685	0.660	0.215	2.028
cc_dementia	-0.1965	0.5531	0.1263	0.7223	0.822	0.278	2.429
cc_psych	0.6016	0.2101	8.1984	0.0042	1.825	1.209	2.755
cc_hemiplegia	0.4615	0.3240	2.0288	0.1543	1.586	0.841	2.994
cc_neuropathy	0.5196	0.2047	6.4397	0.0112	1.681	1.126	2.512
cc_chf	0.5898	0.1607	13.4701	0.0002	1.804	1.316	2.471
cc_atherosclerosis	0.3117	0.1104	7.9784	0.0047	1.366	1.100	1.696
cc_hypertension	-0.0394	0.0700	0.3166	0.5737	0.961	0.838	1.103
cc_arrhythmias	0.0223	0.1224	0.0332	0.8554	1.023	0.804	1.300
cc_stroke	0.0374	0.6031	0.0038	0.9505	1.038	0.318	3.385
cc_vascular	0.2830	0.0968	8.5505	0.0035	1.327	1.098	1.604
cc_copd	0.1050	0.1415	0.5502	0.4583	1.111	0.842	1.466
cc_pneumonia	0.2349	0.3218	0.5328	0.4654	1.265	0.673	2.377
cc_esrd	0.4746	0.6551	0.5249	0.4688	1.607	0.445	5.804
cc_renal	0.6975	0.1623	18.4677	<.0001	2.009	1.461	2.761
cc_decubitus	0.1687	0.3849	0.1921	0.6612	1.184	0.557	2.517
cc_cellulites	1.2544	0.1851	45.9356	<.0001	3.506	2.439	5.039

	Analysis of Maximum Likelihood Estimates				Odds Ratio Estimates		
Effect	Estimate	Standard Error	Wald Chi-Square	Pr>ChiSq	Point Estimate	95% Wald Confidence Limits	
cc_other_injury	0.3855	0.1111	12.0463	0.0005	1.470	1.183	1.828
cc_major_symptoms	0.0965	0.0920	1.0997	0.2943	1.101	0.920	1.319
Designated hospital	-0.2187	0.0693	9.9686	0.0016	0.804	0.702	0.920

Table 17

Hip replacement: Parameters from Logistic Model with Readmission in 30 Days as Dependent Variable

	Analysis of Maximum Likelihood Estimates				Odds Ratio Estimates		
Effect	Estimate	Standard Error	Wald Chi-Square	Pr>ChiSq	Point Estimate	95% Wald Confidence Limits	
Intercept	-3.6760	0.1564	552.1657	<.0001	--	--	--
male	0.000414	0.0613	0.0000	0.9946	1.000	0.887	1.128
age_minus18	0.00139	0.00406	0.1169	0.7325	1.001	0.993	1.009
cc_infection	0.3352	0.1485	5.0990	0.0239	1.398	1.045	1.870
cc_metastatic	0.3482	0.4256	0.6692	0.4133	1.416	0.615	3.262
cc_cancer	0.0284	0.1232	0.0532	0.8175	1.029	0.808	1.310
cc_diabetes	0.1519	0.0837	3.2972	0.0694	1.164	0.988	1.372
cc_protein	0.3409	0.3939	0.7491	0.3868	1.406	0.650	3.043
cc_fluid	0.3641	0.0931	15.3100	<.0001	1.439	1.199	1.727
cc_arthritis	0.3109	0.1245	6.2412	0.0125	1.365	1.069	1.742
cc_hematological	0.5696	0.3869	2.1674	0.1410	1.768	0.828	3.773
cc_dementia	0.3752	0.4060	0.8538	0.3555	1.455	0.657	3.225
cc_psych	0.7452	0.1772	17.6853	<.0001	2.107	1.489	2.982
cc_hemiplegia	0.9149	0.2367	14.9384	0.0001	2.497	1.570	3.970
cc_neuropathy	0.4576	0.1826	6.2825	0.0122	1.580	1.105	2.260
cc_chf	0.4585	0.1619	8.0236	0.0046	1.582	1.152	2.172
cc_atherosclerosis	0.2222	0.1018	4.7627	0.0291	1.249	1.023	1.525
cc_hypertension	0.2103	0.0607	12.0094	0.0005	1.234	1.096	1.390
cc_arrhythmias	-0.0473	0.1149	0.1693	0.6807	0.954	0.761	1.195
cc_stroke	-0.1541	0.5241	0.0865	0.7687	0.857	0.307	2.394
cc_vascular	0.1816	0.0963	3.5506	0.0595	1.199	0.993	1.448
cc_copd	0.2257	0.1187	3.6151	0.0573	1.253	0.993	1.582
cc_pneumonia	-0.1181	0.3203	0.1360	0.7122	0.889	0.474	1.665
cc_esrd	1.0424	0.6096	2.9241	0.0873	2.836	0.859	9.367
cc_renal	0.3527	0.1601	4.8528	0.0276	1.423	1.040	1.947
cc_decubitus	0.4471	0.3377	1.7529	0.1855	1.564	0.807	3.031

Effect	Analysis of Maximum Likelihood Estimates				Odds Ratio Estimates		
	Estimate	Standard Error	Wald Chi-Square	Pr>ChiSq	Point Estimate	95% Wald Confidence Limits	
cc_cellulites	-0.0274	0.2539	0.0116	0.9141	0.973	0.592	1.600
cc_other_injury	0.3101	0.1059	8.5802	0.0034	1.364	1.108	1.678
cc_major_symptoms	0.3226	0.0749	18.5282	<.0001	1.381	1.192	1.599
Designated hospital	-0.1945	0.0645	9.0860	0.0026	0.823	0.725	0.934

Table 18

Hip and Knee Replacement: Parameters from Gamma Model with Total 90 day Costs as Dependent Variable^{*}

Effect	Knee Replacement		Hip Replacement	
	Estimate	Pr > t	Estimate	Pr > t
male	-0.52%	0.069	-1.43%	0.0006
age_minus18	0.06%	0.0171	-0.07%	0.0202
cc_arrhythmias	4.00%	<.0001	2.20%	0.0096
cc_arthritis	3.92%	<.0001	7.38%	<.0001
cc_atherosclerosis	1.02%	0.0532	0.08%	0.9249
cc_cancer	1.47%	0.028	5.37%	<.0001
cc_cellulites	6.38%	<.0001	7.10%	0.001
cc_chf	9.11%	<.0001	14.69%	<.0001
cc_copd	1.82%	0.0102	4.21%	<.0001
cc_decubitus	18.83%	<.0001	12.47%	0.0004
cc_dementia	-0.84%	0.7644	2.30%	0.5409
cc_diabetes	2.97%	<.0001	4.35%	<.0001
cc_esrd	41.60%	0.0002	67.42%	<.0001
cc_fluid	5.68%	<.0001	6.20%	<.0001
cc_hematological	85.19%	<.0001	21.45%	<.0001
cc_hemiplegia	10.62%	<.0001	15.44%	<.0001
cc_hypertension	0.84%	0.0044	1.34%	0.0019
cc_infection	5.38%	<.0001	6.98%	<.0001
cc_major_symptoms	3.09%	<.0001	4.98%	<.0001
cc_metastatic	16.85%	0.0007	23.59%	<.0001
cc_neuropathy	5.81%	<.0001	6.12%	0.0008
cc_other_injury	1.02%	0.0365	3.66%	<.0001
cc_pneumonia	1.16%	0.5217	1.72%	0.5443
cc_protein	28.69%	<.0001	19.57%	<.0001
cc_psych	5.60%	<.0001	15.55%	<.0001
cc_renal	16.37%	<.0001	18.23%	<.0001
cc_stroke	15.78%	<.0001	30.26%	<.0001
cc_vascular	6.77%	<.0001	2.84%	0.0002

* Model also included whether hospital was designated as a center of excellence and fixed effects for each state

Table 19

For Readmissions Within 30 Days, Top 20 Primary Diagnosis Codes Used Hip Replacement

Designated Hospitals	Other Hospitals
996.66: REACTION IN JOINT PROSTHESES	998.59: OTHER POSTOPERATIVE INFECTION
998.59: OTHER POSTOPERATIVE INFECTION	996.66: REACTION IN JOINT PROSTHESES
996.42: DISLOCATED PROSTHETIC JOINT	996.42: DISLOCATED PROSTHETIC JOINT
998.12: HEMATOMA COMPLICATION	998.12: HEMATOMA COMPLICATION
996.44: PERIPROSTHETIC FRACTURE	996.44: PERIPROSTHETIC FRACTURE
415.19: PULM EMBOLISM/INFARCT	415.19: PULM EMBOLISM/INFARCT
996.77: COMPLICATION - JOINT PROSTHESES	996.77: COMPLICATION - JOINT PROSTHESES
415.19: PULM EMBOLISM/INFARCT	453.41: DVT/EMP PROX LOWER EXT
682.6: CELLULITIS OF LEG	997.2: SURG COMPLICATION - VASC SYST
486: PNEUMONIA, ORGANISM NOS	998.51: INFECTED POSTOPERATIVE SEROMA
780.2: SYNCOPE AND COLLAPSE	415.11: IATROGEN PULM EMB/INFARC
997.2: SURGICAL COMP - VASC SYSTEM	599.0: URIN TRACT INFECTION NOS
998.51: INFECTED POSTOPERATIVE SEROMA	682.6: CELLULITIS OF LEG
599.0: URIN TRACT INFECTION NOS	715.95: OSTEOARTHROS NOS-PELVIS
715.35: LOC OSTEOARTH RITIS NOS-PELVIS	998.13: SEROMA COMPLICAT. PROCEDURE
427.31: ATRIAL FIBRILLATION	715.35: LOC OSTEOARTHROS NOS-PELVIS
453.41: DVT/PE PROXIMAL LOWER EXT	276.51: DEHYDRATION
008.45: INFECTION CLOSTRIDIUM DIFF	038.9: SEPTICEMIA NOS
285.1: POST-OP HEMMORHAGIC ANEMIA	285.1: POST-OP HEMMORHAGIC ANEMIA
410.71: SUBENDO INFARCT, INITIAL	486: PNEUMONIA, ORGANISM NOS

Knee Replacement	
Designated Hospitals	Other Hospitals
998.59: OTHER POSTOPERATIVE INFECTION	998.59: OTHER POSTOP INFECTION
996.66: REACTION IN JOINT PROSTHESES	996.66: REACTION IN JOINT PROSTHESES
996.77: COMPLICATION - JOINT PROSTHESES	415.19: PULM EMBOL/INFARCT
998.12: HEMATOMA COMPLICATION	996.77: COMPLICATION - JOINT PROSTHESES
415.19: PULM EMBOL/INFARCT	415.19: PULM EMBOL/INFARCT NEC
682.6: CELLULITIS OF LEG	998.12: HEMATOMA COMPLIC PROC
415.11: IATROGENIC PULM EMB/INFARC	715.36: LOC OSTEOARTH NOS-L/LEG
997.2: SURGICAL COMP-VASCULAR SYSTEM	997.2: SURG COMP-VASCULAR SYSTEM
427.31: ATRIAL FIBRILLATION	682.6: CELLULITIS OF LEG
338.18: ACUTE POSTOP PAIN NEC	715.96: OSTEOARTHROS NOS-L/LEG
453.42: DVT/PE DISTAL LOWER EXT	453.42: DVT/EMP DISTAL LOWER EXT
998.32: DISRUPTION OPERATIVE WOUND	453.41: DVT/EMP PROX LOWER EXT
786.59: CHEST PAIN	998.32: DISRUP-EXTERNAL OP WOUND
486: PNEUMONIA, ORGANISM NOS	427.31: ATRIAL FIBRILLATION
038.9: SEPTICEMIA NOS	338.18: ACUTE POSTOP PAIN NEC

Knee Replacement	
276.51: DEHYDRATION	486: PNEUMONIA, ORGANISM NOS
562.11: DIVERTICULOSIS COLON	996.67: REACTION ORTHOPEDIC DEV
715.36: LOC OSTEOARTH NOS-L/LEG	414.01: CAD NATVIE VESSEL
715.96: OSTEOARTHROS NOS-L/LEG	780.2: SYNCOPE AND COLLAPSE
584.9: ACUTE RENAL FAILURURE NOS	786.59: CHEST PAIN NEC

We have also included more details on the Prometheus algorithm.

Details on Prometheus Algorithm

As noted in the manuscript and Table 13 of the Appendix, we used the Prometheus algorithm as a sensitivity analysis when comparing costs at designated hospitals and other hospitals.

The underlying logic and methodology underlying Prometheus has been described elsewhere (e.g., de Brantes F, Rosenthal MB, Painter M. Building a bridge from fragmentation to accountability -- the Prometheus Payment model. *N Engl J Med* 2009;361:1033-1036).

The publicly-available software takes health plan claims in the six months after a joint replacement surgery and, based on criteria such as the diagnosis and procedure codes on the claim, divides them into claims that are related to the surgery or unrelated. The algorithm also designates specific claims related to the surgery as potentially avoidable complications. The underlying goal is to identify providers who provide higher value care and use the data to modify payments to those providers.

As noted above under Table 13, we were forced to modify the Prometheus Payment model's analytical software in several ways. First, we used a longer list of exclusion criteria for patients. We wanted the exclusion criteria for this analysis to be consistent with the outcomes analysis. Second, we used a more restricted list of procedure codes to define a primary knee or hip replacement. For example, Prometheus includes hip resurfacing procedures which we excluded because we felt they were inappropriate for this project. Third, we only looked at costs during the 90 days post-procedure, instead of the 180 day follow-up period typically used in the Prometheus algorithm. We shortened it because the 90 day period is consistent with the follow-up period for our clinical outcome measures. This period includes the vast majority of costs for these procedures.

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Figure 1.

Adjusted odds ratio of selected complications and readmissions at designated hospitals compared to other hospitals

Footnote: Panel a shows odds ratios for the selected complications and readmission for knee replacement, and Panel b shows the odds ratios for hip replacement. All analyses adjusted for age, gender, and comorbidities. The point estimates for the odds ratios are represented by the box and the horizontal lines represent the 95% confidence intervals.

Table 1Summary of criteria for being a designated hospital for knee and hip replacement^a

Required Criteria	
Comprehensive Inpatient Facility (ED, ICU and other specialized services)	Required
Accreditation (full accreditation by a CMS-deemed national accreditation organization)	Required
Duration of surgery service (>12 months)	Required
Surgeons must be Board Certified	Required
Volume (100 knee and hip replacement surgeries annually with 25 TKR and 25 THR replacements; Average and median surgeon volume 50 primary or revision TKR or THR)	Required
Facility is provider in health plan's network	Required
All identified surgeons have active network participating provider contracts with health plan	Required
Other Criteria (need 60 out of 100 points)	
Structure – Total Possible 63 points	Points
Participation in IHI (formal commitment to ≥ 6 improvement maps)	2
Reports to Leapfrog or comparable local initiative	1
Accepts AAMC principles for conduct and reporting of clinical trials	1
Health Information Technology (certified EMR, e-prescribing, medication reconciliation)	3
Nursing Excellence (Magnet designation or reports to NDNQI)	1
Participates in HCAHPS survey and makes data available on Hospital Compare	1
National Quality Improvement Initiatives (Universal Protocol/WHO Safety Checklist)	1
Participates in SCIP (Points for performance and tracking and reporting results)	9
Disclosure Policies (e.g., conflict of interest, relationship to device manufacturers)	4
Pain Management (protocols based on national guidelines for peri-operative surgical patients)	4
Dedicated Unit (for orthopedic/spine surgery)	2
Multidisciplinary Clinical Pathways and Teams	20
Fellowship Training in Adult Reconstructive Orthopedics (50% of surgeons)	1
Continuous Quality Improvement (e.g., collection of data, development of improvement goals and demonstrated improvement, ongoing physician learning)	2
Data Management and Patient Tracking (Internal registry for treatment and outcomes, process to track complications and revisions, evaluates patient satisfaction)	9
Data Reporting to a national or international database (e.g., NSQIP)	2
Process – Possible 20 points	Points
Patient Selection Criteria (written criteria, depression and anxiety screening)	4
Preoperative Patient Education (classes, materials, protocol informing of risks)	5
Medical Management (utilize established guidelines, such as ADA Standards of Diabetes Care)	2
Thromboprophylaxis protocol (specific for knee/hip)	1
Anesthesia practices (evaluated for use of regional anesthesia, normothermia protocol)	1
Physical Therapy and Rehabilitation Services (protocols for assessment and treatment)	1
Functional Assessments (standardized indexes for pre- and post-op assessments)	3
Transitions of Care (case management, discharge planning, monitoring of transitions)	3
Outcomes and Volume — Total Possible 17 points	Points

Facility Volume for TKR and THR combined (250 surgeries during reported 12-month period)	3
Facility Volume for TKR and THR combined (500 surgeries during reported 12-month period)	2 (add'l)
Revisions (Performs 50 net revisions for TKR and THR)	2
Average length of stay (TKR 3.5, THR 4)	6
30-Day Readmission Rate for TKR and THR patients (10%)	4

Abbreviations: TKR – total knee replacement, THR – total hip replacement, ADA – American Diabetes Association, NSQIP – National Surgical Quality Improvement Program, NDNQI – National Database of Nursing Quality Indicators, WHO – World Health Organization, CMS – Centers for Medicare & Medicaid Services, ICU – Intensive Care Unit, ED – Emergency Department, IHI – Institute for Healthcare Improvement, AAMC – Association of American Medical Colleges

^aTo be designated hospital for knee and hip replacement, hospitals must have met the required criteria and also achieve a score of at least 60 points out of 100 on the rest of the criteria. Hospitals are designated for both knee and hip replacement. The selection criteria shown in this table are specific to the 2009 cycle of designation.

Table 2

Characteristics of designated hospitals and other hospitals

Hospital characteristics	Designated hospitals ^a	Other hospitals ^a	p-value ^b
Number of hospitals	647	2,149	
Number of beds-- (% of hospitals)			
<100	7.0	36.2	<0.01
100–400	63.4	52.4	
>400	29.7	9.7	
Region—(% of hospitals)			
West	15.3	17.2	<0.01
Midwest	30.8	27.1	
South	32.5	39.2	
Northeast	21.5	16.5	
For-profit (% of hospitals)	11.8	20.2	<0.01
Academic hospital ^c (% of hospitals)	20.9	4.9	<0.01
Urban setting (% of hospitals)	99.1	89.1	<0.01
Medical/surgical ICU (% of hospitals)	97.6	87.9	<0.01
Medicare insurance (average % of patients) ^d	44.0	46.3	<0.01
Medicaid insurance (average % of patients) ^d	15.5	17.2	<0.01
Number of nurses/1000 patient-days (average)	6.72	8.36	0.07
All inpatient surgical operations per year (average)	5,319	2,410	<0.01
H-CAHPS measures (average percentage across all hospitals)			
Nurses “Always” communicated well	73.0	73.8	<0.01
Doctors “Always” communicated well	77.6	79.2	<0.01
Patient “Always” received help as soon as they wanted it	59.0	61.7	<0.01
Pain was “Always” well controlled	67.1	68.1	<0.01
Staff “Always” explained medicines before giving it to them	57.4	58.4	<0.01
Room and bathroom were “Always” clean	65.7	69.0	<0.01
Area around their room was “Always” quiet at night	51.9	55.8	<0.01
Patients given information about what to do after discharge	81.5	80.7	<0.01
Rated hospital as 9 or 10 on a scale from 0 to 10 (highest)	65.1	64.4	0.09
Definitely would recommend the hospital	24.3	26.4	<0.01
Surgical Care Improvement Project (SCIP) Measures (average percentage across hospitals)			
Patients given antibiotic within one hour before surgery	95.0	92.5	<0.01
Antibiotics stopped within 24 hours	92.2	89.0	<0.01
Patients given appropriate antibiotic	97.6	95.8	<0.01
Patients received appropriate timing of DVT prophylaxis	91.7	87.9	<0.01
Patients received DVT prophylaxis	94.0	90.4	<0.01

Hospital characteristics	Designated hospitals ^a	Other hospitals ^a	p-value ^b
Patients received appropriate glucose control	88.1	84.5	<0.01
Patients received appropriate hair removal	98.6	97.6	<0.01
Patients on beta blockers continued on beta blockers	89.3	87.7	<0.01

Abbreviations: ICU=intensive care unit, DVT=deep vein thrombosis

^aHospitals included are those with at least one knee or hip replacement during the study period

^bSignificant difference between designated hospitals and other hospitals based on a chi-square test or t-test

^cAs defined by hospital's membership in Council of Teaching Hospitals

^dAcross all admissions to hospital

Table 3

Characteristics of Patients with Total Knee Replacement or Total Hip Replacement Performed in Designated Hospitals and Other Hospitals, July 2007-September 2009

Patient Characteristic	Total Knee Replacement			Total Hip Replacement		
	Designated Hospitals N=42,255		Other Hospitals N=38,676	Designated Hospitals N=22,329		Other Hospitals N=17,203
	N	%	N	N	%	N
Age						
18-44	1,422	3.4	1,346	1,121	9.5	1,494
45-54	11,076	26.2	10,440	7,207	32.3	5,319
55-64	29,757	70.4	26,890	13,001	58.2	10,390
Gender (% Male)	16,114	38.1	14,806	11,714	52.5	8,921
Co-morbidities ^b						
Hypertension	25,049	59.3	23,461	10,709	48.0	8,645
Diabetes	7,537	17.8	7,244	2,374	10.6	1,950
Chronic Atherosclerosis	3,385	8.0	3,116	1,542	6.9	1,214
Vascular Disease	3,143	7.4	2,614	1,958	8.8	1,307

^a Significant difference between designated hospitals and other hospitals based on a chi-square test ($P < .05$).

^b Selected co-morbidities are shown in this table. A complete set of all 26 co-morbidities included in the models is provided in the Appendix.

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^aFor each complication among patients having a knee or hip replacement, this represents the odds ratio comparing designated hospitals to other hospitals. Models included age, gender, and presence of 26 comorbidities.

^bFor this outcome, the odds ratios and p-values are based on a model with fewer covariates because initially the model did not converge. See Appendix for details.