Risk Factors Associated With Health Care Utilization and Costs of Patients Undergoing Lower Extremity Joint Replacement

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Abstract

Background: The Comprehensive Care for Joint Replacement program implemented by the Centers for Medicare and Medicaid Services did not incorporate risk adjustment for lower extremity joint replacement (LEJR). Lack of adjustment places hospitals at financial risk and creates incentives for adverse patient selection.

Objective: To identify patient-level risk factors associated with health care utilization and costs of patients undergoing LEJR.

Methods: A comprehensive search of research databases from January 1, 1990, through January 31, 2016, was conducted. The databases included Ovid MEDLINE In-Process & Other Non-Indexed Citations, Ovid MEDLINE, Ovid EMBASE, Ovid Cochrane Central Register of Controlled Trials, Ovid Cochrane Database of Systematic Reviews, and SCOPUS and is reported according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement. The search identified 2020 studies. Eligible studies focused on primary unilateral and bilateral LEJR. Independent reviewers determined study eligibility and extracted utilization and cost data.

Results: Seventy-nine of 330 studies (24%) were included and were abstracted for analysis. Comorbidities, age, disease severity, and obesity were associated with increased costs. Increased number of comorbidities and age, presence of specific comorbidities, lower socioeconomic status, and female sex had evidence of increased length of stay. We found no significant association between indication for surgery and the likelihood of readmission.

Conclusion: Developing a risk adjustment model for LEJR that incorporates clinical variables may serve to reduce the likelihood of adverse patient selection and enhance appropriate reimbursement aligned with procedural complexity.

Recent projections suggest that the number of total hip arthroplasties and total knee arthroplasties performed in the United States may more than double from 2005 to 2030. Data from the voluntary Bundled Payments for Care Improvement project introduced by the Centers for Medicare and Medicaid Services (CMS) suggest that bundled payments reduce costs. The CMS implemented the Comprehensive Care for Joint Replacement (CJR) program, which dramatically transformed payment design for lower extremity joint replacement (LEJR). Although variation exists in patient and procedural complexity for LEJR, CMS-paid hospitals set episode prices with limited consideration for patient-level complexity. Due to the absence of a validated risk adjustment model in this context, the CJR program adjusted target pricing for joint replacement due to hip fracture only. The CMS did include protection for providers from monetary loss during the course of a single performance year, including patient exclusions for conditions such as end-stage renal disease, service exclusions for use of clotting factors, and graduated stop-loss (and conversely stop-gain) provisions.
Despite considerations in the CJR program to shield providers from excessive cost, a potential unintended consequence of the bundled payment strategy is preferential marketing to and selection of patients who are less likely to develop medical complications. Conversely, surgeons and health care systems will have incentive to delay or decline surgeries for higher-risk patients or to refer these patients to public or tertiary care centers.\(^5\)\(^{-7}\) Risk-adjusted payments have been proposed as a solution to remove disincentives for providing care to higher-risk patients.\(^8\)

The primary aim of this systematic review was to identify patient-level risk factors potentially associated with increased health care utilization and costs for patients undergoing LEJR. Results inform an ongoing empirical analysis focused on examining the implications of including these factors in CJR program target price setting methods.

**METHODS**

This systematic review was conducted according to guidance from the Cochrane Collaboration and is reported according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement.

**Inclusion Criteria**

We sought to replicate the bundle of services included in the LEJR bundle.\(^9\) The episode for the LEJR bundle of care begins with the index hospitalization that results in discharge under Medicare Severity Diagnosis Related Group 469 (major joint replacement or reattachment of lower extremity with major complications or comorbidities) or 470 (major joint replacement or reattachment of lower extremity without major complications or comorbidities) and ends 90 days after discharge. As such, we included studies of primary unilateral or bilateral LEJR (hip, knee, or ankle) with health care utilization and cost outcomes reported for the index hospitalization, including 3 days before admission and 90 days after discharge.

We excluded studies reporting no patient-level outcomes, including those reporting only hospital- or surgeon-level characteristics, such as hospital/surgeon volume, partial vs total joint replacement, hospital ward staffing or design, surgical approach, and provision of anticoagulation or antianemia medications. We also excluded studies for the following reasons: (1) language other than English, (2) full text not available through our library or inter-library loan, (3) published as abstracts only, (4) focused solely on a pediatric population, (5) reported revision surgeries and primary surgeries together, and (6) reported only outcome timeframes greater than 90 days after surgery.

**Search Strategy and Criteria**

A comprehensive search of research databases from January 1, 1990, through January 31, 2016, was conducted. The databases included Ovid MEDLINE In-Process & Other Non-Indexed Citations, Ovid MEDLINE, Ovid EMBASE, Ovid Cochrane Central Register of Controlled Trials, Ovid Cochrane Database of Systematic Reviews, and SCOPUS. The search strategy used controlled vocabulary to search for health care utilization, expenditures, and costs (Supplemental Appendix 1, available online at http://www.mcpiqojournal.org). We used search terms focusing on (1) patients with LEJR (knee, hip, or ankle), (2) resource expenditure including cost or utilization, and (3) the period after surgery, up to 90 days or 13 weeks. All abstracts retrieved by the search were evaluated independently by 2 reviewers according to aforementioned criteria (M.A.K., M.M.J., L.M.P., S.M.). Studies identified for possible inclusion by either reviewer were assessed in full text by 2 reviewers (M.A.K., M.M.J., L.M.P., J.A., B.J.B., M.H.M., A.N.L.). A third reviewer resolved discrepancies in full-text screening (M.A.K., M.M.J., J.A.). Data were abstracted by 1 of 4 abstracters (M.A.K., M.M.J., J.A., A.N.L.). Ten percent of studies were double abstracted and discrepancies corrected (M.M.J.).

The methodological quality of the studies was judged based on items selected to address risk-of-bias domains in observational studies. Quality of evidence was categorized as high, medium, or low based on domains from the GRADE (Grading of Recommendations Assessment, Development and Evaluation) approach,\(^10\) including the methodological limitations of the studies, the statistically significant effect size (relative association measure >2.0 considered a large effect), sample size (<200, 200-999, ≥1000), inconsistency
in the results of studies looking at the same risk factors and outcomes, and directness of the evidence to the question at hand. Risk factors and outcomes were abstracted as they were found in each manuscript and grouped into categories after all data were abstracted. When multiple studies contributed to the same association and were consistent in the direction of association, we considered that to be evidence warranting high certainty (high quality). When results were inconsistent in the direction of association, we considered that to warrant lower certainty in the evidence.

Search Results
Of the 2025 studies identified in the search (2020 from the database search and 5 from the hand search of the reference lists of included studies and reviews), 1656 (82%) were excluded in abstract review (Figure 1). An additional 39 studies (2%) passing abstract review were excluded because we were unable to obtain full text through our library or interlibrary loan. The remaining 330 studies (16%) were reviewed in full text.

A total of 79 studies were included and abstracted for analysis; 54 reported studies were conducted in the United States. Characteristics of the included studies were summarized, including the outcomes and risk factors reported by each study (Supplemental Appendix 2, available online at http://www.mcpiqojournal.org). After the data were abstracted, we reviewed outcomes and risk factors found in the literature and organized them into 6 categories of outcomes and 20 categories of risk factors (Table 1).

After reviewing all the abstracts retrieved by the search, we determined that outcomes reported in the oldest studies were very different from those in more recent studies. For example, Singh et al11 reported that average length of stay (LOS) was cut in half between 1990 and 2000: from 9.7 days in 1991-1993 to 4.5 days in 2000-2002 for black patients and from 8.3 days to 4.2 days for white patients in the same periods. We, therefore, excluded 21 studies that had passed the abstract review but were published between 1990 and 1999. Thus, the studies included in this systematic review were all published from 2000 through the first 4 weeks of 2016.

Data Synthesis
Given that the purpose of the systematic review is to identify risk factors of health care utilization and cost that can be added to risk-adjustment models, point estimates of the effect of each predictor were not developed or pooled owing to the heterogeneity in study design, population, and outcome reporting.

RESULTS
The literature included evidence on 61 pairs of risk factors and outcomes (Figure 2). Of these 61 risk factor and outcome pairs, 9 were supported by high-quality evidence, with 9 pairs finding a nonzero association between the risk factor and outcome. Moderate-quality evidence supported 42 risk factor and outcome pairs, 34 with a nonzero association; low-quality evidence was found on 10 risk factor and outcome pairs, 7 with a nonzero association.

The evidence base was strongest for the LOS and cost outcomes, which were the most common in the literature and reported by 50 and 26 studies, respectively. Most studies (53 of 79 [67%]) reported outcomes during the index hospitalization only. A further 16 studies (20%) reported outcomes during the surgery + 90-d window.
for the hospitalization and some period after, with 11 of those studies (69%) reporting outcomes for the 90-day period included in the CJR program.

We briefly report herein the risk factor and outcome pairs supported by high quality of evidence. Complete results are available in Figure 2 and Supplemental Appendixes 2 and 3 (available online at http://www.mcpiqojournal.org). Samples of effects reported in studies of high methodologic quality are reported in Table 2.

**Cost Outcomes**

Eight studies observed that medical comorbidities were associated with increased costs.\(^\text{12-19}\) Age,\(^\text{13,14,20-22}\) disease severity,\(^\text{20,23-26}\) and obesity were associated with increased cost. Most of the effect of body weight seems to be driven by morbid or severe obesity.\(^\text{21}\)
mass index [BMI; calculated as the weight in kilograms divided by the height in meters squared] >35 or 40) compared with normal weight (BMI of 18-25) and overweight (BMI of 25-29).16,20,21,27-32

**LOS Outcomes**

The bulk of the evidence suggests a moderate increase in LOS associated with either increased numbers of medical comorbidities or the presence of specific comorbidities, for example, diabetes, metabolic syndrome, coronary artery disease, and chronic heart failure.12,15,17-19,33-41

The perioperative risk factor category incorporated a broad variety of measures indicating increased complexity of medical decision making or care of the patient during or after surgery. The most frequently reported measure was the American Society of Anesthesiologists physical classification system score,42 reported in 12 of the 22 studies.34,41,43-52 The strongest evidence supported increased LOS associated with perioperative risk factors.21,34,41,43-46,48,51,53-58

Lower socioeconomic status,14,39,41,59 female sex,21,34-36,38-41,43,45,46,48,53,60-63 and increased age21,22,35-41,43-46,48,51,53,54,59,63-65 were also risk factors for longer LOS.

**Readmission Outcomes**

Quality of evidence for the association between disease/indication for surgery and readmission was high but suggested no effect.66

**DISCUSSION**

In this systematic review, 20 risk factor categories were identified that are associated with health care utilization and cost for patients undergoing LEJR. These patient-level risk factors could be used in the development of

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**FIGURE 2.** Risk factors and outcomes. The association was considered large (2 arrows) when a relative association measure was greater than 2.0, otherwise the effect was considered smaller (single arrow). A sideways arrow indicates evidence of no effect. Brown, orange, and blue colors denote low-, moderate-, and high-quality evidence, respectively.
a risk-adjustment or risk-stratification method used by the CMS and other payers. Building on claims-based risk-adjustment approaches currently used by the CMS, including the Hierarchical Condition Category diagnostic classification method, inclusion of risk factors identified via systematic approaches such as this may facilitate the development of more robust risk-adjustment approaches to guide appropriate payment policies. By incorporating risk adjustment as part of LEJR payments, it could decrease the risk of adverse selection while promulgating the development and uptake of alternative payment models.

Strengths of this study include a rigorous method for the search strategy and inclusion of studies. This study has several limitations. First, the search included only studies focused on the total joint replacement population and, therefore, missed risk factors from the broader literature on surgery-associated utilization and cost not specific to LEJR. For example, we identified no studies meeting the inclusion criteria evaluating the effect of a patient’s

| Risk factor         | Outcome | Example study | Quantitative estimates                                                                 |
|---------------------|---------|---------------|----------------------------------------------------------------------------------------|
| Age                 | Cost    | Cram et al,° 14 2015 | 1.06% (95% CI, 1.03%-1.08%) increase in Medicare payments for entire episode of care associated with 1-y increase in age |
|                     | LOS     | Bou Monsef and Boettner;° 53 2014 | Mean ± SD LOS: <60 y: 3.2±1.2 d; 60-69 y: 3.3±1.2 d; 70-79 y: 3.5±1.2 d; ≥80 y: 3.8±1.6 d; P value from Kruskal-Wallis test<.0001 |
| Comorbidities       | Cost    | Cram et al,° 14 2015 | 5.10% (95% CI, 5.03%-5.17%) increase in Medicare payments for entire episode of care associated with 1 additional comorbidity |
|                     | LOS     | Stundner et al,° 19 2013 | Odds ratio for prolonged LOS: Depression: 1.28 (95% CI, 1.22-1.35); Anxiety: 1.20 (95% CI, 1.15-1.25); Depression and anxiety: 1.79 (95% CI, 1.33-2.40) |
| Obesity             | Cost    | D’Apuzzo, et al° 28 2015 | Mean total cost (range): Nonobese: $14,715 ($31-$305,526); Morbidly obese: $15,174 ($24-$121,202); P<.001 |
| Perioperative risk factors | LOS | Bou Monsef and Boettner;° 53 2014 | Mean ± SD LOS by anticoagulant drug use: Aspirin: 3.3±1.1 d; Coumadin: 3.6±1.1 d; Aspirin + coumadin: 3.6±1.4d |
| Socioeconomic status | LOS     | Styron et al,° 39 2011 | Increased LOS by income; P value for no difference from reference category: ≥$45,000 (reference) ≤$25,000: 4% higher; P=.008 ≤$25,000 to $34,999: 1% higher; P=.012 ≤$35,000-$44,999: 1% higher; P=.013 |
| Severity of disease | Cost    | Adrados et al,° 25 2015 | Costs for hip replacement by severity of illness: Minor: $19,072 (95% CI, $18,863-$19,281); Moderate: $20,542 (95% CI, $20,329-$20,744); Major: $27,159 (95% CI, $6646-$27,672); Extreme: $43,626 (95% CI, $42,153-$45,099) |
| Sex (female)        | LOS     | Bou Monsef and Boettner;° 53 2014 | Mean ± SD LOS by sex: Male: 3.3±1.3 d; Female: 3.5±1.2 d; P>.0001 from Wilcoxon rank sum test |

LOS = length of stay.
previous health care costs, which have been shown to be associated with future health care costs.67-70 Second, risk factors and outcomes were abstracted as they were found in the literature and then were grouped into thematic categories. Other researchers might have created different groupings that could change the evidence quality ratings. Third, although the inclusion criteria were based broadly on the CJR program bundle definition, studies meeting the inclusion criteria do not precisely replicate the population and time horizon captured in the CJR program bundled payment. For example, a study examining costs only within a 30-day window would meet the inclusion criteria for the present study, whereas the CJR program bundle definition uses a 90-day window. Finally, the abstracted data were too heterogeneous to pool for meta-analysis. These limitations do not affect the success of the primary aim of this study: to apply a scientifically rigorous method to identify candidate risk factors to include in models testing risk-adjustment methods for bundled payments.

This study responds to an immediate need for information in a rapidly shifting payment policy environment. Under the CJR program, hospitals selected for participation are subject to price setting that excludes sophisticated risk adjustment methods. The CMS has acknowledged that the absence of a model developed for or specified to the CJR program bundled payment context was a factor in excluding risk adjustment from price setting.3 A study by Ellimoottil et al5 determined that with the application of claims-based risk adjustment (CMS Hierarchical Condition Category), hospitals with the least medically complex patient populations could experience a reduction in annual payments by as much as $146,360. Conversely, hospitals with the most medically complex patient populations could experience reconciliation payment increases by as much as $114,184. This study suggests that risk adjustment is needed to ensure that hospitals will not be penalized for providing care to medically complex patients.13

A large body of evidence examines the association between patient-level risk factors and increased utilization and cost in LEJR. We identified key risk factors from high-quality studies that should be further evaluated in target pricing for bundled payments. This study serves as the basis for ongoing work to develop and test more comprehensive risk-adjustment models for LEJR.

SUPPLEMENTAL ONLINE MATERIAL Supplemental material can be found online at http://www.mcpiqojournal.org. Supplemental material attached to journal articles has not been edited, and the authors take responsibility for the accuracy of all data.

Abbreviations and Acronyms: ADL/IADL = activity of daily living/instrumental activity of daily living; APR-DRG = All Patient Refined Diagnosis Related Group; ASA = American Society of Anesthesiologists; BMI = body mass index; CJR = Comprehensive Care for Joint Replacement; CMS = Centers for Medicare and Medicaid Services; LEJR = lower extremity joint replacement; LOS = length of stay

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REFERENCES

1. Kurtz S, Ong K, Lau E, et al. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am. 2007;89(4):780-785.
2. Siddiqi A, White PB, Mistry JR, et al. Effect of bundled payments and health care reform as alternative payment models in total joint arthroplasty: a clinical review. J Arthroplasty. 2017;32(8):2590-2597.
3. Department of Health and Human Services. Medicare program; comprehensive care for joint replacement payment model for acute care hospitals furnishing lower extremity joint replacement services; final rule. Fed Regist. 2015;80(226):73323-73324.
4. American Health Care Association. Comprehensive Care for Joint Replacement (CJR) final rule summary. https://www.ahcancal.org/facility_operations/medicare/Documents/AHCA%20Summary%20of%20CJR%20Final%20Rule.pdf. Accessed July 9, 2018.
5. Parker JC. Cherry picking in ESRD: an ethical challenge in the era of pay for performance. Semin Dial. 2011;24(1):3-8.
6. Ferrara ML, Johnson DW, Elpem DJ. Cherry picking in the ‘Aina: inequalities of access to dermatologic care in Hawai‘i. Hawai‘i Med Public Health. 2015;74(6):197-199.
7. Cram P, Pham HH, Bayman L, et al. Insurance status of patients admitted to specialty cardiac and competing general hospitals: are accusations of cherry picking justified? Med Care. 2008;46(3):467-475.
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8. Ellimoottil C, Ryan AM, Hou H, et al. Medicare’s new bundled payment for joint replacement may penalize hospitals that treat medically complex patients. Health Aff (Millwood). 2016;35(9):1651-1657.

9. Centers for Medicare & Medicaid Services. Comprehensive care for joint replacement payment model for acute care hospitals furnishing lower extremity joint replacement services; final rule. Fed Regist. 2015;80(226):73274-73554.

10. Grading of Recommendations Assessment, Development and Evaluation. GRADE website, http://www.gradeworkinggroup.org/. Accessed July 9, 2018.

11. Maradit Kremers H, Visscher SL, Kremers WK, et al. The effect of obesity on direct medical costs in total knee arthroplasty. J Bone Joint Surg Am. 2014;96(9):718-724.

12. Vincent HK, Vincent KR, Lee LW, et al. Effect of obesity on inpatient rehabilitation outcomes following total knee arthroplasty. J Orthop Pract. 2007;21(2):182-190.

13. Vincent HK, Vincent KR. Obesity and inpatient rehabilitation outcomes following knee arthroplasty: a multicenter study. Obesity (Silver Spring). 2008;16(1):30-136.
49. Paxton EW, Inacio MCS, Singh JA, et al. Are there modifiable risk factors for hospital readmission after total hip arthroplasty in a US healthcare system? Clin Orthop. 2015;473(1):3446-3455.

50. Schaeffer JF, Scott DJ, Godin JA, et al. The association of ASA class on total knee and total hip arthroplasty readmission rates in an academic hospital. J Arthroplasty. 2015;30(5):723-727.

51. Schneider M, Kawahara I, Ballantyne G, et al. Predictive factors influencing fast track rehabilitation following primary total hip and knee arthroplasty. Arch Orthop Trauma Surg. 2009;129(12):1585-1591.

52. Tellisi N, Abusitta G, Fernandes R, et al. Blood transfusion following primary hip arthroplasty: a review of transfusion practice. Eur J Orthop Surg Traumatol. 2007;17(5):457-460.

53. Bou Monsef J, Boettner F. Blood management may have an impact on length of stay after total hip arthroplasty. HSS J. 2014;10(2):124-130.

54. Freedman J, Luke K, Escobar M, et al. Experience of a network of transfusion coordinators for blood conservation (Ontario Transfusion Coordinators [ONTraC]). Transfusion. 2008;48(2):237-250.

55. Klika AK, Myers T, Szubski CR, et al. Early postoperative outcomes of primary total knee arthroplasty after solid organ transplantation in the United States, 1998-2011. J Arthroplasty. 2015;30(10):1716-1723.

56. March LM, Cross M, Tribe KL, et al. Two knees or not two knees? patient costs and outcomes following bilateral and unilateral total knee joint replacement surgery for OA. Osteoarthritis Cartilage. 2004;12(5):400-408.

57. Poultsides L, Mermoutsous S, Gonzalez Della Valle A, et al. Perioperative morbidity and mortality of same-day bilateral TKAs: incidence and risk factors. Clin Orthop Relat Res. 2011;469(1):111-120.

58. Suleiman UI, Edelstein AI, Thompson RM, et al. Perioperative outcomes following unilateral versus bilateral total knee arthroplasty. J Arthroplasty. 2015;30(1):1927-1930.

59. Cookson R, Laudicella M. Do the poor cost much more? the relationship between small area income deprivation and length of stay for elective hip replacement in the English NHS from 2001 to 2008. Soc Sci Med. 2011;72(2):173-184.

60. Doh R, Dimick J, Wainess R, et al. Hospital volume and inpatient mortality outcomes of total hip arthroplasty in the United States. J Arthroplasty. 2006;21(suppl 2):10-16.

61. Faber JC, Hardin SR. Outcomes of knee replacement patients using autotransfusion. Orthop Nurs. 2010;29(5):333-337.

62. Turkri ASA, Dakhil YA, Turkri AA, et al. Total knee arthroplasty: effect of obesity and other patients' characteristics on operative duration and outcome. World J Orthop. 2015;6(2):284-289.

63. Le Mar KJ, Whitehead D. Preoperative indicators of length of stay following total hip arthroplasty: a New Zealand-based retrospective, observational study. J Clin Nurs. 2014;23(13-14):2022-2030.

64. Clement ND, MacDonald D, Howie CR, et al. The outcome of primary total hip and knee arthroplasty in patients aged 80 years or more. J Bone Joint Surg Br. 2011;93(9):1265-1270.

65. Smith IDM, Elton R, Ballantyne JA, et al. Pre-operative predictors of the length of hospital stay in total knee replacement. J Bone Joint Surg Br. 2008;90(11):1435-1440.

66. Liao C-Y, Chan H-T, Chao E, et al. Comparison of total hip and knee joint replacement in patients with rheumatoid arthritis and osteoarthritis: a nationwide, population-based study. Singapore Med J. 2015;56(1):58-64.

67. Ash AS, Zhao Y, Ellis RP, et al. Finding future high-cost cases: comparing prior cost versus diagnosis-based methods. Health Serv Res. 2001;36(6):194-206.

68. Maciejewski ML, Liu CF, Derleth A, et al. The performance of administrative and self-reported measures for risk adjustment of Veterans Affairs expenditures. Health Serv Res. 2005;40(3):887-904.

69. Newhouse JP, Manning WG, Keeler EB, et al. Adjusting capitation rates using objective health measures and prior utilization. Health Care Financ Rev. 1989;10(3):1-54.

70. Robst J. Developing models to predict persistent high-cost cases in Florida Medicaid. Popul Health Manag. 2015;18(6):467-476.