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Changes in Discharge to Rehabilitation: Potential Unintended Consequences of Medicare THA/TKA Bundled Payments Should They Be Implemented on a Nationwide Scale

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Abstract

Introduction: As a part of the 2010 ACA, Medicare committed to changing 50% of its reimbursement to alternative payment models by 2018. One strategy included introduction of “bundled payments” or a fixed price for an episode of care. Early studies of the first operative bundles for elective total hip and knee arthroplasty (THA/TKA) suggest changes in discharge to rehabilitation. It remains unclear the extent to which such changes affect patient well-being. In order to address these concerns, the objective of this study was to estimate projected changes in discharge to various type of rehabilitation, 90-day outcomes, extent of therapy received, and patient health-related quality-of-life before and after introduction of bundled payments should they be implemented on a nationwide scale.

Methods: A nationwide policy simulation was conducted using decision-tree methodology in order to estimate changes in overt and patient-centered outcomes. Model parameters were informed by published research on bundled payment effects and anticipated outcomes of patients discharged to various types of rehabilitation.

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Results: Following bundled payment introduction, discharge to inpatient-rehabilitation facilities decreased by 16.9 percentage-points (95%CI: 16.5-17.3-16.5) among primary TKA patients (THA: 16.8 percentage-points), a relative decline from baseline of 58.9%. Skilled-nursing facility use fell by 24.0 percentage-points (95%CI: 23.6-24.4). It was accompanied by a 36.7 percentage-point (95%CI: 36.3-37.2) increase in home-health agency use. While simulation models predicted minimal changes in overt outcome measures such as unplanned readmission (TKA: +0.8 percentage-points), changes in discharge-disposition were accompanied by significant increases in the need for further assistive care (TKA: +8.0 percentage-points) and decreases in patients' functional recovery and extent of therapy received. They collectively accounted for a 30% reduction in recovered motor gains.

Conclusion: The results demonstrate substantial changes in discharge to rehabilitation with accompanying declines in average functional outcomes, extent of therapy received, and health-related quality-of-life. Such findings challenge notions of reduced cost at no harm previously attributed to the bundled payment program and lend credence to concerns about reductions in access to facility-based rehabilitation.

Keywords

Bundle; bundled payment; rehabilitation; Medicare; quality of life; physical therapy; Comprehensive Care for Joint Replacement; Bundled Payment for Care Improvement; THA/TKA

Introduction

As a part of the 2010 Patient Protection and Affordable Care Act (ACA), the Centers for Medicare and Medicaid Services (CMS) committed to changing 50% of their Medicare reimbursement to alternative payment models by 2018. One strategy included the introduction of “bundled payments” or a fixed price for an episode of care. The idea behind the bundled-payment initiative was to promote improved care-coordination and enhanced efficiency. Bundled payments for total hip and total knee arthroplasty (THA/TKA) were among the first operative episodes that CMS considered.¹

Early evaluation of THA/TKA bundled payments suggest significant cost savings for Medicare on the order of \$1,200⁶ to \$1,900⁷ per patient. Studies report minimal changes in overt outcomes such as unplanned readmission and Emergency Department (ED) visits without subsequent hospitalization but also an apparent drop in discharge to facility-based rehabilitation.^{3,6-11} The latter change is concerning given known associations between access to post-discharge rehabilitation and functional recovery following THA/TKA for more complex cases.¹²⁻¹⁵ There remains limited understanding of the impact that changes in discharge to rehabilitation might have, especially among older and frailer orthopaedic patients. It is possible that in a well-intended effort to streamline care, Medicare beneficiaries with greater medical, psychosocial, and functional complexity are being increasingly diverted away from skilled-nursing facilities (SNF) and inpatient-rehabilitation facilities (IRF) toward less expensive home-based and outpatient care.¹²⁻¹⁵ Such a trend, if true, raises important questions about bundled payments' impact on the well-being of patients.

The objective of this study was to begin to answer these questions by using simulation modeling and an extensive body of prior research on the anticipated outcomes of THA/TKA patients discharged to various types of post-discharge rehabilitation^{16–31} in order to estimate projected changes in: (1) discharge to specific types of rehabilitation; (2) post-discharge outcomes including 90-day unplanned readmission, 90-day ED visit(s) without subsequent hospitalization, 90-day complication(s), need for further assistive care, number of facility-based rehabilitation days, and ambulation distance; (3) characteristics of rehabilitation therapy received; and (4) patients' health-related quality-of-life before and after THA/TKA bundled payments should they be implemented among Medicare beneficiaries on a nationwide scale.

Methods

Using decision-tree methodology, we modeled the probability of transitions between defined health states from hospital admission through discharge under four conditions: (1) primary THA prior to bundled payment enrollment ("pre-policy implementation"), (2) primary THA after bundled payment enrollment ("post-policy implementation"), (3) primary (unilateral) TKA after bundled payment enrollment ("pre-policy implementation"), and (4) primary (unilateral) TKA after bundled payment enrollment ("post-policy implementation"). Base models outlined in Figure 1A for each of the four conditions were used to estimate the probability of discharge to various types of rehabilitation, including IRF, SNF, home-health agency (HHA), and discharge home without further assistance.

Discharge distributions before and after bundled payment enrollment

While multiple studies report discharge distributions prior to bundled payment implementation,^{6,8} enabling a relatively consistent estimate of baseline discharge dispositions to be found, only a single-center report⁸ provided distributions of discharge dispositions after enrollment. Information from these studies was used to define expected probabilities of discharge to various types of rehabilitation among Medicare beneficiaries before (FY2012) and after (FY2014) hypothetical enrollment on a nationwide scale. Model distributions were based on information for Medicare's Bundled Payment for Care Improvement Model 2.¹ In order to account for potential bias as a result of using the single center post-policy implementation discharge distribution in the model, a set of sensitivity analyses was conducted in which the post-policy implementation probability of discharge to facility-based rehabilitation was increased and decreased by a relative 5%, 10%, and 20%.

Progression from hospital admission to discharge

Progression of THA/TKA patients through the hospital was modeled using two sets of national 90-day care pathways for unilateral primary (1) THA and (2) TKA outlined by Nichols and Vose³² in their 2009–2013 assessment of data on 159,390 primary THA and 323,803 primary TKA patients contained within the Truven Health Analytics' MarketScan research databases (mean ages 62.5±11.6 and 63.5±9.8 years, respectively). The simplified care continuums accounted for differences in patients' probabilities of discharge to different types of rehabilitation based on differences in the presence of pre-existing medical conditions, occurrence of in-hospital complications, and need for allogenic/autologous

transfusions. The resultant pathway stages provided with consistent cohort-specific progression probabilities of primary THA and TKA patients through the hospital system. They were used to define the initial part of the model outlined in Figure 1A.

In order to account for differences in the probability of discharge to rehabilitation between MarketScan patients and the results observed among Medicare beneficiaries aged 65 years, ^{6,8} discharge disposition probabilities from Nichols and Vose³²'s primary THA and TKA care pathways were scaled to match the relative distributions of discharge dispositions reported among Medicare beneficiaries before and after bundled payment enrollment.^{6,8} Population sizes for each model were set in accordance with the approximate annual number of primary THA ($n=111,000$)³³ and TKA ($n=250,000$)³⁴ operations meeting the same criteria performed/reported in 100% Medicare fee-for-service data. Transition matrices for each of the four base models are reported in Supplemental Table 1.

Defining dichotomous and continuous outcomes based on base model discharge dispositions

Anticipated changes in post-discharge outcomes including 90-day unplanned readmission, 90-day ED visit(s) without subsequent hospitalization, 90-day complication(s), need for further assistive care, number of facility-based rehabilitation days, and ambulation distance; characteristics of therapy received; and patients' health-related quality-of-life were taken from a body of experimental and observational literature published based on known differences in THA and TKA patients' utilization of different types of post-discharge rehabilitation.^{16–31} Specific references for abstracted probabilities and anticipated mean values are presented in Supplemental Table 2. In order to account for differences in the complexity of case-mix among patients discharged to IRF, SNF, HHA, and home without further assistance, where possible, all dichotomous outcomes (binary yes/no values, *e.g.* need for a subsequent ED visit) included in the extended models and all continuous outcomes (values measured on a numerical scale, *e.g.* ambulation distance in feet) assigned as mean values based on the outcomes of the base models (see Figure 1A) were taken from studies that reported risk-adjusted outcome measures among matched patients, risk-adjusted regression models, or the results of randomized controlled trials.^{16–31} Example transition matrices for each of the extended dichotomous models are presented for TKA patients during the pre-policy implementation period in Supplemental Table 3.

Predicted changes in therapy characteristics included: overall therapy intensity defined as the total number of therapy minutes divided by the total number of therapy days, total amount of occupational therapy (OT) time in minutes, total amount of physical therapy (PT) time in minutes, total amount of psychological counseling in minutes, total number of OT days, total number of PT days, and total number of psychological counseling days. Measures of health-related quality-of-life included: Functional Independence Measure (FIM) motor score (possible range 13-91 with higher values indicating better scores),^{35–38} transformed SF-12 Physical Component Score (possible range 0-100 with higher values indicating better scores),³⁹ transformed SF-12 Mental Component Score (possible range 0-100 with higher values indicating better scores),³⁹ overall FIM motor gains from the time of surgery through

post-discharge follow-up, FIM motor gains achieved during facility-based rehabilitation, and FIM motor gains achieved after discharge or outside of facility-based rehabilitation.

Testing variability in the model & statistical analyses

In order to assess the extent of variability in the model, we performed 50, 100, and 1,000 random Monte Carlo simulations of each of the base models using population sizes equal to the approximate annual national Medicare population for each operation. Average point-estimates did not appreciably differ (Supplemental Figure 1). For this reason, differences in extended dichotomous outcomes and continuous post-discharge outcomes were reported using the most computationally-conservative approximation with the widest variation based on 50 runs through the model.

Model output was analyzed using a steady-state approximation with absolute differences in pre- and post-policy implementation compared using independent univariate descriptive statistics and an allowable two-sided alpha of 0.05. This resulted, for continuous post-discharge outcomes, in an assessment of the absolute difference in estimated means during the pre- and post-policy implementation periods (*mean value post-mean value pre*). For dichotomous outcomes, it resulted in an estimate of the absolute difference in probabilities (*probability post-probability pre*). Relative differences in probabilities were calculated after simulation as the ratio of probabilities during the post- and pre-policy implementation periods.

All simulations were conducted using PyCharm Professional 2018.1 running Python 3.6.5. The study did not involve any human subjects or patient data and, as such, was exempt from institutional review board review.

Results

Base model results: Changes in discharge disposition

Simulated changes in discharge to various types of rehabilitation before and after bundled payment enrollment are presented in Table 1. Under the parameters specified in the base model, discharge to IRF decreased by an absolute value of 16.9 percentage-points among primary TKA patients (95%CI: 16.5-17.3), a relative decline from baseline of 58.9%. Among primary THA patients, discharge to IRF decreased by 16.8 percentage-points (95%CI: 16.2-17.4). SNF use fell by 24.0 percentage-points (TKA 95%CI: 23.6-24.4). This was offset by an absolute 36.7 percentage-point (TKA 95%CI: 36.3-37.2) increase in HHA use, a relative increase from baseline of 126.6%. Discharge home with no formal rehabilitation increased by 4.2 percentage-points (TKA 95%CI: 3.9-4.4), resulting in a relative increase from baseline of 63.6%. Results for THA patients were similar (Table 1).

Sensitivity analysis: Potential over-/under-specification of post-policy discharge distributions

Decreasing potential post-policy implementation discharge to facility-based rehabilitation by a relative 5%, 10%, and 20% increased the magnitude of predicted changes in discharge to IRF among primary TKA patients to absolute values of 17.5, 18.1, and 19.3 percentage-

points (Figure 1B). Increasing potential post-policy implementation discharge to facility-based rehabilitation by a relative 5%, 10%, and 20% decreased the magnitude of predicted changes in discharge to IRF to absolute values of 16.3, 15.7, and 14.6 percentage-points. This corresponded to absolute predicted declines in discharge to SNF that ranged from 21.7 to 26.3 percentage-points and absolute predicted increases in discharge to HHA that ranged from 32.1 to 41.4 percentage-points. Results among primary THA patients were similar. Complete distributions are presented in Figure 1B.

Changes in unplanned healthcare utilization

Predicted changes in post-discharge outcomes are presented in Table 2. Consistent with prior literature,^{3,6–11} models predicted minimal changes in overt outcomes. Among primary TKA patients, unplanned readmissions within 90 days were found to increase by an absolute value of 0.8 percentage-points (95%CI: 0.5-1.1), a relative increase of 9.0% from a baseline value of 8.9%. Among primary THA patients, unplanned readmissions increased by 1.1 percentage-points (95%CI: 0.7-1.5). ED visits without subsequent hospitalization followed a similar trend, increasing by a modest absolute value of 3.1 percentage-points (95%CI: 2.8-3.4) among primary TKA patients, a relative increase from baseline of 35.9%. ED visits showed no difference for primary THA patients (95%CI: 0.0-0.5 percentage-points). Changes in complications also demonstrated minimal policy effect with predicted absolute increases of 0.7 (95%CI: 0.3-1.0) and 1.1 (95%CI: 0.5-1.6) percentage-points.

Where outcomes began to diverge was in the need for further assistive care, which increased following bundled payment enrollment by 8.0 percentage-points (95%CI: 7.5-8.4) among primary TKA patients, a relative increase from baseline of 11.8%. Among primary THA patients, the need for further assistive care increased by 7.9 percentage-points (95%CI: 7.2-8.5). Following reductions in discharge to facility-based rehabilitation, the predicted mean number of facility-based rehabilitation days also declined, dropping by an absolute average of 6.5 days among both primary TKA and THA patients. This was accompanied by average declines of 37.6 and 37.2 feet in anticipated ambulation distance at the end of 90 days.

Changes in rehabilitation utilization

Predicted changes in therapy characteristics are presented in Table 3. With a shift toward increased utilization of home-health and outpatient rehabilitation (and an increased percentage of patients discharged home without any further assistance), the model saw a consistently significant decline in the intensity and duration of post-discharge rehabilitation. Among primary TKA patients, the overall intensity of therapy decreased by a predicted mean value of 34.7 min/rehabilitation day (95%CI: 34.3-35.1). Total OT exposure decreased by 192.3 minutes (190.0-194.5), and total PT exposure decreased by 110.5 minutes (108.7-112.3). Among primary THA patients, overall therapy intensity decreased by 34.4 min/rehabilitation day (95%CI: 33.7-35.0). Total OT exposure decreased by 190.4 minutes (95%CI: 187.1-193.8), and total PT exposure decreased by 109.2 minutes (95%CI: 106.6-111.9). The number of OT, PT, and psychological counseling days also declined.

Changes in functional and quality-of-life outcomes

Predicted changes in health-related quality-of-life are presented in Table 3. On average, overall physical health-related quality-of-life was predicted to modestly decrease, dropping by a relative 5.6% (absolute value: -2.7 units) on the transformed Physical Component Score of the SF-12 for both primary TKA and THA patients. Transformed SF-12 Mental Component Scores decreased by a relative 4.5% (absolute value: -1.9 units). Functional motor independence as measured by the FIM motor score decreased overall by an average value of 3.2 units (95% CIs TKA: 3.1-3.3, THA: 3.1-3.3 units). This resulted in an overall loss of FIM motor gains from the time of surgery of 9.2 units (95% CI: 9.1-9.3) for primary TKA and 9.1 units (95% CI: 8.9-9.3) for primary THA, relative decreases from baseline of 28.2% and 27.7%.

Discussion

This study modeled changes in post-acute care utilization and subsequent implications of nationwide bundled payment implementation among Medicare patients. The results of the 90-day episodic models show a substantial shift in discharge disposition among primary THA and TKA patients that appears to be driving complex cases away from facility-based post-acute care settings and into home health and outpatient settings. Such a change in discharge disposition has been identified as a primary driver of reduced joint-replacement episode costs.⁶⁻¹¹ Early studies of bundled payment-related effects suggest that this shift is associated with only minimal changes in overt outcome measures.^{3,6-11} The results of our simulation models agree, pointing toward slightly increased risks of readmission, complication(s), and ED visit(s) within a THA/TKA patient's first 90 post-operative days. More concerning was the apparent negative impact on patient outcomes. Increases in the need for further assistive care and decreases in the extent of functional recovery paralleling decreases in the extent of therapy received were all present; they negatively affected patients' health-related quality-of-life. The results of the simulation models collectively suggest that prior to widespread adoption of THA/TKA bundled payments on a national scale, careful attention needs to be paid to potential unintended consequences of the program. Further research on observed patient data throughout the 90-day episode of care is encouraged, using our simulated data for hypothesis generation, in order to determine the impact that changes in discharge disposition have on functional outcomes and surgical satisfaction among THA and TKA patients.

Beyond modeling potential changes were THA/TKA bundled payments to be implemented on a nationwide scale, the study also builds on what is known about bundled payment effects by disaggregating discharge into various types of rehabilitation and accounting for projected changes in the medical complexity of patients discharged to rehabilitation as bundled payment utilization expands. IRF use is projected to decrease by approximately 17 percentage-points, SNF utilization by 24 percentage-points. These changes are anticipated to be mirrored by a 37 percentage-point increase in HHA utilization, suggesting that nearly all patients diverted from post-acute care facilities are likely to utilize home-health care. This is a novel finding, one that has important implications for access to and provision of HHA services. A recent study of Medicare patients reported an absolute 10 percentage-point

reduction in the total number of rehabilitation visits received by THA/TKA patients discharged to HHA in rural versus urban areas.⁴⁰ If the bundled payment program continues to grow beyond the confines of larger urban centers where it is currently primarily based, the US will have to grapple with ensuring adequate access to HHA care or employing alternative models in rural areas such as the use of rehabilitation telemedicine.^{41–44} Bearing these changes in mind, future studies are encouraged to address the extent to which variations in geography and changes in the practice of joint replacement over time influence overt and functional outcomes within the bundled payment program as well as corresponding shifts in the utilization of standalone ambulatory surgical centers versus hospital-based procedures and rates of, for example, unilateral compartment replacements versus total arthroplasty.

The finding of significant reductions in overall therapy intensity coupled with reduced exposure to PT and OT time is troubling. Over the course of a 90-day episode of care, the model predicted a nearly 300-minute decrease in exposure to post-discharge rehabilitation. Such a change could explain the corresponding projected reductions in SF-12 and FIM motor scores as well as the anticipated 35-foot reduction in walking distance that patients were able to achieve during rehabilitation. While small in magnitude, such changes likely represent meaningful alterations in functional independence for patients. A single unit change on a quality-of-life scale like the SF-12/FIM can be the difference between walking with a cane and walking unaided without an assistive device or between needing help bathing and being able to perform the task independently. It remains unclear whether predicted changes in functional outcomes are substantial enough to influence later disability and healthcare utilization. A lack of changes in overt outcome measures suggests that the change is likely to be primarily observed in the day-to-day lived experience of patients.^{3,6–11}

From a policy perspective, recognition of the need to account for patient experience is not new, particularly for elective THA and TKA patients.^{45–48} As Medicare's bundled payment program and other alternative payment models continue to become more prevalent in Medicare reimbursement schemes, there is growing recognition of a need for patient-reported outcome measures (PROMs) capable of capturing patients' broader experience of care. While potentially unfeasible on a nationwide scale, Medicare has already begun experimenting with the introduction of PROMs in regional trials though funding to hospitals participating in accountable care organizations.^{45,46} As it grows, the bundled payment program might benefit from more focused tracking and reporting of PROMs in order to further capture patient perceptions of care. When assigning payments, the bundled payment program needs to remain aware of patient-level differences in severity, frailty, and underlying comorbidities that drive differences in functional outcomes, quality of life, and justifiable utilization of post-discharge care. Fear of financial penalty should not enable unilateral discounting of these issues in the face of minimal changes in overt outcome measures.

This study is not without limitations, the largest of which comes from its reliance on simulated data. The results of the study were drawn from probabilistic models and Monte Carlo simulation with parameters informed by limited prior data. Through sensitivity analyses and careful selection of included studies, we attempted to explore and control for

potential variability and bias in our estimates. However, the results should still be interpreted for what they are: an estimate of what could happen given what we have currently observed. Future studies are both needed and encouraged to explore the veracity of these findings, particularly as they relate to changes in the functional recovery and lived-experience of THA/TKA patients and potential geographic variability in HHA access should the bundled payment program expand.

In creating a model, our goal was to estimate average patient-level changes in post-discharge outcomes as a result of potential expansion of bundled payments. The model predicted substantial changes in discharge to rehabilitation with significant accompanying declines in average functional outcomes, extent of therapy receipt, and health-related quality-of-life. Such findings challenge notions of reduced cost at no harm previously attributed to the THA/TKA bundled payment program and lend credence to concerns voiced about observed reductions in access to facility-based rehabilitation.^{12–15} As the program continues to develop, caution is warranted until we more clearly understand the impact of changes in discharge to rehabilitation and its potential unintended consequences on the lives of one of the country's largest populations of elective surgical patients.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

- Centers for Medicare & Medicaid Services. Comprehensive Care for Joint Replacement Model. 2018 <https://innovation.cms.gov/initiatives/cjr> Accessed December 7, 2018.
- Centers for Medicare & Medicaid Services. Comprehensive Care for Joint Replacement Model Policy Changes and Cancellation of Episode Payment Models and Cardiac Rehabilitation Incentive Payment Model (CMS-5524-F and IFC). 2017 <https://www.cms.gov/newsroom/fact-sheets/comprehensive-care-joint-replacement-model-policy-changes-and-cancellation-episode-payment-models> Accessed September 30, 2018.
- Finkelstein A, Ji Y, Mahoney N, Skinner J. Mandatory Medicare Bundled Payment Program for Lower Extremity Joint Replacement and Discharge to Institutional Postacute Care: Interim Analysis of the First Year of a 5-Year Randomized Trial. *JAMA*. 2018;320(9):892–900. [PubMed: 30193277]
- Navathe AS, Liao JM, Dykstra SE, et al. Association of Hospital Participation in a Medicare Bundled Payment Program With Volume and Case Mix of Lower Extremity Joint Replacement Episodes. *JAMA*. 2018;320(9):901–910. [PubMed: 30193276]
- Siddiqi A, White PB, Mistry JB, 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. [PubMed: 28438453]
- Dummit LA, Kahvecioglu D, Marrufo G, et al. Association Between Hospital Participation in a Medicare Bundled Payment Initiative and Payments and Quality Outcomes for Lower Extremity Joint Replacement Episodes. *JAMA*. 2016;316(12):1267–1278. [PubMed: 27653006]

7. Navathe AS, Troxel AB, Liao JM, et al. Cost of Joint Replacement Using Bundled Payment Models. *JAMA Intern Med.* 2017;177(2):214. [PubMed: 28055062]
8. Iorio R, Clair AJ, Inneh IA, Slover JD, Bosco JA, Zuckerman JD. Early Results of Medicare's Bundled Payment Initiative for a 90-Day Total Joint Arthroplasty Episode of Care. *J Arthroplasty.* 2016;31(2):343–350. [PubMed: 26427938]
9. Courtney PM, Ashley BS, Hume EL, Kamath AF. Are Bundled Payments a Viable Reimbursement Model for Revision Total Joint Arthroplasty? *Clin Orthop Relat Res.* 2016;474(12):2714–2721. [PubMed: 27357691]
10. Ellimoottil C, Miller S, Ayanian JZ, Miller DC. Effect of Insurance Expansion on Utilization of Inpatient Surgery. *JAMA Surg.* 2014;149(8):829–836. [PubMed: 24988945]
11. Dundon JM, Bosco J, Slover J, Yu S, Sayeed Y, Iorio R. Improvement in Total Joint Replacement Quality Metrics: Year One Versus Year Three of the Bundled Payments for Care Improvement Initiative. *J Bone Joint Surg Am.* 2016;98(23):1949–1953. [PubMed: 27926675]
12. McLawhorn AS, Buller LT. Bundled Payments in Total Joint Replacement: Keeping Our Care Affordable and High in Quality. *Curr Rev Musculoskelet Med.* 2017;10(3):370–377. [PubMed: 28741101]
13. Schroer WC, Diesfeld PJ, LeMarr AR, Morton DJ, Reedy ME. Hip Fracture Does Not Belong in the Elective Arthroplasty Bundle: Presentation, Outcomes, and Service Utilization Differ in Fracture Arthroplasty Care. *J Arthroplasty.* 2018;33(7S):S56–S60. [PubMed: 29622493]
14. Piccinin MA, Sayeed Z, Kozlowski R, Bobba V, Knesek D, Frush T. Bundle Payment for Musculoskeletal Care: Current Evidence (Part 1). *Orthop Clin North Am.* 2018;49(2):135–146. [PubMed: 29499815]
15. Piccinin MA, Sayeed Z, Kozlowski R, Bobba V, Knesek D, Frush T. Bundle Payment for Musculoskeletal Care: Current Evidence (Part 2). *Orthop Clin North Am.* 2018;49(2):147–156. [PubMed: 29499816]
16. Ponnusamy KE, Naseer Z, El Dafrawy MH, et al. Post-Discharge Care Duration, Charges, and Outcomes Among Medicare Patients After Primary Total Hip and Knee Arthroplasty. *J Bone Jt Surg.* 2017;99(11):e55.
17. Middleton A, Lin Y-L, Graham JE, Ottenbacher KJ. Outcomes Over 90-Day Episodes of Care in Medicare Fee-for-Service Beneficiaries Receiving Joint Arthroplasty. *J Arthroplasty.* 2017;32(9):2639–2647. [PubMed: 28476495]
18. Walsh MB, Herbold J. Outcome After Rehabilitation for Total Joint replacement at IRF and SNF: A Case-Controlled Comparison. *Am J Phys Med Rehabil.* 2006;85(1):1–5. [PubMed: 16357542]
19. Mahomed NN, Davis AM, Hawker G, et al. Inpatient Compared with Home-Based Rehabilitation Following Primary Unilateral Total Hip or Knee Replacement: A Randomized Controlled Trial. *J Bone Jt Surgery-American Vol.* 2008;90(8):1673–1680.
20. Chimenti CE, Ingersoll G. Comparison of Home Health Physical Therapy Outcomes Following Total Knee Replacement With and without Subacute Rehabilitation. *J Geriatr Phys Ther.* 2007;30(3):102–108. [PubMed: 18171493]
21. Bini SA, Fithian DC, Paxton LW, Khatod MX, Inacio MC, Namba RS. Does Discharge Disposition After Primary Total Joint Arthroplasty Affect Readmission Rates? *J Arthroplasty.* 2010;25(1):114–117. [PubMed: 19150214]
22. Lovald ST, Ong KL, Lau EC, Schmier JK, Bozic KJ, Kurtz SM. Mortality, Cost, and Downstream Disease of Total Hip Arthroplasty in Patients in the Medicare Population. *J Arthroplasty.* 2014;29(1):242–246. [PubMed: 23711799]
23. Tian W, DeJong G, Horn SD, Putman K, Hsieh C-H, DaVanzo JE. Efficient Rehabilitation Care for Joint Replacement Patients. *Med Decis Mak.* 2012;32(1): 176–187.
24. Fu MC, Samuel AM, Sculco PK, MacLean CH, Padgett DE, McLawhorn AS. Discharge to Inpatient Facilities After Total Hip Arthroplasty Is Associated With Increased Postdischarge Morbidity. *J Arthroplasty.* 2017;32(9):S144–S149. [PubMed: 28455181]
25. Keswani A, Tasi MC, Fields A, Lovy AJ, Moucha CS, Bozic KJ. Discharge Destination After Total Joint Arthroplasty: An Analysis of Postdischarge Outcomes, Placement Risk Factors, and Recent Trends. *J Arthroplasty.* 2016;31 (6): 1155–1162. [PubMed: 26860962]

26. DeJong G, Hsieh C-H, Gassaway J, et al. Characterizing Rehabilitation Services for Patients with Knee and Hip Replacement in Skilled Nursing Facilities and Inpatient Rehabilitation Facilities. *Arch Phys Med Rehabil.* 2009;90(8):1269–1283. [PubMed: 19651261]
27. DeJong G, Horn SD, Smout RJ, Tian W, Putman K, Gassaway J. Joint Replacement Rehabilitation Outcomes on Discharge From Skilled Nursing Facilities and Inpatient Rehabilitation Facilities. *Arch Phys Med Rehabil.* 2009;90(8): 1284–1296. [PubMed: 19651262]
28. DeJong G, Tian W, Smout RJ, et al. Use of Rehabilitation and Other Health Care Services by Patients With Joint Replacement After Discharge From Skilled Nursing and Inpatient Rehabilitation Facilities. *Arch Phys Med Rehabil.* 2009;90(8): 1297–1305. [PubMed: 19651263]
29. DeJong G, Tian W, Smout RJ, et al. Long-Term Outcomes of Joint Replacement Rehabilitation Patients Discharged From Skilled Nursing and Inpatient Rehabilitation Facilities. *Arch Phys Med Rehabil.* 2009;90(8):1306–1316. [PubMed: 19651264]
30. Mallinson TR, Bateman J, Tseng H-Y, et al. A Comparison of Discharge Functional Status After Rehabilitation in Skilled Nursing, Home Health, and Medical Rehabilitation Settings for Patients After Lower-Extremity Joint Replacement Surgery. *Arch Phys Med Rehabil.* 2011;92(5):712–720. [PubMed: 21530718]
31. Mallinson T, Deutsch A, Bateman J, et al. Comparison of Discharge Functional Status After Rehabilitation in Skilled Nursing, Home Health, and Medical Rehabilitation Settings for Patients After Hip Fracture Repair. *Arch Phys Med Rehabil.* 2014;95(2):209–217. [PubMed: 23850612]
32. Nichols CI, Vose JG. Clinical Outcomes and Costs Within 90 Days of Primary or Revision Total Joint Arthroplasty. *J Arthroplasty.* 2016;31(7):1400–1406. [PubMed: 26880328]
33. Kurtz SM, Lau EC, Ong KL, Adler EM, Kolisek FR, Manley MT. Hospital, Patient, and Clinical Factors Influence 30- and 90-Day Readmission After Primary Total Hip Arthroplasty. *J Arthroplasty.* 2016;31(10):2130–2138. [PubMed: 27129760]
34. Cram P, Lu X, Kates SL, Singh JA, Li Y, Wolf BR. Total Knee Arthroplasty Volume, Utilization, and Outcomes Among Medicare Beneficiaries, 1991–2010. *JAMA.* 2012;308(12): 1227–1236. [PubMed: 23011713]
35. Linacre JM, Heinemann AW, Wright BD, Granger CV, Hamilton BB. The Structure and Stability of the Functional Independence Measure. *Arch Phys Med Rehabil.* 1994;75(2):127–132. [PubMed: 8311667]
36. Hamilton BB, Laughlin JA, Fiedler RC, Granger CV. Interrater Reliability of the 7-level Functional Independence Measure (FIM). *Scand J Rehabil Med.* 1994;26(3): 115–119. [PubMed: 7801060]
37. Granger CV, Hamilton BB, Linacre JM, Heinemann AW, Wright BD. Performance Profiles of the Functional Independence Measure. *Am J Phys Med Rehabil.* 1993;72(2):84–89. [PubMed: 8476548]
38. Heinemann AW, Linacre JM, Wright BD, Hamilton BB, Granger C. Relationships Between Impairment and Physical Disability as Measured by the Functional Independence Measure. *Arch Phys Med Rehabil.* 1993;74(6):566–573. [PubMed: 8503745]
39. Ware J, Kosinski M, Keller SD. A 12-Item Short-Form Health Survey: Construction of Scales and Preliminary Tests of Reliability and Validity. *Med Care.* 1996;34(3):220–233. [PubMed: 8628042]
40. Falvey J, Bade M, Forster J, et al. Utilization of Home-Health Physical Therapy Improves Early Functional Recovery in Medicare Beneficiaries Following Total Knee Arthroplasty. *J Bone Jt Surg Am.* 2018 [In press].
41. Jhaveri MM, Benjamin-Garner R, Rianon N, et al. Telemedicine-Guided Education on Secondary Stroke and Fall Prevention Following Inpatient Rehabilitation for Texas Patients with Stroke and their Caregivers: A Feasibility Pilot Study. *BMJ Open.* 2017;7(9):e017340.
42. Eichler S, Rabe S, Salzwedel A, et al. Effectiveness of an Interactive Telerehabilitation System with Home-base Exercise Training in Patients After Total Hip or Knee Replacement: Study Protocol for a Multicenter, Superiority, No-blinded Randomized Controlled Trial. *Trials.* 2017;18(1):438. [PubMed: 28934966]
43. Nelson MJ, Crossley KM, Bourke MG, Russell TG. Telerehabilitation Feasibility in Total Joint Replacement. *Int J telerehabilitation.* 2017;9(2):31–38.
44. Rybarczyk Y, Kleine Deters J, Cointe C, Esparza D. Smart Web-Based Platform to Support Physical Rehabilitation. *Sensors.* 2018;18(5):1344.

45. Centers for Medicare & Medicaid Services. Next Steps in Measuring Quality of Care in Medicare (Report Fo the Congress: Medicare and the Health Care Delivery System).; 2015 <http://www.medpac.gov/docs/default-source/reports/chapter-8-next-steps-in-measuring-quality-of-care-in-medicare-june-2015-report-.pdf?sfvrsn=0> Accessed September 30, 2018.
46. Ayers DC. Implementation of Patient-reported Outcome Measures in Total Knee Arthroplasty. J Am Acad Orthop Surg. 2017;25:S48–S50. [PubMed: 27941415]
47. Hung M, Saltzman CL, Greene T, et al. Evaluating Instrument Responsiveness in Joint Function: The HOOS JR, the KOOS JR, and the PROMTS PF CAT. J Orthop Res. 2017;36(4): 1178–1184. [PubMed: 28921658]
48. Hung M, Bounsanga J, Voss MW, Saltzman CL. Establishing Minimum Clinically Important Difference Values for the Patient-Reported Outcomes Measurement Information System Physical Function, Hip Disability and Osteoarthritis Outcome Score for Joint Reconstruction, and Knee Injury and Osteoarthritis Outcome Score for Joint Reconstruction in Orthopaedics. World J Orthop. 2018;9(3):41–49. [PubMed: 29564213]

A.

B.

Figure 1.

A. Diagram of simulation model showing the simplified continuum of THA/TKA care from admission through discharge to rehabilitation. Four base models were built: (1) primary THA pre-policy implementation, (2) primary THA post-policy implementation, (3) primary TKA pre-policy implementation, and (4) primary TKA post-policy implementation. Base models were used to simulate the probability of discharge to various types of rehabilitation (IRF, SNF, HHA, discharged home without care). Based on estimated distributions of discharge dispositions for each operation before and after policy implementation, anticipated changes in mean continuous post-discharge outcomes were assigned. Probabilities of dichotomous post-discharge outcomes were modeled using four additional expanded models

for each of the four base models' distributions of discharge dispositions (*e.g.* probability of unplanned readmission given the outcomes anticipated among primary TKA patients in the pre-policy implementation period).

B. Sensitivity analysis: Potential over- or under-specification of post-policy discharge distributions. The effects of relative increases and decreases of 5%, 10%, and 20%.

Table 1
Simulated Changes in Discharge to Various Types of Rehabilitation Before and After Bundled Payment Implementation.

Discharge Disposition	Pre-Policy		Post-Policy		Absolute Percentage-Point Change		RR
	Percentage	95% CI	Percentage	95% CI	Percentage	95% CI	
Primary total knee arthroplasty							
Inpatient rehabilitation facility	28.7%	28.5 to 28.9	11.8%	11.6 to 11.9	-16.9%	-17.3 to -16.5	0.41
Skilled nursing facility	35.8%	35.6 to 35.9	11.8%	11.7 to 11.9	-24.0%	-24.4 to -23.6	0.33
Home health agency	29.0%	28.8 to 29.1	65.7%	65.5 to 65.9	36.7%	36.3 to 37.2	2.27
Home without rehabilitation	6.6%	6.5 to 6.7	10.8%	10.6 to 10.9	4.2%	3.9 to 4.4	1.63
Primary total hip arthroplasty							
Inpatient rehabilitation facility	29.1%	28.8 to 29.4	12.3%	12.1 to 12.5	-16.8%	-17.4 to -16.2	0.42
Skilled nursing facility	36.1%	35.8 to 36.4	12.5%	12.3 to 12.7	-23.7%	-24.3 to -23.1	0.35
Home health agency	28.4%	28.1 to 28.6	64.8%	64.5 to 65.1	36.4%	35.7 to 37.1	2.28
Home without rehabilitation	6.4%	6.3 to 6.6	10.5%	10.3 to 10.6	4.1%	3.6 to 4.5	1.63

CI, confidence interval; RR, relative risk.

Table 2

Simulated Changes in Post-Discharge Overt Outcomes, Accounting for Differences in Case-Mix of Discharge Disposition.

Outcome	Pre-Policy			Post-Policy			Absolute Percentage-Point Change			RR
	Percentage	95% CI		Percentage	95% CI		Percentage	95% CI		
Primary total knee arthroplasty										
Unplanned readmission within 90 d	8.9%	8.8 to 9.0		9.7%	9.6 to 9.8		0.8%	0.5 to 1.1		1.09
ED visits (without hospitalization) within 90 d	8.7%	8.6 to 8.8		11.8%	11.6 to 11.9		3.1%	2.8 to 3.4		1.36
Complications within 90 d	13.9%	13.7 to 14.0		14.5%	14.4 to 14.7		0.7%	0.3 to 1.0		1.05
Post-rehabilitation need for further assistive care	67.4%	67.2 to 67.6		75.4%	75.2 to 75.5		8.0%	7.5 to 8.4		1.12
Number of facility-based rehabilitation days (mean)	10.11	10.07 to 10.13		3.57	3.54 to 3.60		-6.53	-6.61 to -6.46		-
Ambulation distance in feet (mean)	291.3	291.0 to 291.6		253.7	253.5 to 254.0		-37.6	-38.3 to -36.9		-
Primary total hip arthroplasty										
Unplanned readmission within 90 d	6.7%	6.5 to 6.8		7.7%	7.6 to 7.9		1.1%	0.7 to 1.5		1.16
ED visits (without hospitalization) within 90 d	5.9%	5.7 to 6.0		6.0%	5.8 to 6.1		0.1%	0.0 to 0.5		1.02
Complications within 90 d	13.1%	12.9 to 13.3		14.2%	14.0 to 14.4		1.1%	0.5 to 1.6		1.08
Post-rehabilitation need for further assistive care	67.2%	66.9 to 67.5		75.1%	74.8 to 75.3		7.9%	7.2 to 8.5		1.12
Number of facility-based rehabilitation days (mean)	10.22	10.17 to 10.27		3.76	3.72 to 3.80		-6.46	-6.58 to -6.35		-
Ambulation distance in feet (mean)	292.3	291.9 to 292.7		255.1	254.7 to 255.5		-37.2	-38.2 to -36.1		-

CI, confidence interval; RR, relative risk; ED, emergency department.

Table 3

Simulated Changes in Therapy Characteristics and Health-Related Quality-of-Life, Accounting for Differences in Case-Mix of Discharge Disposition.

Outcome	Pre-Policy		Post-Policy		Absolute Percentage-Point Change	
	Mean	95% CI	Mean	95% CI	Mean	95% CI
Primary total knee arthroplasty						
Therapy characteristics						
Overall therapy intensity (min/rehabilitation days)	75.8	75.6 to 76.0	41.1	40.9 to 41.2	-34.7	-35.1 to -34.3
Total occupational therapy (min)	323.7	322.7 to 324.6	131.4	130.6 to 132.2	-192.3	-194.5 to -190.0
Total physical therapy (min)	524.9	524.2 to 525.7	414.4	413.7 to 415.1	-110.5	-112.3 to -108.7
Psychological counseling (min)	2.70	2.68 to 2.71	1.09	1.08 to 1.10	-1.60	-1.64 to -1.57
Occupational therapy (d)	5.68	5.66 to 5.69	2.29	2.27 to 2.30	-3.39	-3.43 to -3.35
Physical therapy (d)	8.15	8.14 to 8.16	7.05	7.04 to 7.06	-1.10	-1.12 to -1.08
Counseling days	0.07	0.07 to 0.07	0.03	0.03 to 0.03	-0.04	-0.04 to -0.04
Health-related quality-of-life						
FIM motor score (possible 13-91)	83.1	83.1 to 83.2	79.9	79.9 to 79.9	-3.2	-3.3 to -3.2
Transformed SF-12 Physical Component Score (possible 0-100)	48.0	48.0 to 48.1	45.3	45.3 to 45.3	-2.7	-2.8 to -2.7
Transformed SF-12 Mental Component Score (possible 0-100)	42.4	42.4 to 42.4	40.5	40.5 to 40.5	-1.9	-1.9 to -1.9
Overall FIM motor gains from time of surgery	32.7	32.6 to 32.7	23.5	23.4 to 23.5	-9.2	-9.3 to -9.1
FIM motor gains during facility-based rehabilitation	15.1	15.1 to 15.2	5.6	5.6 to 5.6	-9.5	-9.6 to -9.4
FIM motor gains post-discharge (or outside of facility-based care)	14.3	14.3 to 14.4	11.2	11.2 to 11.2	-3.1	-3.2 to -3.1
Primary total hip arthroplasty						
Therapy characteristics						
Overall therapy intensity (min/rehabilitation days)	76.5	76.2 to 76.8	42.2	41.9 to 42.4	-34.4	-35.0 to -33.7
Total occupational therapy (min)	327.5	326.1 to 328.9	137.1	135.9 to 138.4	-190.4	-193.8 to -187.1
Total physical therapy (min)	527.6	526.6 to 528.7	418.4	417.3 to 419.4	-109.2	-111.9 to -106.6
Psychological counseling (min)	2.73	2.71 to 2.76	1.14	1.13 to 1.16	-1.59	-1.64 to -1.54
Occupational therapy (d)	5.74	5.71 to 5.77	2.39	2.37 to 2.41	-3.36	-3.41 to -3.30
Physical therapy (d)	8.18	8.17 to 8.19	7.10	7.08 to 7.11	-1.08	-1.12 to -1.05
Counseling days	0.07	0.07 to 0.07	0.03	0.03 to 0.03	-0.04	-0.04 to -0.04
Health-related quality-of-life						
FIM motor score (possible 13-91)	83.2	83.2 to 83.2	80.0	80.0 to 80.1	-3.2	-3.3 to -3.1

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Outcome	Pre-Policy		Post-Policy		Absolute Percentage-Point Change	
	Mean	95% CI	Mean	95% CI	Mean	95% CI
Transformed SF-12 Physical Component Score (possible 0-100)	48.1	48.1 to 48.1	45.4	45.4 to 45.4	-2.7	-2.8 to -2.6
Transformed SF-12 Mental Component Score (possible 0-100)	42.4	42.4 to 42.4	40.5	40.5 to 40.5	-1.9	-1.9 to -1.9
Overall FIM motor gains from time of surgery	32.9	32.8 to 33.0	23.8	23.7 to 23.8	-9.1	-9.3 to -8.9
FIM motor gains during facility-based rehabilitation	15.3	15.3 to 15.4	5.9	5.8 to 5.9	-9.4	-9.6 to -9.3
FIM motor gains post-discharge (or outside of facility-based care)	14.4	14.4 to 14.4	11.3	11.3 to 11.3	-3.1	-3.2 to -3.1

CI, confidence interval; FIM, functional independence measure; SF-12, 12-item Short Form Health Survey.