# Physician Practice Variation Under Orthopedic Bundled Payment

*Joshua M. Liao, MD, MSc; Ezekiel J. Emanuel, MD, PhD; Gary L. Whittington, BSBA; Dylan S. Small, PhD; Andrea B. Troxel, ScD; Jingsan Zhu, MS, MBA; Wenjun Zhong, PhD; and Amol S. Navathe, MD, PhD*

To increase value and address substantial cost and quality variation in care, CMS has rapidly expanded orthopedic bundled payment initiatives. By receiving a single "bundled" amount for an entire episode of care, hospitals and physicians are accountable for quality and costs under bundled payment.

After early success bundling acute care among a small group of providers in the voluntary Acute Care Episode (ACE) demonstration,[1] CMS extended its focus across the care continuum. In 2012, it launched the Bundled Payments for Care Improvement (BPCI) initiative,[2] a large national program through which many hospitals voluntarily accept bundled payment for joint replacement episodes encompassing acute and postacute care (PAC). More recently, in April 2016, CMS used the BPCI framework to initiate the Comprehensive Care for Joint Replacement model,[3] a mandatory program that initially held approximately 800 hospitals in 67 metropolitan areas financially accountable for the costs and quality of episodes spanning hospitalization through 90 days of PAC.

Early evidence from BPCI suggests that bundled payment can reduce episode costs and produce savings for both CMS and hospitals while possibly increasing quality.[4,5] Because physician practice style contributes to large variation in hospital and postacute spending for surgeries such as hip replacement,[6] variation reduction is frequently championed in bundle payment strategy.[7,8] However, there is little empirical evidence about whether organizational strategies must reduce physician practice variation in order to succeed.

In this study, we describe physician practice variation at Baptist Health System (BHS), a continuous participant in Medicare joint replacement bundles since 2009. BHS achieved high performance—demonstrating notable reductions in total episode payments and hospital savings during a period when joint replacement expenditures rose nationwide[5,9]—by engaging physicians to reduce surgical implant costs and postdischarge utilization of institutional PAC providers.[5,10] We evaluate the extent of and longitudinal changes in physician practice variation with respect to implant costs, institutional PAC provider utilization, and total episode payments, as well as the associations among physician volume and quality and these 3 outcomes.



## ABSTRACT

**OBJECTIVES:** To describe the extent of and longitudinal changes in physician practice variation with respect to implant costs, institutional postacute care (PAC) provider utilization, and total episode payments, as well as to evaluate the association between physician volume and quality and these outcomes.

**STUDY DESIGN:** Observational study.

**METHODS:** We combined claims and internal hospital cost data for 34 physicians responsible for 3614 joint replacement episodes under bundled payment at Baptist Health System (BHS). Multilevel multivariable generalized linear models were employed and the intraclass correlation (ICC) was used to quantify between-physician variation.

**RESULTS:** There was significant between-physician variation in implant costs, institutional PAC provider utilization, and total episode payments not explained by observable variables ($P$ <.001 for all). Over 5 years, the ICC decreased from 0.26 to 0.06, 0.15 to 0.13, and 0.12 to 0.10 for implant costs, institutional PAC provider utilization, and total episode payments, respectively, but differences were not statistically significant. Both higher physician case volume and quality were associated with decreased total episode payments and institutional PAC provider utilization, but not with changes in implant costs.

**CONCLUSIONS:** Considerable physician practice variation was observed under bundled payment at BHS and decreased to a greater degree for implant costs than institutional PAC provider utilization or total episode payments. Institutional PAC provider utilization and total episode payments were associated with physician volume and quality. Although some organizational strategies achieve gains by reducing physician practice variation, variation reduction is not an absolute requisite for success under bundled payment.

*Am J Manag Care*. 2018;24(6):287-293

## TAKEAWAY POINTS

Amid the proliferation of orthopedic bundles, organizations can benefit from understanding whether strategies must reduce physician practice variation in order to succeed. Analyzing the experience of a long-standing participant in Medicare orthopedic joint replacement bundles, we found that although some strategies achieve gains by reducing physician practice variation, variation reduction is not an absolute requisite for success under bundled payment.

- There was significant physician practice variation in implant costs, institutional postacute care (PAC) provider utilization, and total episode payments.
- Over time, physician practice variation decreased to a greater degree for implant costs than for institutional PAC provider utilization or total episode payments.

# METHODS

### Study Period

The study was divided into 4 periods. The first was the baseline period (July 2008-December 2008), when BHS received nonbundled fee-for-service payments prior to ACE participation. The second was the ACE period (July 2009-June 2012), during which BHS implemented joint replacement bundles for acute hospitalization. The ACE period consisted of 3 years: ACE year 1 (July 2009-June 2010), ACE year 2 (July 2010-June 2011), and ACE year 3 (July 2011-June 2012). The third was the transition period (July 2012-September 2013), when BHS prepared to transition to BPCI Model 2 and did not receive bundled payment. The fourth was the BPCI period (October 2013-June 2015), in which BHS implemented joint replacement bundles for episodes spanning acute hospitalization through 30 days of PAC. The BPCI period consisted of 2 years: BPCI year 1 (October 2013-June 2014) and BPCI year 2 (July 2014-June 2015).

### Data Sources

We obtained both Medicare claims and internal hospital cost data directly from BHS.[5] Using Medicare data, we constructed care episodes that were consistent with the health system's BPCI arrangement with CMS and encompassed acute hospitalization plus 30 days of PAC.[5] Data were not available during the transition period between ACE and BPCI when BHS was not paid by CMS under bundled payment.

### Study Population

Our analytic sample consisted of 3614 patient episodes from a panel of 34 physicians who performed at least 1 joint replacement surgery in both the ACE and BPCI periods. Overall, 51 orthopedic surgeons affiliated with BHS performed a combined total of 3725 joint replacement surgeries on Medicare beneficiaries under Medicare Severity Diagnosis Related Group 470, Major joint replacement or reattachment of lower extremity without major complications or comorbidities. We excluded physicians who performed surgeries only in the ACE period (n = 9) or BPCI period (n = 8).

### Variables and Outcomes

Patient demographics and clinical data were calculated from Medicare claims, and patient illness severity was estimated using the Elixhauser Comorbidity Score.[11-13] Medicare data were also used to calculate 2 quality of care measures, 30-day readmission and emergency department (ED) visit rates, based on CMS demonstration project specifications.[14] Characteristics of operating physicians (gender, years of experience, allopathic vs osteopathic degree, graduation from US or non-US medical school, and board certification status) were obtained from publicly available information on consumer websites.

We evaluated variation in 3 outcomes of interest: implant costs, total episode payments, and institutional PAC provider utilization. Internal hospital cost data were used to quantify the costs of orthopedic implants (implant costs), while BHS used a time-driven activity-based costing approach[15] to quantify other nonsupply hospital costs. Medicare data were used to calculate the sum of all Medicare payments for an episode of care (total episode payments) by combining claims for all acute hospital facility payments, physician fees during hospitalization, and total PAC payments through 30 days post discharge. Total PAC payments consisted of those corresponding to outpatient visits, ED visits, readmissions, physician fees, durable medical equipment, and utilization of PAC providers, such as skilled nursing facilities (SNFs), inpatient rehabilitation facilities (IRFs), and home health agencies (HHAs).

We used Medicare data to define a dichotomous variable (institutional PAC provider utilization) as discharge from hospitalization to either SNFs or IRFs as institutional PAC providers, compared with discharge home or home with HHA services. Patients were discharged to 1 of 4 destinations in nearly all (99.4%) episodes.

Finally, we defined several variables to evaluate associations between physician practice characteristics and our outcomes. We assessed practice quality by calculating the proportion of episodes for each physician with prolonged length of stay (PLOS), a validated measure of complications of orthopedic lower extremity joint replacement.[16,17] PLOS evaluates the pattern of patient discharges as a function of length of stay (ie, number of days in the hospital) and identifies a point at which discharge is less likely than continued hospitalization, representing a complication. We assess practice volume using total case volume over the study period. Due to data skewness, we analyzed volume as a continuous variable, as well as a dichotomous variable with the top 10 physicians by volume (each with more than 100 cases and representing more than 70% of total cases) defined as high-volume physicians.

### Statistical Analysis

Descriptive statistics were reported using means and SDs for continuous variables and percentages for categorical variables. Multilevel generalized linear models, adjusted for study year and patient and physician characteristics, were employed to evaluate

the extent of physician variation in the 3 outcomes of interest. Models were clustered at the physician level and included a physician random effect. To account for multiple patients per operating physician and heteroscedasticity, all models utilized clustered standard errors with the Huber-White correction.

We utilized linear random effects models with a log link and gamma distribution for the outcomes of implant cost and total episode spending.[18] To evaluate institutional PAC provider utilization, we used a random effects model with a logit link and binominal distribution to estimate the logit of the probability of discharge to institutional PAC providers as a linear function of covariates and operating physician random effect.[19]

The significance of between-physician variation was determined by testing whether the variance of the physician random effect differed significantly from 0 and was reported using the intraclass correlation (ICC). The ICC is a measure that reflects the proportion of overall variance explained by variation between, rather than within, clusters of individual observations. In this study, the calculated ICC corresponds to the proportion of variation explained by differences in practice patterns among physicians (ie, between-physician variation), as opposed to among cases for individual physicians (ie, within-physician variation). A linear threshold method was used to calculate ICC for institutional PAC provider utilization.[20] To compare changes in the ICC across the study period, we used bootstrapping to calculate standard errors for ICCs in ACE year 1 and BPCI year 2 before using the *z* statistic and pairwise tests for each outcome to evaluate whether there were significant differences between the 2 years.

Random effects models were also used to calculate and compare between-physician variation and ICC for implant costs and total episode payments across our study period (ACE year 1 vs BPCI year 2). Because bundle definitions did not include PAC until the BPCI program period, we compared between-physician variation and ICC for PAC provider utilization among ACE year 1, ACE year 3, and BPCI year 2.

Separately, we used random effects models to test the associations among physician quality and case volume and our 3 outcomes of interest. All cost and spending figures were adjusted for inflation and reported in 2015 US$ equivalents. Implant cost data were aggregated at the level of individual physician per quarter and weighted by episode volume. Analyses were conducted using SAS version 9.4 (SAS Institute; Cary, North Carolina). All tests of significance were 2-tailed and considered statistically significant at an α of .05. The University of Pennsylvania Institutional Review Board approved the study.

# RESULTS

The overall patient and program characteristics across the BHS bundled payment program have been described previously.[5] From that sample, we included 34 physicians in this analysis, 97% of whom were male, 100% whom had obtained allopathic medical degrees, 91% of whom had graduated from US medical schools, and 82% of whom were board certified (**Table**). On average, physicians in this cohort had 26 years of experience and a total volume of 106 cases across our study period, ACE year 1 to BPCI year 2.

The mean age of patients cared for by these physicians was 72 years. They were predominantly female, and the mean Elixhauser Comorbidity Score was 1.1, with the 5 most common coexisting clinical conditions being hypertension (76%), diabetes (21%), hypothyroidism (21%), obesity (19%), chronic obstructive pulmonary disease (16%), and depression (10%). Readmissions and ED visits occurred in 5% and 6% of cases, respectively.

## Implant Costs

Overall, mean implant costs decreased 5.8% across the study period, from $5026 in the first year of bundled payment (ACE year 1) to $4732 through 5 years (BPCI year 2). There was also an overall downward shift in distribution of implant costs among physicians. Compared with ACE year 1, for example, more physicians in BPCI year 2 had average implant costs between $4500 and $5000 (22 vs 9) and fewer physicians had average implant costs of $5550 or greater (1 vs 10) (**Figure 1**).

After accounting for patient and physician characteristics, higher implant cost was associated with younger patient age and earlier study year. There was a decline in between-physician variation across study year and program period (**eAppendix Figures 1** and **2** [eAppendix available at **ajmc.com**]), from an ICC of 0.26 in ACE year 1 to 0.06 in BPCI year 2, a difference that was not statistically significant on pairwise testing ($P = .26$). Adjusted random effects analysis demonstrated statistically significant between-physician variation in implant costs (overall ICC = 0.11) unexplained by observable variables ($P < .001$) (**eAppendix Table 1**).

## Institutional PAC Provider Utilization

The proportion of patients discharged to institutional PAC providers remained relatively steady during ACE: 42% in ACE year 1 and 40% in ACE year 3 when PAC was not included in bundled payment. When PAC was included in bundles under BPCI, however, discharge to institutional PAC providers decreased to 31% in BPCI year 1 and to 25% in BPCI year 2. Across the ACE program period, most physicians discharged at least half of their patients to institutional PAC providers (**Figure 2**). In comparison, by BPCI year 2, most physicians discharged at least half of their patients to home or HHAs (80% of physicians in BPCI year 2 compared with 38% and 42% in ACE year 3 and ACE year 1, respectively).

After multivariable adjustment, higher institutional PAC provider utilization was associated with earlier study year, female patient sex, younger patient age, higher Elixhauser Comorbidity score, and readmissions. Between-physician variance in institutional PAC provider utilization decreased over the study period from 0.59 in ACE year 1 to 0.48 by BPCI year 2, with ICCs of 0.15, 0.14, and 0.13

**TABLE.** Physician and Patient Characteristics in Final Sample

| | Overall | ACE Year 1 | ACE Year 2 | ACE Year 3 | BPCI Year 1 | BPCI Year 2 |
|---|---|---|---|---|---|---|
| **Physician Characteristics (n = 34)** | | | | | | |
| Physicians, n | | 26 | 28 | 32 | 33 | 30 |
| Male, n (%) | 97 | 25 (96%) | 27 (96%) | 31 (97%) | 32 (97%) | 29 (97%) |
| Years of experience, mean (SD) | 26 (10) | 27 (10) | 25 (10) | 25 (10) | 25 (10) | 25 (10) |
| Total case volume, mean (SD) | 106 (133) | 26 (32) | 25 (34) | 22 (27) | 18 (17) | 31 (32) |
| Allopathic medical degree, % | 100 | 100 | 100 | 100 | 100 | 100 |
| US medical graduate, n (%) | 91 | 24 (92%) | 25 (89%) | 29 (91%) | 30 (91%) | 27 (90%) |
| Board certification, n (%) | 82 | 22 (85%) | 23 (82%) | 27 (84%) | 27 (82%) | 25 (83%) |
| **Patient Characteristics (n = 3614)** | | | | | | |
| Age, mean (SD) | 72 (8.1) | 73 (8.1) | 72 (8.2) | 72 (8.6) | 72 (7.6) | 72 (8.0) |
| Male, % | 34 | 32 | 34 | 34 | 34 | 37 |
| Coexisting clinical conditions, % | | | | | | |
| Hypertension | 76 | 76 | 80 | 78 | 77 | 73 |
| Diabetes | 21 | 21 | 23 | 22 | 23 | 19 |
| Hypothyroidism | 21 | 21 | 18 | 19 | 22 | 22 |
| Obesity | 19 | 13 | 17 | 22 | 21 | 20 |
| Chronic obstructive pulmonary disease | 16 | 16 | 17 | 15 | 15 | 14 |
| Depression | 10 | 8 | 9 | 11 | 12 | 12 |
| Elixhauser Comorbidity score, mean (SD) | 1.1 (4.5) | 1.1 (4.0) | 1.1 (4.3) | 1.0 (4.7) | 1.1 (4.6) | 1.1 (4.7) |
| Cases with readmissions, % | 5.2 | 4.3 | 5.9 | 6.2 | 5.7 | 4.2 |
| Cases with ED visits, % | 6.3 | 6.1 | 6.5 | 6.1 | 7.2 | 6.0 |
| Discharge location, % | | | | | | |
| Home/self-care | 5.5 | 9.8 | 4.8 | 4.2 | 5.1 | 4.2 |
| Home with HHA services | 59 | 47 | 56 | 56 | 64 | 71 |
| SNF | 25 | 25 | 21 | 23 | 23 | 19 |
| IRF | 13 | 16 | 17 | 17 | 8 | 6 |
| Other[a] | 0.5 | 1.6 | 0.6 | 0.3 | 0.5 | 0.1 |

ACE indicates Acute Care Episode; BPCI, Bundled Payments for Care Improvement; ED, emergency department; HHA, home health agency; IRF, inpatient rehabilitation facility; SNF, skilled nursing facility.
[a]Other includes patients discharged to long-term care hospitals, intermediate care facilities, other short-term general hospitals, hospital-based swing beds, and hospice, as well as those who left against medical advice.

in ACE year 1, ACE year 3, and BPCI year 2, respectively, without a statistically significant overall change ($P = .86$). Overall, the extent of between-physician variation (overall ICC = 0.09) unexplained by observable variables was also statistically significant ($P < .001$) (**eAppendix Table 2**).

## Total Episode Payments

Over the 5 years of the study, mean total episode payments decreased 21% from $23,634 in ACE year 1 to $18,699 in BPCI year 2. Compared with ACE year 1, there was an overall narrowing and downward shift in distribution of total episode payments among physicians. For example, the number of physicians with total episode payments less than $20,000 increased from 6 to 21 and there were fewer physicians with total episode payments greater than $27,500 (9 vs 2) (**Figure 3**).

After accounting for readmissions and ED visits, as well as patient and physician characteristics, higher total episode payment was associated with younger patient age and earlier study year.

Between-physician variance in total episode payments increased slightly over time (**eAppendix Figures 3** and **4**), and the ICC decreased by a statistically nonsignificant amount, from 0.12 in ACE year 1 to 0.10 in BPCI year 2 ($P = .81$). The extent of between-physician variation (overall ICC = 0.07) unexplained by observable variables was also statistically significant ($P < .001$) (**eAppendix Table 3**).

## Association Between Physician Practice Characteristics and Outcomes of Interest

In multivariable analyses, increasing physician clinical practice volume was associated with small but significant decreases in total

episode payments (coefficient, −0.00022; $P$ <.001) and institutional PAC provider utilization (coefficient, −0.00020; $P$ <.001), but not changes in implant costs (coefficient, 0.00015; $P$ = .32). Results from analysis using a dichotomized volume indicator did not yield qualitatively different results. Similarly, lower practice quality, defined as increasing proportion of episodes with PLOS, was associated with increased total episode payments (0.2086; $P$ = .002) and increased institutional PAC provider utilization (2.2347; $P$ = .001) but not changes in implant costs (0.1695; $P$ = .19).

## DISCUSSION

This study demonstrates that bundled payment strategy can reduce costs and generate savings by decreasing variation in some practices but not others. Three conclusions are particularly notable.

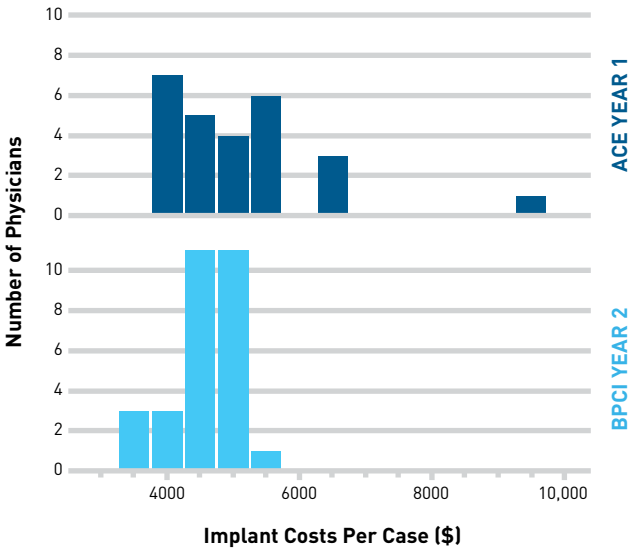
First, our analysis demonstrates the presence of and change in physician practice variation in implant costs, institutional PAC provider utilization, and total episode payments. In ACE year 1, practice variation between physicians accounted for 15% to 26% of overall variation in these outcomes. The decreases in between-physician variation by BPCI year 2 demonstrate the role of practice variation reduction in decreasing costs and utilization.

This observation is illustrated by the downward shift and narrowing in distributions of our outcomes: Over time, more physicians achieved lower mean implant costs and total episode payments, and fewer physicians discharged a significant portion of patients to institutional PAC providers. Furthermore, the presence of statistically significant physician variation across the study period that was unexplained by observable variables suggests that attention to individual physician practice patterns may help other organizations identify cost and utilization reduction strategies under bundled payment.

Second, this study suggests that reducing physician practice variation may not be an absolute requisite for succeeding in joint replacement bundles. Although physician practice variation only accounted for a portion of overall implant costs and differences in ICC were not statistically significant, we nonetheless observed a steady decrease in between-physician variation over time. In the first year of the bundled payment program, BHS leaders used quality and cost data transparency to leverage physician engagement and lower implant costs program-wide over several rounds of negotiations.[10] The observed trend in physician variation reflects the result of this strategy: more consistent pricing across available implant options and systematic cost reductions across physicians.

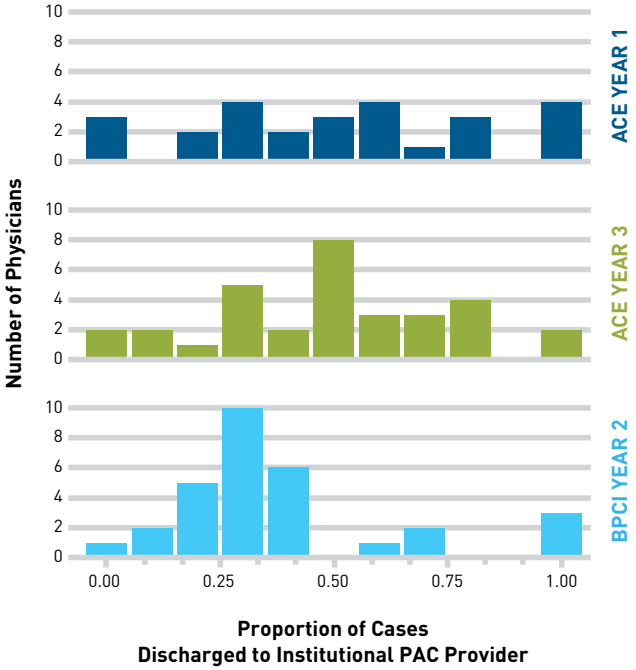
Conversely, despite the fact that physician practice patterns also accounted for approximately 10% of variation in PAC provider utilization, there was a 40% decrease in institutional PAC provider utilization without substantial reductions in between-physician variation over time. Unlike efforts to reduce implant costs beginning in 2009, BHS was not incentivized to address postdischarge utilization until it was included in bundles in late 2013 under BPCI. In turn, despite a clear

**FIGURE 1.** Distribution of Implant Costs Among Physicians in the BHS Bundled Payment Program (by program year)



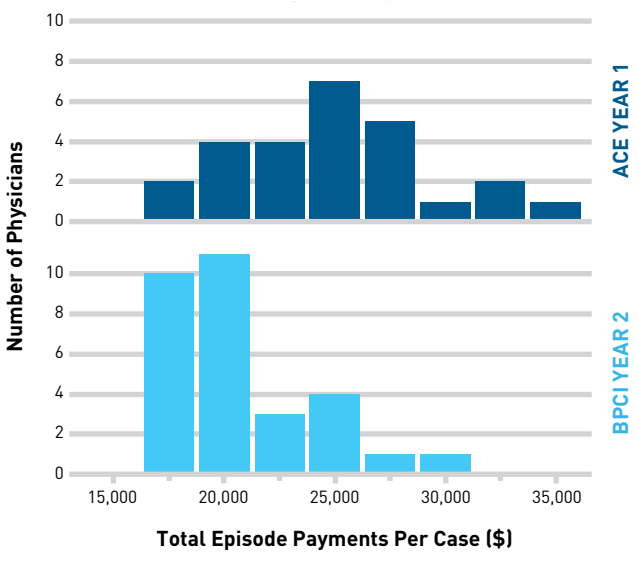

ACE indicates Acute Care Episode; BHS, Baptist Health System; BPCI, Bundled Payments for Care Improvement.

**FIGURE 2.** Distribution of Institutional PAC Utilization Among Physicians in the BHS Bundled Payment Program (by program year)




ACE indicates Acute Care Episode; BHS, Baptist Health System; BPCI, Bundled Payments for Care Improvement; PAC, postacute care.

**FIGURE 3.** Distribution of Total Episode Payments Among Physicians in the BHS Bundled Payment Program (by program year)




ACE indicates Acute Care Episode; BHS, Baptist Health System; BPCI, Bundled Payments for Care Improvement.

shift away from institutional PAC provider utilization under the health system's BPCI "appropriate discharge location" program, some degree of variation persisted through its first 2 years. These findings suggest that organizations may be able to significantly reduce overutilization even in the early stages of some variation reduction efforts.

Similarly, between-physician variation did not decline amid a 21% decrease in total episode payments. As an outcome, total episode payment reflects the entire array of redesign efforts implemented across a bundle over time. For example, beyond its long-standing implant cost strategy and emerging PAC provider utilization program, BHS also interspersed initiatives to standardize hospital care, increase patient engagement in discharge planning, and implement a postdischarge transitional care management program. The health system's ability to achieve total episode payment reductions amid multiple initiatives underscores the ability to control episode costs even as physician practice variation persists in some specific processes.

Together, these dynamics may provide insight into the relationships among physician quality and volume with study outcomes. The lack of association between physician quality or volume and implant costs is consistent with organizational strategy designed to drive down variation across high-/low-volume and high-/low-quality physicians. In contrast, the finding that physician volume and quality were associated with PAC provider utilization and total episode payments amid stable between-physician variation suggests that certain physician characteristics may contribute to the effectiveness of other variation reduction strategies.

Third, our findings emphasize the opportunity to preserve clinical appropriateness amid efforts to drive down costs and unwarranted physician variation. As stated previously, a central element of the BHS approach to orthopedic bundles was the preservation of physician choice and patient well-being. For example, physicians were able to seek approval and use implants beyond those on the standard approved list if clinically indicated.[10] They were also able to deviate from standardized care pathways when needed to prioritize patient needs. Our results suggest that retaining clinical flexibility amid variation reduction efforts does not impede success under bundled payment.

### Limitations

Our analysis possesses several limitations. First, it is descriptive and not designed for causal inference. Second, our study describes the experience of a single institution and therefore may not be generalizable to all organizational and market environments. However, as the first analysis to quantify physician practice variation in both internal hospital costs and Medicare payments under bundled payment, it provides important information for a growing number of organizations considering or entering into similar bundling arrangements. Additionally, this analysis provides insight into potential mechanisms underlying the previously described impressive cost savings BHS achieved compared with other hospitals and BPCI participants nationwide.[4,5] Third, our results must be contextualized within unresolved questions about bundled payment, including whether it induces hospitals to perform more procedures and/or select healthier patients, thereby undercutting any touted cost savings.[21] However, although further work is needed in this area, volume increases may represent improved value and do not by themselves represent policy failure.[22,23] Finally, our analytic approach was unable to account for changes in implant technology or other concurrent nonbundled payment policies over the study period.

## CONCLUSIONS

Significant physician practice variation was observed under bundled payment at BHS. Over time, variation decreased by varying amounts for all 3 outcomes of interest, although differences were not statistically significant. Additionally, physician volume and quality were associated with institutional PAC provider utilization and total episode payments, but not implant costs. These findings demonstrate that although some organizational strategies achieve gains by reducing physician practice patterns, variation reduction among physicians is not an absolute requisite for success under bundled payment. ■

**Acknowledgments**

The authors thank Gary Whittington, Richard Bajner, and Brian Fisher for access to the data. Written permission has been obtained from all persons named.

***Author Affiliations:*** University of Washington School of Medicine (JML), Seattle, WA; UW Medicine Value and Systems Science Lab (JML), Seattle, WA; Leonard Davis Institute of Health Economics (JML, EJE, ASN), and Perelman School of Medicine (EJE, DSS, JZ, WZ, ASN), University of Pennsylvania, Philadelphia, PA; Lovelace Health System (GLW), Albuquerque, NM; New York University School of Medicine (ABT), New York, NY; Corporal Michael J. Cresencz VA Medical Center (ASN), Philadelphia, PA.

***Source of Funding:*** This work was supported in part by The Commonwealth Fund, which had no role in study design; data collection, management, analysis, and interpretation; or manuscript preparation or approval.

***Author Disclosures:*** Dr Emanuel reports board membership on VillageMD, *JAMA* editorial board, and Council on Foreign Relations; paid advisory board membership on Peterson Foundation Advisory Board; employment with Fox News Channel, University of Pennsylvania, and Oak HC/FT; representation by the Leigh Bureau, a speaker's agency; and stock ownership in Nuna. Mr Whittington reports employment as the Market CFO of Baptist Health System, which is involved in bundled payments; membership on the system's advisory board of directors; attendance at healthcare conferences on bundled payments; and stock ownership in Tenet Health, the parent company of Baptist Health System. Dr Zhong reports employment with Merck (unrelated to the present work) and the University of Pennsylvania. Dr Navathe reports consultancies for Navvis and Company, Navigant Inc, Lynx Medical, Indegene Inc, and Sutherland Global Services; grants received from Hawaii Medical Services Association and Oscar Health; and honoraria from Elsevier Press. The remaining authors report no relationship or financial interest with any entity that would pose a conflict of interest with the subject matter of this article.

***Authorship Information:*** Concept and design (JML, EJE, GLW, ASN); acquisition of data (JML, GLW, ASN); analysis and interpretation of data (JML, EJE, DSS, ABT, JZ, WZ, ASN); drafting of the manuscript (JML); critical revision of the manuscript for important intellectual content (JML, EJE, GLW, DSS, ABT, JZ, WZ, ASN); statistical analysis (DSS, ABT, JZ, WZ); provision of patients or study materials (GLW); obtaining funding (ASN); and supervision (ASN).

***Address Correspondence to:*** Joshua M. Liao, MD, MSc, 1959 NE Pacific St, BB 1240, Seattle, WA 98195. Email: joshliao@uw.edu.

# REFERENCES

1. Medicare Acute Care Episode (ACE) demonstration. CMS website. innovation.cms.gov/initiatives/ACE. Updated June 16, 2017. Accessed January 24, 2017.
2. Bundled Payments for Care Improvement (BPCI) initiative: general information. CMS website. innovation.cms.gov/initiatives/bundled-payments. Updated April 19, 2018. Accessed January 24, 2017.
3. Comprehensive Care for Joint Replacement model. CMS website. innovation.cms.gov/initiatives/cjr. Updated June 2, 2018. Accessed January 23, 2017.
4. 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. doi: 10.1001/jama.2016.12717.
5. Navathe AS, Troxel AB, Liao JM, et al. Costs of joint replacement using bundled payment models. *JAMA Intern Med*. 2017;177(2):214-222. doi: 10.1001/jamainternmed.2016.8263.
6. Miller DC, Gust C, Dimick JB, Birkmeyer N, Skinner J, Birkmeyer JD. Large variations in Medicare payments for surgery highlight savings potential from bundled payment programs. *Health Aff (Millwood)*. 2011;30(11):2107-2115. doi: 10.1377/hlthaff.2011.0783.
7. Mouille B, Higuera C, Woicehovich L, Deadwiler M. How to succeed in bundled payments for total joint replacement. *NEJM* Catalyst website. catalyst.nejm.org/how-to-succeed-in-bundled-payments-for-total-joint-replacement. Published October 24, 2016. Accessed February 25, 2017.
8. Schlosser M, Kelly M, Duncan S, Jaffe E, Young J. Succeeding at bundles: the physician perspective. *Becker's Hospital Review* website. beckershospitalreview.com/hospital-physician-relationships/succeeding-at-bundles-the-physician-perspective.html. Published November 18, 2016. Accessed March 2, 2017.
9. New Medicare data available to increase transparency on hospital utilization [news release]. Baltimore, MD: CMS; June 1, 2016. cms.gov/Newsroom/MediaReleaseDatabase/Fact-sheets/2015-Fact-sheets-items/2015-06-01.html. Accessed May 17, 2018.
10. Liao JM, Holdofski A, Whittington GL, et al. Baptist Health System: succeeding in bundled payments through behavioral principles. *Healthc (Amst)*. 2017;5(3):136-140. doi: 10.1016/j.hjdsi.2016.04.008.
11. Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. *Med Care*. 1998;36(1):8-27.
12. Southern DA, Quan H, Ghali WA. Comparison of the Elixhauser and Charlson/Deyo methods of comorbidity measurement in administrative data. *Med Care*. 2004;42(4):355-360. doi: 10.1097/01.mlr.0000118861.56848.ee.
13. van Walraven C, Austin PC, Jennings A, Quan H, Forster AJ. A modification of the Elixhauser comorbidity measures into a point system for hospital death using administrative data. *Med Care*. 2009;47(6):626-633. doi: 10.1097/MLR.0b013e31819432e5.
14. The Lewin Group. CMS Bundled Payments for Care Improvement (BPCI) initiative models 2-4: year 1 evaluation & monitoring annual report. CMS website. innovation.cms.gov/Files/reports/BPCI-EvalRpt1.pdf. Published February 2015. Accessed March 2, 2017.
15. Kaplan RS, Anderson SR. *Time-Driven Activity-Based Costing: A Simple and More Powerful Path to Higher Profits*. Boston, MA: Harvard Business School Press; 2007.
16. Silber JH, Rosenbaum PR, Koziol LF, Sutaria N, Marsh RR, Even-Shoshan O. Conditional length of stay. *Health Serv Res*. 1999;34(1 pt 2):349-363.
17. Sedrakyan A, Kamel H, Mao J, Ting H, Paul S. Hospital readmission and length of stay over time in patients undergoing major cardiovascular and orthopedic surgery: a tale of 2 states. *Med Care*. 2016;54(6):592-599. doi: 10.1097/MLR.0000000000000528.
18. Buntin MB, Zaslavsky AM. Too much ado about two-part models and transformation? comparing methods of modeling Medicare expenditures. *J Health Econ*. 2004;23(3):525-542. doi: 10.1016/j.jhealeco.2003.10.005.
19. Lipitz-Snyderman A, Sima CS, Atoria CL, et al. Physician-driven variation in nonrecommended services among older adults diagnosed with cancer. *JAMA Intern Med*. 2016;176(10):1541-1548. doi: 10.1001/jamainternmed.2016.4426.
20. Snijders TAB, Bosker RJ. *Multilevel Analysis: An Introduction to Basic and Advanced Multilevel Modeling*. 1st ed. Thousand Oaks, CA: SAGE; 1999.
21. Fisher ES. Medicare's bundled payment program for joint replacement: promise and peril? *JAMA*. 2016;316(12):1262-1264. doi: 10.1001/jama.2016.12525.
22. Navathe AS, Liao JM, Emanuel EJ. Volume increases and shared decision-making in joint replacement bundles. *Ann Surg*. 2018;267(1):35-36. doi: 10.1097/SLA.0000000000002283.
23. Liao JM, Navathe AS, Chu D. Reframing the value proposition of coronary artery bypass graft bundles. *JAMA Surg*. 2018;153(3):199-200. doi: 10.1001/jamasurg.2017.4903.

**eAppendix Table 1.** Random Effects Analysis of Implant Costs[a]

| | Estimate | SE | *P* |
|---|---|---|---|
| Year | | | |
| ACE year 1 | 0.06262 | 0.01656 | .0002 |
| ACE year 2 | 0.07069 | 0.01623 | <.0001 |
| ACE year 3 | 0.05688 | 0.01599 | .0004 |
| BPCI year 1 | 0.1004 | 0.01658 | <.0001 |
| BPCI year 2 | Reference | – | – |
| Patient characteristics[b] | | | |
| Age | –0.00343 | 0.001614 | .0343 |
| Sex[c] | 0.02892 | 0.03043 | .3426 |
| Elixhauser Comorbidity Score | –0.00496 | 0.002774 | .0743 |
| Physician characteristics | | | |
| Sex[c] | –0.02779 | 0.1082 | .7975 |
| Years of experience | –0.00092 | 0.002187 | .6747 |
| US vs non-US medical school graduate | 0.05578 | 0.09999 | .5773 |
| Board certification | –0.08315 | 0.07754 | .2842 |
| Medical degree type[d] | 0 | – | – |
| | | | |
| Within-physician variation | 0.08708 | 0.006068 | |
| Between-physician variation | 0.01036 | 0.003194 | <.0001[e] |

ACE indicates Acute Care Episode; BPCI, Bundled Payments for Care Improvement; SE, standard error.

[a]Physician-level analysis.

[b]Grouped within physician.

[c]Male as referent.

[d]All physicians had MD degrees.

[e]Based on the residual pseudo-likelihood $\chi^2$ test.

**eAppendix Table 2.** Random Effects Analysis of PAC Utilization[a]

| | Estimate | SE | *P* |
|---|---|---|---|
| Year | | | |
| ACE year 1 | 0.8364 | 0.126 | <.0001 |
| ACE year 2 | 0.7335 | 0.1243 | <.0001 |
| ACE year 3 | 0.7905 | 0.1226 | <.0001 |
| BPCI year 1 | 0.2404 | 0.1295 | .0635 |
| BPCI year 2 | Reference | . | . |
| Patient characteristics | | | |
| Age | 0.08968 | 0.005609 | <.0001 |
| Sex[b] | 0.6747 | 0.08669 | <.0001 |
| Elixhauser Comorbidity Score | 0.05128 | 0.009105 | <.0001 |
| Number of readmissions | 0.6886 | 0.1613 | <.0001 |
| Number of ED visits | –0.2593 | 0.14 | .064 |
| Physician characteristics | | | |
| Sex[b] | 0.3749 | 0.6059 | .5361 |
| Years of experience | –0.01301 | 0.01282 | .3103 |
| US vs non-US medical school graduate | –0.8698 | 0.5893 | .14 |
| Board certification | –0.1459 | 0.4564 | .7491 |
| Medical degree type[c] | 0 | – | – |
| | | | |
| Within-physician variation[d] | | | |
| Between-physician variation | 0.3067 | 0.1097 | <.0001[e] |

ACE indicates Acute Care Episode; BPCI, Bundled Payments for Care Improvement; ED, emergency department; PAC, post acute care; SE, standard error.

[a]Patient-level analysis.

[b]Male as referent.

[c]All physicians had MD degrees.

[d]Calculated using the linear threshold method.

[e]Based on the residual pseudo-likelihood $\chi^2$ test.

**eAppendix Table 3.** Random Effects Analysis of Total Episode Payments[a]

| | Estimate | SE | *P* |
|---|---|---|---|
| Year | | | |
| ACE year 1 | 0.2237 | 0.01226 | <.0001 |
| ACE year 2 | 0.2275 | 0.01204 | <.0001 |
| ACE year 3 | 0.2012 | 0.01188 | <.0001 |
| BPCI year 1 | 0.01765 | 0.01238 | .154 |
| BPCI year 2 | Reference | – | – |
| Patient characteristics | | | |
| Age | 0.009169 | 0.000498 | <.0001 |
| Sex[b] | 0.07339 | 0.008257 | <.0001 |
| Elixhauser Comorbidity Score | 0.008678 | 0.000903 | <.0001 |
| Number of readmissions | 0.4085 | 0.01582 | <.0001 |
| Number of ED visits | 0.01969 | 0.01318 | .1353 |
| Physician characteristics | | | |
| Sex[b] | 0.1024 | 0.06823 | .1336 |
| Years of experience | –0.00182 | 0.001416 | .1995 |
| US vs non-US medical school graduate | –0.1059 | 0.06538 | .1053 |
| Board certification | –0.05341 | 0.05053 | .2905 |
| Medical degree type[c] | 0 | – | – |
| | | | |
| Within-physician variation | 0.05479 | 0.001296 | |
| Between-physician variation | 0.003986 | 0.001332 | <.0001[d] |

ACE indicates Acute Care Episode; BPCI, Bundled Payments for Care Improvement; ED, emergency department; SE, standard error.

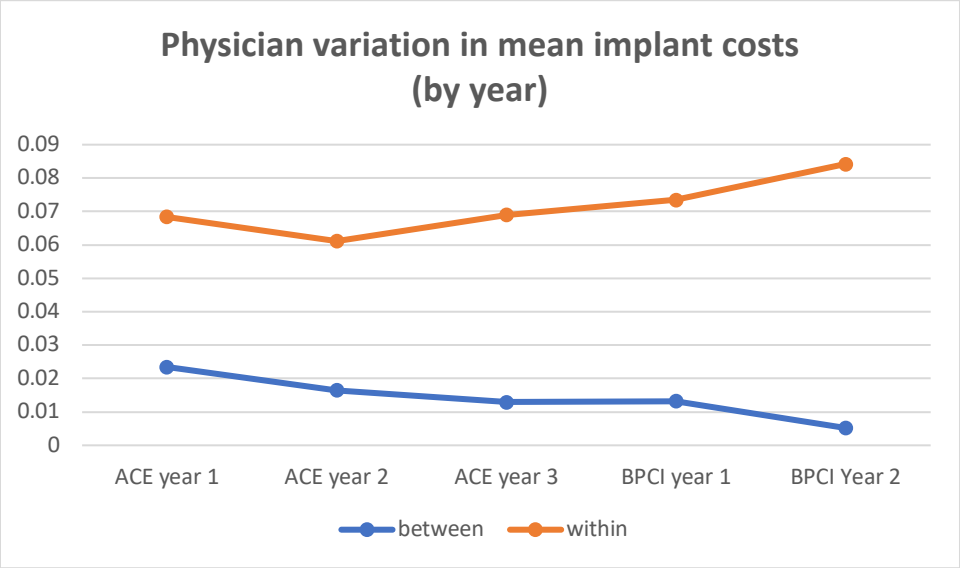
[a]Patient-level analysis.

[b]Male as referent.

[c]All physicians had MD degrees.

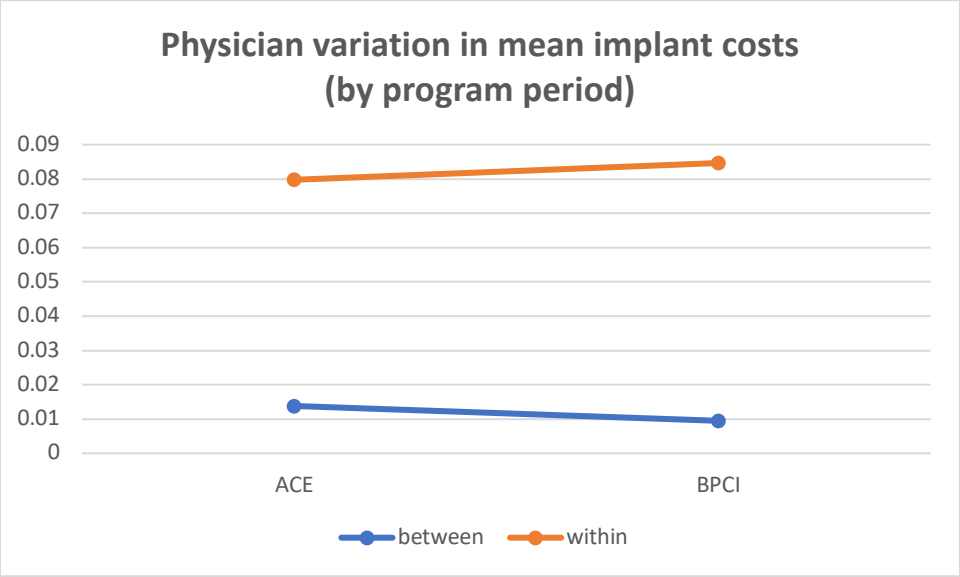
[d]Based on the residual pseudo-likelihood $\chi^2$ test.

**eAppendix Figure 1.** Physician Variation in Mean Implant Costs (by year)



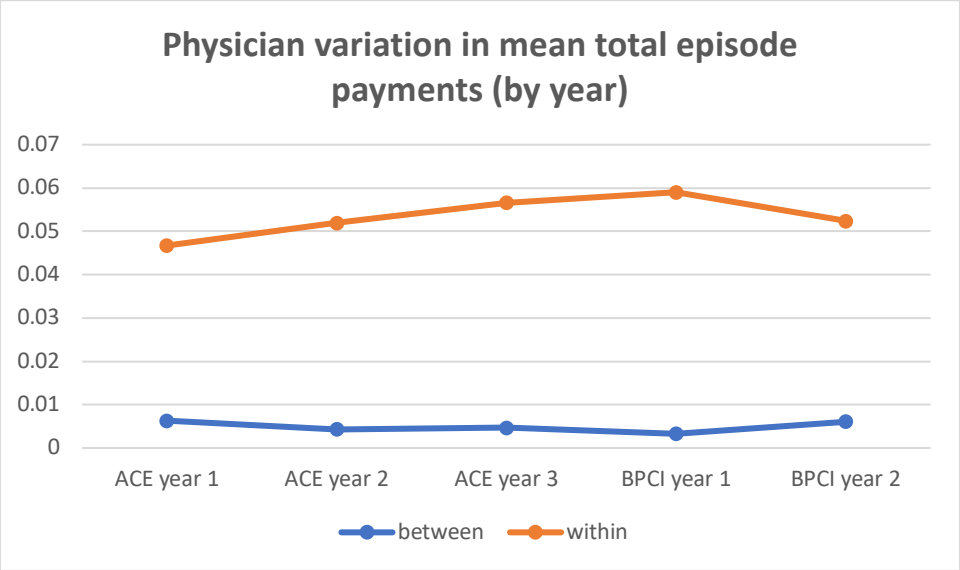

ACE indicates Acute Care Episode; BPCI, Bundled Payments for Care Improvement.

**eAppendix Figure 2.** Physician Variation in Mean Implant Costs (by program period)



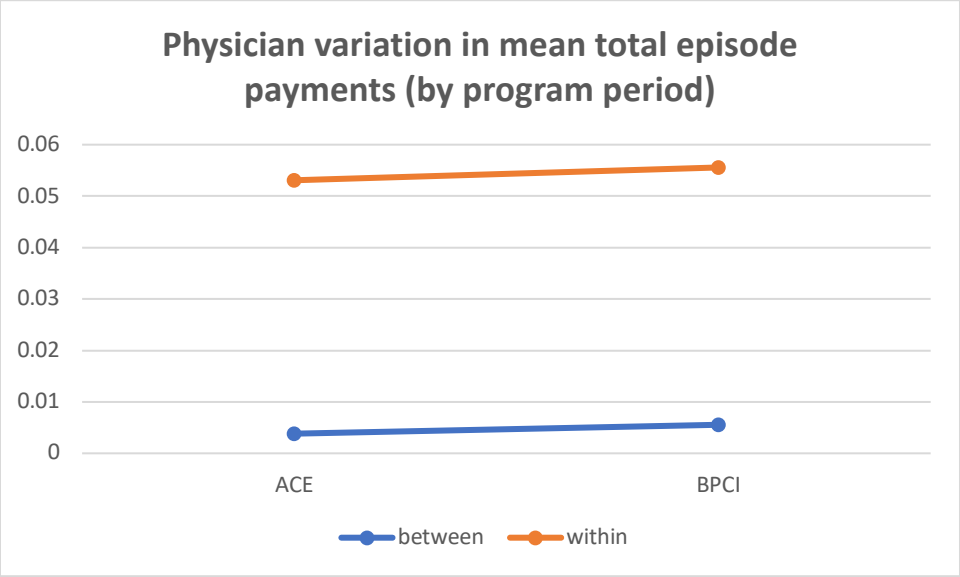

ACE indicates Acute Care Episode; BPCI, Bundled Payments for Care Improvement.

**eAppendix Figure 3.** Physician Variation in Mean Total Episode Payments (by year)




ACE indicates Acute Care Episode; BPCI, Bundled Payments for Care Improvement.

**eAppendix Figure 4.** Physician Variation in Mean Total Episode Payments (by program period)




ACE indicates Acute Care Episode; BPCI, Bundled Payments for Care Improvement.