Original research

Can an arthroplasty risk score predict bundled care events after total joint arthroplasty?

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ARTICLE INFO

ABSTRACT

Background: The validated Arthroplasty Risk Score (ARS) predicts the need for postoperative triage to an intensive care setting. We hypothesized that the ARS may also predict hospital length of stay (LOS), discharge disposition, and episode-of-care cost (EOCC).
Methods: We retrospectively reviewed a series of 704 patients undergoing primary total hip and knee arthroplasty over 17 months. Patient characteristics, 90-day EOCC, LOS, and readmission rates were compared before and after ARS implementation.
Results: ARS implementation was associated with fewer patients going to a skilled nursing or rehabilitation facility after discharge (63% vs 74%, P = .002). There was no difference in LOS, EOCC, readmission rates, or complications. While the adoption of the ARS did not change the mean EOCC, ARS >3 was predictive of high EOCC outlier (odds ratio 2.65, 95% confidence interval 1.40-5.01, P = .003). Increased ARS correlated with increased EOCC (P = .003).
Conclusions: Implementation of the ARS was associated with increased disposition to home. It was predictive of high EOCC and should be considered in risk adjustment variables in alternative payment models.
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Introduction

The number of total joint arthroplasties (TJAs) performed continues to rise, and due to the progress in modern medicine, older patients with more medical comorbidities are now among those undergoing TJA [1,2]. Despite TJA being widely regarded as a safe, successful surgery with excellent patient outcomes, complications can occur [3-6]. Additionally, surgeons and hospitals are increasingly focused on optimizing perioperative care following TJA given the rise in value-based payment strategies, which include episode-of-care and bundled payment models. Alternative payment models aim to provide quality care in a cost-efficient manner by homing in on hospital length of stay (LOS), discharge disposition, and readmission rates. However, current reimbursement schemes do not account for variability in patient and technical factors. Initial hospital stay costs may be significantly increased based on patient comorbidities and if a revision surgery is performed [7,8]. Moreover, postdischarge costs and readmissions still make up the majority of the total episode-of-care costs (EOCC) [9].

At our institution, Kamath et al developed the Arthroplasty Risk Score (ARS), a model based on preoperative risk factors, which was implemented as a quality improvement initiative but then showed that mortality and unplanned intensive care unit (ICU) admissions could be reduced by stratifying patients undergoing elective THA [10-12]. Further work and iterations of the quality improvement intervention identified medical comorbidities associated with increased likelihood for requiring critical care, and the group noted that intraoperative factors may be more important than preoperative factors in this estimation [10-12]. The ARS was shown to accurately predict the need for postoperative triage to an intensive care setting. Given that the preoperative and intraoperative factors

utilized in the ARS also relate to elements of care within bundled care systems, our group questioned if the ARS would have utility in anticipating health resource utilization. In the current healthcare economic milieu, it is increasingly important to stratify patients to bundled care and nonbundled care payment systems in order to be cost effective while still providing optimal patient care. Our hypothesis is that the ARS could be applied to predict hospital LOS, discharge disposition, and total EOCC.

The primary purpose is to study whether the adoption of ARS at our institution for risk stratification resulted in decreased LOS, change in discharge disposition, and decline in readmission rate. A secondary objective of the study included whether the ARS model resulted in decreased EOCC. We also sought to identify potential independent risk factors for high EOCC.

Material and methods

We retrospectively reviewed a consecutive series of 704 patients undergoing primary total hip and knee arthroplasty procedures within a single high-volume academic institution from October 2013 to March 2015. This study was approved and conducted per guidelines set by our institutional review board. No outside funding was received for this study. Patients undergoing arthroplasty procedures for fracture or malignancy, as well as those patients under the age of 18 years, were excluded from the study. From October 2013 to September 2014, patients were triaged to the orthopedic floor or to the ICU postoperatively based on our previously published risk stratification protocol [10]. Patients with 2 or more of the following risk factors were sent to the ICU postoperatively: age >75 years, body mass index (BMI) >35 kg/m^2, revision arthroplasty, creatinine clearance <60 mL/min, and history of coronary artery disease. After September 2014 until March 2015, patients were triaged to the ICU postoperatively if they had 3 or more points on the ARS scale, which included history of cardiac disease, chronic obstructive pulmonary disease, renal disease, BMI >35 kg/m^2, intraoperative vasopressors, and estimated blood loss >1 L [10-12].

Before surgery, all patients underwent preoperative evaluation and medical optimization by a single group of internists and were co-managed by the same group throughout the duration of their inpatient stay. This group confirmed all medical comorbidity diagnoses used in this study. Patient demographics and risk factors were identified and entered into our institution's arthroplasty database. These comorbidities and variables included a history of cardiac, chronic obstructive pulmonary, and renal disease; BMI and intraoperative vasopressor use; and estimated blood loss >1 L. Comorbidities required to calculate the Charlson Comorbidity Index (CCI), as defined by the original paper, were also recorded [13].

We also recorded LOS, readmission rate, discharge disposition, and postoperative complications within 90 days of surgery. Complications were defined and graded per a published definition [14]. Grade I complications not requiring intervention were excluded from the study. EOCC data were collected by our third party bundled convener and standardized to CMS costs from the date of surgery until 90 days postoperatively.

Statistical analysis

An *a priori* power analysis was first performed to determine the appropriate sample size. Our primary outcome measure was to determine whether adoption of the ARS model resulted in decreased EOCC. Based on prior published data [15] on mean CMS costs, to detect a $3000 difference in EOCC, we would need to enroll a total of 352 patients to achieve a power of 0.80 assuming at type I error rate of 0.05. Statistical analysis was first performed comparing

those patients who were risk stratified per the ARS and those who were not. Binary and categorical variables between the 2 groups were analyzed using a chi-square test. When expected variables were <5, we employed the Fisher's exact test. Continuous variables such as age and BMI were analyzed with the Student's *t*-test. The level of statistical significance was set at $P < .05$. Patient demographics, medical comorbidities, 90-day EOCC data, LOS, and readmission rates were compared between groups before and after implementation of the ARS tool in September 2014. To control for confounding variables, multivariate logistic regression analysis was then performed on all 704 patients to identify the independent effect of the ARS on patients in the upper quartile of EOCC at our institution ($31,804).

Results

We found no differences in the patient characteristics of the pre-ARS ($n = 410$) versus post-ARS ($n = 294$) groups in terms of age, BMI, household income, or ethnicity (Table 1). There were 260 men and 444 women with a mean age of 69 years (range 26-95). The mean BMI was 30.94 kg/m^2 (range 14.47-70.600). Mean EOCC was $28,342.80 ($11,381.23-$191,045.80) in the pre-ARS cohort and $28,995.26 in the post-ARS cohort (range $14,222.15-$140,449.30) (Table 1). Mean LOS was 3.61 days (range 1-19) in the pre-ARS group and 3.86 days (range 1-2) in the post-ARS group. The mean ARS score in the pre-ARS group was 1.49 (range 0-6) and 1.42 in the post-ARS group (range 0-6) (Table 1).

After institution of the ARS, the number of ICU admissions decreased from 70 patients to 36 patients over the study period (17% vs 12%, $P = .077$) (Table 2). Of these ICU patients, the proportion of patients discharged to rehab decreased from 100% to 83% ($P = .001$). Among the subset of ICU patients, there was no difference between the pre-ARS and post-ARS groups with respect to mean age (71.2 vs 74.5 years, $P = .105$), mean BMI (31.5 vs 30.7, $P = .640$), mean CCI (3.0 vs 2.7, $P = .611$), or the proportion of female

Table 1
Summary of the characteristics of pre-ARS and post-ARS implementation groups.

Characteristic	Post-ARS	Pre-ARS	P value
Mean age (y)	69.27	69.35	.921
Gender (%)			
Female	58.16	66.10	.031
Male	41.84	33.90	.031
Mean BMI (kg/m^2)	30.78	31.22	.450
Mean length of stay (d)	3.86	3.61	.133
Mean household income in ZIP code of residence (USD)	62,557.36	63,001.45	.837
Bottom quartile of median household income (%)	22.10	21.46	.837
Mean episode of care costs (USD)	28,995.26	28,342.80	.590
Mean index inpatient admission costs (USD)	12,387.86	12,321.12	.839
Mean postdischarge rehabilitation costs (USD)	1929.04	17,093.15	.633
Mean home-health costs (USD)	2667.72	2850.28	.131
Mean postdischarge outpatient care (USD)	841.34	834.93	.947
Ethnicity (%)			
White	69.73	67.32	.497
Non-White	30.27	32.68	.497
Mean CCI	2.25	2.02	.329
CCI 3 or greater (%)	27.89	26.10	.596
Mean ARS	1.42	1.49	.498
ARS >3 (%)	5.78	6.83	.575
In-hospital complication (%)	26.87	27.07	.952
Discharge disposition (%)			
Home	37.10	26.30	.002
Skilled nursing or rehabilitation facility	62.90	73.70	.002
Surgery (%)			
Knee arthroplasty	50.00	53.41	.371
Hip arthroplasty	50.00	46.59	.371

Table 2
Summary of values from subanalysis of ICU patient characteristics and costs pre-ARS and post-ARS implementation.

	Pre-ARS	Post-ARS	*P* value
ICU admissions (number of admissions)	70 (17%)	36 (12%)	.077
Proportion of patients discharged to rehabilitation facilities	100%	83%	.001
Proportion of patients in upper quartile of EOCC	100%	47%	<.001
Total episode of care costs	$2,151,551	$1,340,213	N/A
Total anchor inpatient costs	$857,949	$511,722	N/A

N/A, not applicable.

patients (71% vs 75%, *P* = .676) or hip patients (40% vs 55%, *P* = .128). The proportion of patients in the upper quartile of EOCCs also decreased from 100% to 47% (*P* < .001). There was no difference in mean EOCCs between the pre-ARD and post-ARS subgroups in the ICU ($37,228 vs 30,736, *P* = .118). Total EOCCs for all ICU patients after adoption of the ARS was $1,340,213, while total EOCCs before the ARS was $2,151,551. Total anchor inpatient costs for these patients decreased to $511,722 post-ARS from a total of $857,949 pre-ARS. Among ICU patients, adoption of the ARS resulted in total cost savings of $811,337. Adjusted for patient volume, the total cost savings to the health system was $282,545.

Implementation of the ARS was associated with a lower proportion of patients going to a skilled nursing facility or rehabilitation center after discharge (63% vs 74%, *P* = .002). However, there was no difference in LOS, readmission rates, or complications before and after utilization of the ARS (all *P* > .05) (Table 3).

The mean EOCC was roughly equivalent between the 2 groups: pre-ARS $28,342.80 versus post-ARS $28,995.26 (*P* = .590). There were no statistically significant differences between the 2 groups in terms of mean index inpatient admission costs, mean post-discharge rehabilitation costs, mean home-health costs, and mean postdischarge care costs (Table 1).

Patient risk factors, represented by the CCI and ARS scores, were equivalent before and after the implementation of ARS (Table 1). The percentage of patients who experienced in-hospital complications before and after implementation of the ARS was not statistically different (27.07 vs 26.87, respectively; *P* = .952). The multivariate regression analysis (Table 3) revealed that an ARS score of >3 was predictive of a high EOCC outlier (odds ratio 2.65, 95% confidence interval 1.40-5.01, *P* = .003). We performed a Hosmer-Lemeshow test to assess the goodness-of-fit test on our model (*P* = .418). A nonsignificant *P*-value indicates that there is not a poor fit. Of note, while an increased ARS score correlated with increased EOCC (*P* = .003), the CCI score had no statistically significant association (*P* = .797).

Table 3
Multivariate analysis for high episode-of-care costs with odds ratio, confidence interval, and *P* value summarized.

Risk factor	Odds ratio	95% CI	*P* value
ARS score >3	2.651	1.402-5.012	.003
CCI score ≥3	0.948	0.631-1.424	.797
Female gender	1.031	0.710-1.496	.872
Bottom quartile household income	1.322	0.806-2.170	.269
Age >75 y	1.387	0.937-2.052	.102
Disposition to SNF or rehabilitation	1.223	0.829-1.803	.311
BMI >35 kg/m^2	1.491	0.981-2.266	.061
Non-White ethnicity	0.894	0.568-1.408	.629
In-hospital complication	1.392	0.901-2.151	.136
Length of stay ≥4 days	0.854	0.549-1.329	.484
Ninety-day readmission	1.322	0.718-2.435	.370
Hip arthroplasty	0.798	0.553-1.150	.226

SNF, skilled nursing facility.

Discussion

In theory, bundled payment models have the potential to motivate surgeons, hospitals, and other members of the perioperative team to provide the best possible care at the lowest cost. However, patients with more comorbidities and patients undergoing revision surgery present a challenge to the bundled payment system, as these patient subsets represent inherent risks of more expensive episodes-of-care [7]. While some risk factors for perioperative complications are modifiable, many are not, and thus surgeons have expressed concern that sicker patients would be denied TJA for fear of fiscal liability despite meeting operative criteria.

The introduction of the ARS provides an example of an institutional risk stratification tool that incorporates preoperative and intraoperative data to stratify postoperative disposition to either routine monitoring postoperatively or an ICU. This tool has demonstrated utility by decreasing the mortality index from 4.77 to 1.62, and the rate of unplanned ICU admissions from 7.1% to 2.2%, following THA [12]. Strengths of our study include assessment of a consecutive series of patients with a variety of comorbidities undergoing primary TJA, thus making it generalizable, and the assessment tool and data collection tool had a 90% capture rate. Additionally, patient groups were similar and did not show any statistically significant differences in patient characteristics or demographics that may have confounded outcomes. Finally, the large sample size ensured adequate power necessary to achieve statistical significance and to avoid type I and II errors. Our study, however, also has several limitations. By virtue of the ARS being a quality improvement initiative, it underwent multiple modifications during the study period in order to optimize its accuracy. Consequently, the data does not reflect the impact of a singular intervention, rather a composite of interventions. Additionally, we included data from 2 hospitals in our health system, which may have variability in discharge planning and readmission. However, our department created protocols to minimize variation in the disposition process for surgeons, social workers, and therapists system-wide, in addition to implementing alerts in the electronic medical record for emergency physicians considering readmission to either hospital (which was not implemented until 1 month prior to the cessation of the study). Another limitation is that readmission rates only account for patients readmitted to our hospital system, which may result in under-reporting. Finally, while we believe that our study provides beneficial information to the reader by identifying that the ARS correlates with the high EOCC outliers, we acknowledge that this finding is limited by the small sample size of this group.

The implementation of the ARS, a risk stratification tool developed at our institution and validated by previous studies [10-12], was associated with increased disposition to home, while maintaining equivalent LOS, complication rates, and readmission rates. This is a powerful finding because it shows that the implementation of the ARS led to an increased number of patients being safely discharged to home, which is a goal of all hospitals and clinicians and thus a very generalizable finding that impacts surgeon and patient satisfaction. While the readmission rate trend is encouraging, causation cannot be attributed entirely to the ARS given other concurrent interventions our institution made to improve patient safety. Of note, when examining the subset of our patient population who went to the ICU, the implementation of the ARS resulted in significant total and patient volume adjusted cost savings of $811,337 and $282,545, respectively, as well as a decrease in the proportion of patients in the upper quartile of the EOCC. The reason for these savings is likely multifactorial, but the implementation of the ARS resulting in decreased costly ICU admissions

[16] as well as a decreased proportion of ICU patients being discharged to rehab, likely contributed.

The goal of a preoperative risk stratification score is first and foremost to promote patient safety, but the ARS demonstrates that it could also result in cost savings by optimizing resource utilization, particularly that of the ICU. Memtsoudis et al [17] estimated that 1 in 30 patients will require critical care services following TJA, thus appropriately triaging patients to the ICU and preventing unplanned ICU admissions has the potential for significant cost savings and improved resource utilization. The statistically significant reduction in the proportion of ICU patients being discharged to rehab as well as the proportion of all patients being discharged to rehab is encouraging in terms of cost savings, but the association between a preoperative risk stratification score and discharge disposition is not entirely clear. However, with the advent of alternative payment models, including bundled payment initiatives, the relationship is evocative given that postdischarge admission to subacute facilities consumes a significant portion of the total sum costs. In a study by Bozic et al [15], postdischarge payments accounted for 36% of total payments in a cohort of 250 Medicare beneficiaries undergoing primary and revision surgery. In this same group, 49% of patients were transferred to post–acute care facilities, which accounted for 70% of postdischarge payments [15]. Discharge to rehabilitation facilities can increase EOCC by 30% when compared to direct discharge to home, a figure that includes any subsequent readmissions within the 90-day episode [18,19]. Thus, discharging more patients to home after surgery may result in an increased margin for physicians and hospitals, as well as other potential benefits of comfort, reduced readmissions, and safety for the patients.

This study showed that utilization of the ARS may also have important cost implications for bundled payment systems for all patients, and particularly for those patients ultimately requiring ICU-level care. An association between the ARS and patients with higher EOCC or cost outliers was noted, although the ability of preoperative risk stratification tool to be considered in the evaluation of risk adjustment variables for reimbursement in alternative payment schemes is yet to be determined. This is a novel benefit of the ARS score, as compared to other risk scores like the CCI. The CCI serves as an effective risk stratification tool to predict complications, but it was not correlated with increased EOCC or EOCC outliers in our study population.

Conclusions

Alternative payment models are well established in our healthcare environment and have great potential to provide more cost-efficient and reproducible care. An aging population and advances in modern medicine have given us the ability to perform TJA in patients with advanced age, more comorbidities, and those requiring revision surgery. To prevent complex patients from having restricted access to healthcare due to a fear of lost profitability, risk stratification scores like the ARS could be utilized to create bundled payment modifiers to augment standard payments, thereby incentivizing surgeons to care for higher risk patients. The ARS can be valuable to surgeons, anesthesiologists, internists, hospital administrators, and insurers alike by providing a tool that promotes patient safety and that can impact and predict cost factors relevant to bundled payment systems.

References

[1] Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am 2007;89:780.
[2] Boettcher WG. Total hip arthroplasties in the elderly: morbidity, mortality, and cost effectiveness. Clin Orthop Relat Res 1992;274:30.
[3] Pulido L, Parvizi J, Macgibeny M, et al. In hospital complications after total joint arthroplasty. J Arthroplasty 2008;23(Suppl 1):139.
[4] Alfonso DT, Toussaint RJ, Alfonso BD, et al. Nonsurgical complications after total hip and knee arthroplasty. Am J Orthop 2006;35(11):503.
[5] Basilico FC, Sweeney G, Losina E, et al. Risk factors for cardiovascular complications following total joint replacement surgery. Arthritis Rheum 2008;58(7):1915.
[6] Mantilla CB, Horlocker TT, Schroeder DR, Berry DJ, Brown DL. Frequency of myocardial infarction, pulmonary embolism, deep venous thrombosis, and death following primary hip or knee arthroplasty. Anesthesiology 2002;96(5):1140.
[7] 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;474:2714.
[8] Rozell JC, Courtney PM, Dattilo JR, Wu CH, Lee GC. Should all patients be included in alternative payment models for primary total hip arthroplasty and total knee arthroplasty? J Arthroplasty 2016;31(9 Suppl):45.
[9] Clair AJ, Evangelista PJ, Lajam CM, et al. Cost analysis of total joint arthroplasty readmissions in a bundled payment care improvement initiative. J Arthroplasty 2016;31(9):1862.
[10] Kamath AF, McAuliffe CL, Baldwin KD, et al. Unplanned admission to the intensive care unit after total hip arthroplasty. J Arthroplasty 2012;27(6):1027.
[11] Kamath AF, Gutsche JT, Kornfield ZN, et al. Prospective study of unplanned admission to the intensive care unit after total hip arthroplasty. J Arthroplasty 2013;28(8):1345.
[12] Courtney PM, Whitaker CM, Gutsche JT, Hume EL, Lee GC. Predictors of the need for critical care after total joint arthroplasty: an update of our institutional risk stratification model. J Arthroplasty 2014;29(7):1350.
[13] Charlson ME, Pompei P, Ales KI, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis 1987;40:373.
[14] Sink EL, Leunig M, Zaltz I, Gilbert JC, Clohisy J, Academic Network for Conservational Hip Outcomes Research Group. Reliability of a complication classification system for orthopaedic surgery. Clin Orthop Relat Res 2012;470:2220.
[15] Bozic KJ, Ward L, Vail TP, Maze M. Bundled payments in total joint arthroplasty: targeting opportunities for quality improvement and cost reduction. Clin Orthop Relat Res 2014;472:188.
[16] Halpern NA, Bettes L, Greenstein R. Federal and nationwide intensive care units and healthcare costs: 1986–1992. Crit Care Med 1994;22(12):2001.
[17] Memtsoudis SG, Rosenberger P, Walz JM. Critical care issues in the patient after major joint replacement. J Intensive Care Med 2007;22:92.
[18] Slover JD. You want a successful bundle: what about post-discharge care? J Arthroplasty 2016;31:936.
[19] Ramos NI, Wang EI, Karia RJ, et al. Correlation between physician specific discharge costs, LOS, and 30-day readmission rates: an analysis of 1,831 cases. J Arthroplaty 2014;29(9):1717.