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Neighborhood socioeconomic disadvantage does not predict outcomes or cost after elective shoulder arthroplasty

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Background: There is growing evidence that the variation in value of shoulder arthroplasty may be mediated by factors external to surgery. We sought to determine if neighborhood-level socioeconomic deprivation is associated with postoperative outcomes and cost among patients undergoing elective shoulder arthroplasty.
Methods: We identified 380 patients undergoing elective total shoulder arthroplasty (anatomic or reverse) between 2015 and 2018 in our institutional registry with minimum 2-year follow-up. Each patient's home address was mapped to the area deprivation index in order to determine the level of socioeconomic disadvantage. The area deprivation index is a validated composite measure of 17 census variables encompassing income, education, employment, and housing conditions. Patients were categorized into 3 groups based on socioeconomic disadvantage (least disadvantaged [deciles 1-3], middle group [4-6], and most disadvantaged [7-10]). Bivariate analysis was performed to determine associations between the level of socioeconomic deprivation with hospitalization time-driven activity-based costs and 2-year postoperative American Shoulder and Elbow Surgeons (ASES) score, Single Assessment Numeric Evaluation (SANE), and pain intensity scores.
Results: Overall 19% of patients were categorized as most disadvantaged. These patients were found to have equivalent preoperative pain intensity ($P = .51$), SANE ($P = .50$), and ASES ($P = .72$) scores compared to the middle and least disadvantaged groups, as well as similar outcome improvement at 2 years postoperatively (ASES): least disadvantaged group [35.7-84.3], middle group [35.1-82.4], and most disadvantaged group [37.1-84.0] [$P = .56$]; SANE: least disadvantaged group [31.8-87.1], middle group [30.8-84.8], and most disadvantaged group [34.2-85.1] [$P = .42$]; and pain: least disadvantaged group [6.0-0.97], middle group [6-0.97], and most disadvantaged group [5.6-0.80] [$P = .88$]. No differences in hospitalization costs were noted between groups ($P = .77$).
Conclusions: Patients undergoing elective shoulder arthroplasty residing in the most disadvantaged neighborhoods demonstrate equivalent preoperative and postoperative outcomes as others, without incurring higher costs. These findings support continued efforts to provide equitable access to orthopedic care across the socioeconomic spectrum.

The New England Baptist Hospital Institutional Review Board approved this study (Assurance # FWA 00009165).

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Social determinants of health (SDOH) have been consistently shown to affect a wide range of health-related measures.[16,17] However, given the nuanced and multifactorial nature of these variables, much of the existing literature across various medical specialties has relied on single or few factors (eg, zip code, income, insurance type) to act as a proxy for socioeconomic status.[5,15,23] While studies utilizing these factors have helped illuminate many inequalities and disparities in health care outcomes, recent public health advancements have made it possible to capture SDOH data at a more granular and comprehensive level. One such emerging tool, the area deprivation index (ADI), is a validated, publicly available resource that provides a composite score of area-level socioeconomic disparities based on 17 different SDOH dimensions encompassing income, education, employment, and housing conditions.[11] By geocoding each address in the United States to census block groups of 600-3000 people, the ADI is able to provide a comprehensive representation of an individual's neighborhood-level disadvantage. The ADI has been shown to provide more granular data than traditional socioeconomic measures gathered from larger geographic areas derived at the zip code or county level.[2,12]

Despite an increasing awareness of the health disparities related to SDOH,[16] concerns over "cherry picking" and "lemon dropping" certain patients have grown in the setting of an expanding emphasis on value-based health care.[9] These concerns may be especially salient in the setting of elective orthopedic procedures.[3] Aside from a recent study showing that the ADI may correlate with preoperative function and pain in patients undergoing anatomic shoulder arthroplasty,[26] little is known if residence in socioeconomically disadvantaged communities affects outcomes and resource utilization after elective shoulder arthroplasty. A clearer understanding of these relationships may help inform future policy and value optimization efforts. As such, we used the ADI to determine if differences in neighborhood socioeconomic deprivation are associated with postoperative outcomes and cost among patients undergoing elective shoulder arthroplasty. We hypothesized that patients living in more disadvantaged neighborhoods would have worse postoperative outcomes and incur higher costs.

Methods

Study design

A retrospective study was performed at a metropolitan hospital in the United States. Our prospectively maintained registry was queried to include all patients who underwent elective primary total shoulder arthroplasty (anatomic or reverse) between February 2015 and November 2018 with a minimum of 2-year follow-up data and a valid home address in the state of the aforementioned metropolitan hospital. Patients who underwent revision shoulder arthroplasty or those with a traumatic indication for surgery were excluded. A single fellowship-trained shoulder surgeon performed all cases. The institutional review board granted study approval (IRB 2021-32).

Area deprivation index

Neighborhood-level socioeconomic deprivation was measured utilizing the ADI. The ADI integrates 17 factors within the domains of income, education, employment, and housing quality to quantify an individual's degree of socioeconomic deprivation.[10,11] By adapting and validating data from the American Community Survey,[4] Kind et al characterized each address in the United States into unique census block groups, compact geographic regions comprising 600-3000 people.[11] Census block groups, which represent an individual's neighborhood, have been shown to provide more granular data than socioeconomic measures gathered from large geographic areas derived at the zip code or county level.[2,12] When indexed to the state level, ADI software provides a score of 1-10, where higher scores represent a greater degree of socioeconomic deprivation. The ADI has been used extensively across various medical specialties given its high degree of internal and external validity.[2,10,11,14,24]

Each patient's home address was collected during the study query period (February 2015-November 2018) and mapped to its corresponding consensus block group as previously described.[2] Patients with post office box addresses were excluded as they could not be accurately geocoded.[2] Patients were classified into 3 groups by their ADI rating: least disadvantaged (ADI values 1-3), middle group (ADI values 4-6), and most disadvantaged (ADI values 7-10).[2]

Covariates

Each patient's age; sex; number of patient-reported allergies; American Society of Anesthesiologists score;[13] body mass index; presence of comorbid conditions including diabetes, depression, and preoperative opioid use (defined as daily opioid use prior to surgery); procedure type (anatomic/reverse total shoulder arthroplasty); preoperative diagnosis (rotator cuff arthropathy, degenerative joint disease, avascular necrosis, rheumatoid arthritis, capsulorrhaphy arthropathy); and preoperative American Shoulder and Elbow Surgeons (ASES), Single Assessment Numeric Evaluation (SANE), and Visual Analog Scale (VAS) for pain scores were collected.

Patient-reported outcomes

Our primary outcome measures included the 2-year postoperative ASES,[25] SANE,[7,30] and VAS pain scores.[6] The ASES score uses a

100-point scale, weighted 50% for pain and 50% for function with higher scores representing greater overall shoulder health.[25] The SANE score also uses a 100-point scale and asks patients to rate their overall shoulder status from 0% to 100%, where 100% is normal.[7,30] The VAS asks patients to rate their pain using a 10-point scale, with higher numbers representing greater pain levels.[6] This information is routinely obtained by our research staff.

Time-driven activity-based costing

Total hospitalization costs, our secondary outcome measure, were estimated for each patient using time-driven activity-based costing (TDABC) methodology. TDABC has been shown to provide more reliable and precise cost data than traditional hospital accounting methodologies.[1,20] The aggregate time each resource is used is multiplied by the cost-per-unit time of that resource to obtain cost. Total hospitalization costs are determined by calculating the sum of all resources utilized over an episode of care.[22] Costs from check-in on the day of surgery through room cleaning after discharge were included.[22] Avant-garde Health (Boston, Massachusetts, USA) software was used for cost calculations. Notably, the same anatomic and reverse prosthesis was utilized for all patients.

Statistical analysis

Bivariate analyses using the Pearson χ^2 test for categorical variables and independent-samples *t* test for continuous variables were performed to determine the association between ADI groups, patient-reported outcome scores, and total hospitalization costs. Categorical variables were presented as frequencies and percentages, whereas continuous variables were presented as means and standard deviations. Due to the fact that individual hospital cost data were confidential, actual dollar amounts were not reported. Instead, patients were categorized into 2 separate groups: those in the top quartile ($\geq 75^{th}$ percentile) of total in-hospital costs vs. those in the lower 3 quartiles ($<75^{th}$ percentile).[22] A threshold of $P < .05$ was used to denote statistical significance.

Results

The cohort consisted of 380 patients, 179 (47.1%) of whom were classified as least disadvantaged, 129 (33.9%) were classified into the middle group, and 72 (18.9%) were classified as most disadvantaged (Fig. 1). Those in the least disadvantaged group were oldest (mean age = 70.5 ± 7.6 years), followed by the most disadvantaged group (68.4 ± 7.7 years) and middle group (67.2 ± 7.8 years) (P = .001) (Table I). No significant differences among sex, number of patient-reported allergies, American Society of Anesthesiologists score, body mass index, presence of comorbid conditions, preoperative ASES/SANE/VAS pain scores, procedure type, or preoperative diagnosis were found between groups (Table I). Patient characteristics are further described in Table I. The overall rate of follow-up for this registry was 75% during the study period. There was no difference in the proportions of patients in each ADI group when comparing patients with follow-up data vs. those lost to follow-up (P = .50)

At 2 years postoperatively, similar improvements in ASES (least disadvantaged group [35.7-84.3], middle group [35.1-82.4], and most disadvantaged group [37.1-84.0] [P = .56] [Fig. 2]), SANE (least disadvantaged group [31.8-87.1], middle group [30.8-84.8], and most disadvantaged group [34.2-85.1] [P = .42] [Fig. 2]), and VAS pain scores (least disadvantaged group [6.0-0.97], middle group [6-0.97], and most disadvantaged group [5.6-0.80] [P = .88] [Fig. 3]) were found among ADI groups.

Additionally, a similar percentage of patients comprised the top quartile of total in-patient hospitalization costs among ADI groups (least disadvantaged group [25.5%], middle group [23.8%], and most disadvantaged group [20.7%] [P = .77] [Fig. 4]).

Discussion

This study sought to characterize the association between socioeconomic deprivation and 2-year postoperative outcomes and cost after elective shoulder arthroplasty. Our primary findings demonstrate that patients undergoing shoulder arthroplasty residing in the most socioeconomically disadvantaged communities demonstrate equivalent preoperative and postoperative outcomes as others, without incurring higher costs.

SDOH have been consistently shown to affect a wide range of health-related metrics across all fields of medicine. However, given the nuanced and multifactorial nature of these variables, many prior studies have relied on individual factors (eg, insurance type, income, zip code) to represent socioeconomic status as a whole.[5,15,21] While this methodology has helped highlight numerous health-related inequities and disparities, it may also fail to capture the full complexity of a patient's situation. With the emergence of precision public health and tools such as the ADI, which utilizes census block groups comprised of 600-3000 people, the ADI is able to connect patients to their neighborhood, a method that more precisely portrays an individual's socioeconomic environment.[11] The ADI is especially useful for several reasons. First, it is an aggregate of 17 different socioeconomic factors (eg, income, education, employment, housing quality) and therefore may represent a more comprehensive picture of a patient's true condition. The second advantage is that it quantifies a patient's level of social deprivation relative to others at both the state and national level. As such, it provides a value that can be reliably compared across studies. Future risk-adjustment models, across all fields of orthopedics, may benefit from the incorporation of the ADI. Third, the ADI is based on a scale that allows for large variation in values. This allows for subtle differences between groups to be appreciated. Fourth, the ADI is an easily accessible publicly available

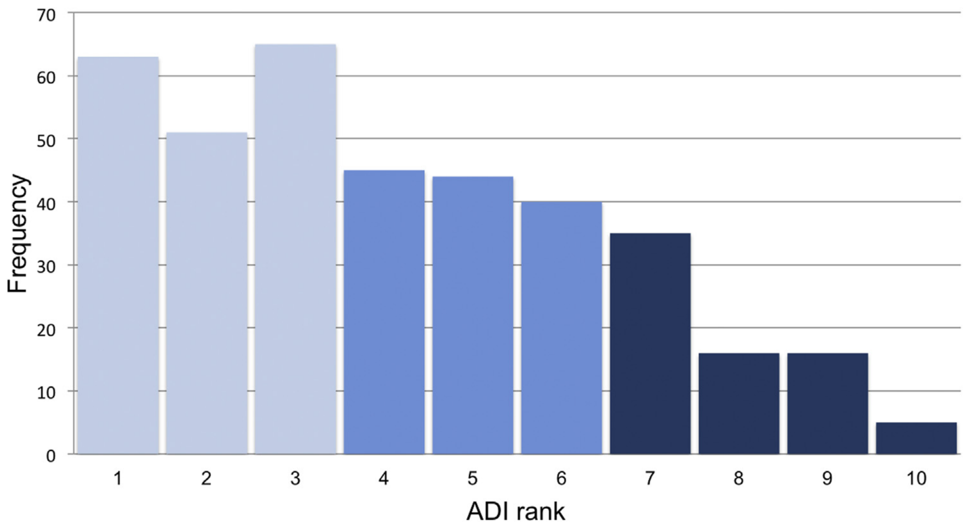

Figure 1 Area of deprivation index (ADI) rank among the study population.

Table I Characteristics of the study population

Parameter	All patients	Least disadvantaged group	Middle group	Most disadvantaged group	*P* value
Total†	380 (100)	179 (47.1)	129 (33.9)	72 (18.9)	
Age* (yr)	69 ± 7.8	70.5 ± 7.6	67.2 ± 7.8	68.4 ± 7.7	**.001**
Sex†					
Female	225 (59.2)	109 (60.9)	75 (58.1)	41 (56.9)	.81
Male	155 (40.8)	70 (39.1)	54 (41.9)	31 (43.1)	
Number of patient-reported allergies*	2.0 ± 2.9	2.2 ± 3.5	1.6 ± 1.8	2.3 ± 2.9	.13
ASA†					
≤2	302 (79.5)	147 (82.1)	101 (78.3)	54 (75)	.41
≥3	78 (20.5)	32 (17.9)	28 (21.7)	18 (25)	
BMI*	30.5 ± 6.1	29.9 ± 6.0	31.4 ± 6.2	30.3 ± 5.7	.08
Comorbid conditions†					
Preoperative opioid use	46 (12.1)	27 (15.1)	11 (8.5)	8 (11.1)	.21
Diabetes	52 (13.7)	21 (11.7)	22 (17.1)	9 (12.5)	.39
Depression	81 (21.3)	34 (19)	32 (24.8)	15 (20.8)	.47
Preoperative ASES score*	35.8 ± 16.7	35.7 ± 16.4	35.1 ± 17.0	37.1 ± 16.9	.72
Preoperative SANE score	31.9 ± 19.9	31.8 ± 20.8	30.8 ± 18.5	34.2 ± 20.3	.50
Preoperative pain score (VAS)	5.9 ± 2.3	6.0 ± 2.2	6.0 ± 2.4	5.6 ± 2.3	.51
Procedure type†					
Anatomic TSA	115 (30.3)	51 (28.5)	41 (31.8)	23 (31.9)	.78
Reverse TSA	265 (69.7)	128 (71.5)	88 (68.2)	49 (68.1)	
Diagnosis†					
Rotator cuff arthropathy	83 (21.8)	35 (19.6)	28 (21.7)	20 (27.8)	.09
Degenerative joint disease	271 (71.3)	137 (76.5)	87 (67.4)	47 (65.3)	
Other‡	26 (6.8)	7 (3.9)	14 (10.9)	5 (6.9)	

ASA, American Society of Anesthesiologists; *BMI*, body mass index; *ASES*, American Shoulder and Elbow Surgeons; *SANE*, Single Assessment Numeric Evaluation; *VAS*, Visual Analog Scale; *TSA*, total shoulder arthroplasty.
* The values are given as the mean and the standard deviation.
† The values are given as the number of patients, with the percentage in parentheses.
‡ Includes avascular necrosis, rheumatoid arthritis, and capsulorrhaphy arthropathy.
Bold values indicate statistical significance.

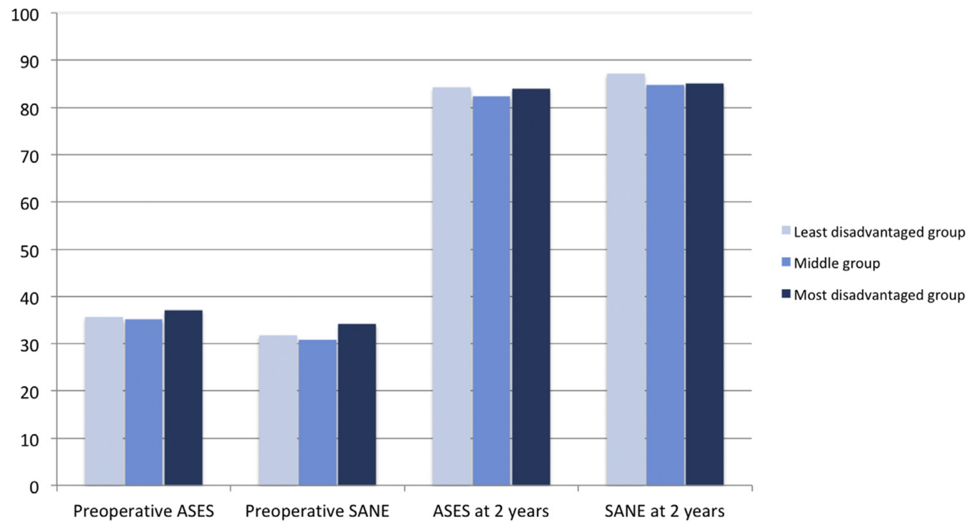

Figure 2 Functional outcome scores 2 years after shoulder arthroplasty based on disadvantaged status. *ASES*, American Shoulder and Elbow Surgeons; *SANE*, Single Assessment Numeric Evaluation.

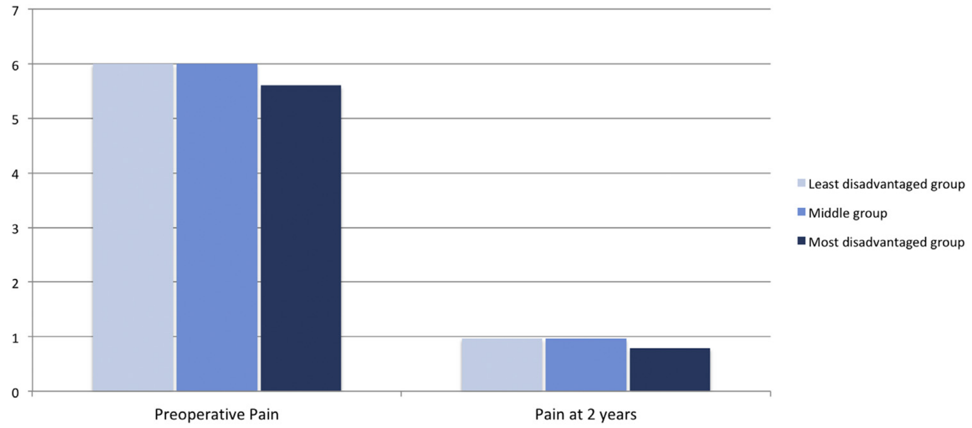

Figure 3 Pain scores 2 years after shoulder arthroplasty based on disadvantaged status.

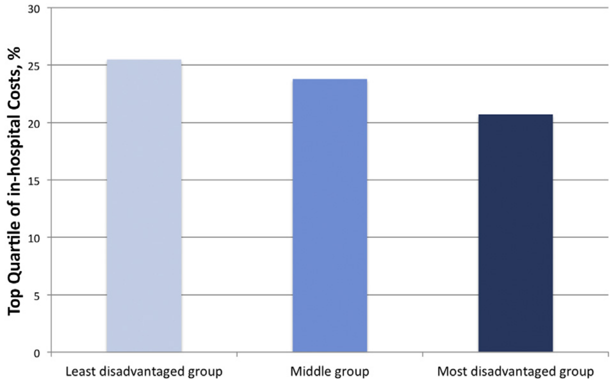

Figure 4 In-hospital costs associated with shoulder arthroplasty based on disadvantaged status.

online resource. Given these factors, we anticipate and encourage the continued utilization of the ADI as a method to characterize neighborhood-level socioeconomic deprivation.

Relatively few studies have been published examining the relationship between individual socioeconomic factors and shoulder arthroplasty outcomes. Waldrop et al[29] found that patients with Medicare and Medicaid insurance undergoing primary shoulder arthroplasty demonstrated worse preoperative and postoperative patient-reported scores (though similar improvement) than those with private insurance. Similarly, the study by Sheth et al,[26] the only other study to our knowledge in the shoulder arthroplasty literature utilizing the ADI, reported lower preoperative ASES scores among patients in the most disadvantaged quartile of their cohort. Notably, postoperative scores were not studied. In contrast to these studies, we report no difference in preoperative or 2-year postoperative ASES, SANE, or VAS pain scores when patients were stratified by the ADI. While this discrepancy may be related to factors not captured by the ADI, it is possible that patients in prior studies with high degrees of socioeconomic deprivation may have undergone surgery later, and with presumably worse preoperative function, than those in our study. Future studies assessing the relationship between socioeconomic deprivation and the presenting severity of arthritic change may be a valuable next step in understanding these questions.

In the second aspect of our study, we similarly found no association between the degree of neighborhood-level socioeconomic deprivation and total hospitalization costs. The relationship between socioeconomic deprivation and hospitalization costs has not been extensively studied in the shoulder arthroplasty literature. Matsen et al,[18] however, did report a longer length of stay after shoulder arthroplasty among patients with Medicaid insurance than among those with private insurance. While length of stay has been shown to be associated with total hospitalization costs,[20] the observed discrepancy in results may be attributed to inherent differences between the ADI and insurance status in characterizing socioeconomic disadvantage. Furthermore, differences in factors such as case management between hospital systems may also contribute to the observed discrepancy. It should be noted that all patients in this study were admitted for at least one night after surgery. As such, our study's cost analysis may not be directly applicable to those undergoing outpatient arthroplasty procedures. As shoulder arthroplasty begins to transition to a primarily outpatient procedure,[19] efforts to understand and optimize potential barriers to discharge among patients of differing socioeconomic status should be emphasized.

When considered collectively, our data support the notion that shoulder arthroplasty is associated with excellent value, irrespective of where one lives. These results are reassuring and support continued efforts to provide equitable access to elective orthopedic care across the socioeconomic spectrum. As the utilization of shoulder arthroplasty continues to increase,[28] in the setting of a growing wealth gap,[27] it is imperative that policies and payment incentives regarding orthopedic conditions are carefully and deliberately constructed.

The primary strengths of our study include its relatively large sample size, the use of TDABC accounting to determine hospitalization costs, and the use of the ADI in order to comprehensively characterize socioeconomic status. Notably, 2018 ADI data (collected from 2014 to 2018) were specifically utilized as they most closely overlapped with our study period (2015-2018). Given the objective and reliable nature of our ADI scores and TDABC costs, we believe that this study has strong internal validity. Nonetheless, our study does have several weaknesses. First, as this study was performed at an urban hospital in the northeast United States, our results may not be generalizable to all patient populations. Second, our 2-year follow-up period may not be long enough to capture the medium- and long-term implications that socioeconomic status may have on shoulder arthroplasty. Third, our study did not report complication, readmission, and revision rates. As such, we encourage additional larger studies with longer-term follow-up on this topic. Fourth, there is the possibility that our results may be due to a type II error. However, we feel as though this is unlikely given the consistency of our results in the setting of small effect sizes and large *P* values across each of our outcomes. Specifically, ASES, SANE, and pain scores were found to differ by only 0.3, 2.0, and 0.09 points at 2 years when comparing the least and most disadvantaged groups. Therefore, a type II error would likely be clinically irrelevant in this case. Furthermore, the corresponding *P* values assessing postoperative outcomes were all well above the 0.05 threshold (0.56, 0.42, and 0.88), indicating that there was no trend toward significance. These same results were noted in our cost analysis as well. Lastly, a power analysis was intentionally not performed given previously reported concerns with performing post hoc power analyses.[8,31] Fifth, our cost analysis only included inpatient costs. Costs that were incurred after discharge (eg, follow-up care, physical therapy) may be different between ADI groups and should be considered in future studies. Sixth, despite there being a statistically significant difference between ADI groups based on age, a regression analysis was not performed due to the small overall effect size between groups (most disadvantaged group, 68.4 years; middle group, 67.2; and least disadvantaged group, 70.5 years) as well as the fact that the largest difference between groups was not between the most and least disadvantaged groups (eg, the mean age for the middle group was the lowest). Seventh, it is possible that certain patients with higher degrees of socioeconomic deprivation were not selected to undergo surgery. Lastly, it is likely that some patients living in areas with high levels of socioeconomic deprivation do have increased access to certain resources, such as transportation, and it is possible that these patients self-selected to be seen at our clinic.

Conclusions

Patients undergoing elective shoulder arthroplasty residing in the most disadvantaged neighborhoods demonstrate equivalent preoperative and postoperative outcomes as others, without incurring higher costs. These findings support continued efforts to provide equitable access to orthopedic care across the socio-economic spectrum.

Disclaimers:

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Conflict of interest: Andrew Jawa is a paid speaker and consultant for DJO Global, is a paid consultant for Ignite Orthopedics, receives royalties from Depuy Synthesis, and has equity in Boston Outpatient Surgical Suites. The other authors, their immediate families, and any research foundation with which they are affiliated did not receive any financial payments or other benefits from any commercial entity related to the subject of this article.

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