JSES International 6 (2022) 867–873

Contents lists available at ScienceDirect

JSES International

journal homepage: www.jsesinternational.org

A novel comorbidity risk score for predicting postoperative 30-day complications in total shoulder arthroplasty and elucidation of potential racial disparities

Robby D. Turk, MD, MBA[a], Lambert T. Li, BS[b], Sundeep Saini, DO[b], Meghan MacAskill, BS[c], Glen Ross, MD[b,c], Sarav S. Shah, MD[b,c,*]

[a]Department of Orthopaedic Surgery, Atrium Health Musculoskeletal Institute, Charlotte, NC, USA
[b]Department of Orthopaedic Surgery, New England Baptist Hospital, Boston, MA, USA
[c]New England Shoulder and Elbow Center, Brighton, MA, USA

ARTICLE INFO

Keywords:
Shoulder arthroplasty
Racial disparities
Comorbidity risk Score
Health disparities
Bundle payment
Complications

Level of evidence: Basic Science Study; Development of Outcome Instrument/ Classification System

Background: Efficient and effective preoperative identification of those patients with elevated risk may allow for more cost-effective interventions, accurate bundled payment adjustments, and overall improved patient care. Few comorbidity indices have provided clinical utility and adequate discriminative ability in the setting of complications after shoulder arthroplasty (SA).

Methods: The American College of Surgeons National Surgical Quality Improvement Program database was queried for anatomic and/or reverse SA procedures between 2010 and 2019. A subset of comorbidities were utilized including end-stage renal disease, history of hypertension, chronic obstructive pulmonary disease, functional status, history of bleeding disorder, and disseminated cancer.

Results: A total of 25,927 patients with an average age of 69.2 (standard deviation ±9.5) years were included in the study. Patients with a comorbidity risk score (CRS) at or above 2 were indicated to have at least a 29.6% 30-day postoperative complication rate after undergoing total shoulder arthroplasty, significantly higher than the described average of approximately 15%. The area under receiver operator curve for the novel CRS scoring system was 0.595, indicating fair discriminative ability to predict 30-day postoperative complications after SA. This illustrates a discriminative ability similar to that of the American Society of Anesthesiologists classification (0.584, confidence interval [CI] 0.578-0.589), modified Charlson Comorbidity Index (0.567, CI 0.561-0.573), and modified Frailty Index (0.534, CI 0.529-0.539), each of which are common comorbidity indices used for the National Surgical Quality Improvement Program database. The average CRS for the population was 0.8537 (CI 0.8011-0.8150; $P < .05$) while that for the Black demographic was 1.08 (CI 1.03-1.13; $P < .001$). Our results suggest that if the disparity in CRS among races was corrected, the average complication rate would be decreased by 2.0%.

Discussion and Conclusion: A higher CRS score resulted in higher rates of 30-day postoperative complications following SA. Black patients had a higher average CRS than all other races illustrating a racial disparity in comorbidity risk. Although the average complication rate of each race would still be unequal, this could mitigate some of the racial disparities observed and decrease the overall 30-day complication rate in SA. With the rise of bundled payments further increasing the need to preoperatively identify patients at high risk for costly complications, the CRS is based on easily identified, relevant comorbidities that may be an advantageous tool to identify patients at increased risk of complications following SA.

Total and reverse shoulder arthroplasties (SAs) are increasingly utilized surgeries for treatment of severe glenohumeral arthritis and a number of other pathologies of the glenohumeral joint. Between 2011 and 2017, the number of SAs increased by 103.7%, and with the aging population, various models project as much as a 235.2% increase in annual volume by 2025.[13,35] Complications occur in approximately 15% of patients undergoing SA,[15] meaning over 40,000 patients may experience postoperative complications

Institutional review board approval was not required for this study.

*Corresponding author: Sarav Shah, MD, New England Baptist Hospital Sports Medicine Division 125 Parker Hill Ave Boston, MA 02120.
E-mail address: saravshah1@gmail.com (S.S. Shah).

https://doi.org/10.1016/j.jseint.2022.08.013

following SA in the year of 2025.[5,35] Some of the most common complications following SA include instability, loosening, infection, notching, nerve injury, and fractures. Many of which may require reoperation.[5,15,35] Although some adverse outcomes are inherent to surgery, many can be mitigated by early identification of those who may be at increased risk of postoperative complications. Efficient and effective preoperative identification of those patients with elevated risk may allow for more cost-effective interventions, accurate bundled payment adjustments, and overall improved patient care.

To that end, a number of comorbidity scores exist in the current literature that attempt to provide prognostic utility related to complications after a major surgery. For SA specifically, the American Society of Anesthesiologists (ASA), modified Charlson Comorbidity Index (mCCI), and modified Frailty Index (mFI) are index scores commonly used in national data sets to evaluate patients' risk of adverse outcomes. However, the discriminative ability and clinical utility of these indices have been limited due to inherent subjectivity and/or not being sensitive enough to adequately capture low comorbidity burdens common in elective orthopedic surgery patient populations, commonly resulting in the overwhelming majority of patients having a comorbidity score of 0.[36]

In addition to the overall rates of SA and associated complications, a growing number of studies continue to highlight racial disparities in orthopedic care including shoulder, hip, and ankle arthroplasties.[1,7,8,24,26,29-31,33,37] However, a limited number of studies have adequately assessed the relationship between race and a comorbidity index with significant discriminative ability for those at elevated risk of surgical complications. With a growing utilization of bundled payments and increasing awareness of racial disparities in health care, early identification of potentially costly complications is of paramount importance to allow for any potential preemptive interventions that may allow improved outcomes. Given the possible implications of an inappropriately adjusted bundled payment, such as potentially furthering already existing disparities due to misaligned incentives, it is a necessity to thoroughly investigate and describe these existing disparities to better guide clinicians in patient education and for optimization of outcomes for all segments of the population.

The primary aim of this study is to identify an at-risk population (utilizing a novel comorbidity risk score [CRS]) that may require additional care beyond typical postoperative management in SA. The secondary aim of the current study is to evaluate potential racial disparities in the use of this tool as they pertain to SA. Our hypothesis is that a higher CRS score will increase the likelihood of postoperative complications. We also hypothesize that a racial disparity will persist and be exhibited with Black patients having a higher CRS than other races.

Materials and methods

Data source

This investigation utilized data from the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database from the years of 2010-2019. NSQIP is a national prospective database that collects over 150 verified variables including demographics, comorbidities, preoperative risk factors, intraoperative variables, and 30-day postoperative mortality and morbidity outcomes for patients undergoing major inpatient and outpatient surgical procedures. The NSQIP database maintains strict data quality standards, and medical centers employ trained surgical clinical reviewers who submit data. There also must be at least an 80% 30-day follow-up rate and an interrater reliability of greater than 95% for a medical center to be included in the final NSQIP database.

Inclusion and exclusion criteria

Total SA (TSA) and reverse total SA (RSA) cases in the NSQIP database between 2010 and 2019 were included. The Current Procedural Terminology (CPT) code 23472 ("total arthroplasty of glenohumeral joint") was used to select patients who underwent anatomic TSA or RSA. The patient inclusion criteria consisted of patients having a complete data set including race, gender, age, preoperative comorbidities, hospital length of stay (LOS), discharge status, and postoperative complications. Patients were excluded if they had the following preoperative diagnosis listed for additional conditions: fracture, sepsis, infection, prosthesis complications, orthopedic after care, and emergent surgery. Patients with the following CPT codes listed for additional procedures were also excluded: revision SA (23473, 23474); hemiarthroplasty (23470); removal of prosthesis (23334); or removal of implant (20680).

Data of interest

Data of interest included patient demography (age, body mass index, sex, race, etc.), comorbidities (diabetes, smoking status, etc.), perioperative course (operative time, postoperative LOS, etc.),[4,17] surgical complications (site infections, wound dehiscence, etc.), and postoperative course (return to operating room, 30-day readmission, etc.). Commonly collected proxies that have been described in the literature to be, in variable degrees, related to social support include end-stage renal disease,[22] history of hypertension,[14] chronic obstructive pulmonary disease (COPD),[2] functional status,[11] bleeding disorder,[23] and disseminated cancer.[34] These values were collected and assessed as influential comorbidities. Information on these factors was available in the NSQIP database and is often readily available in a patient's electronic health record. As such, we specifically chose factors that are clinically relevant that they would be available for any existing patient in a surgeon's practice without additional data collection.

Statistical analysis

A mCCI was calculated from the available NSQIP data.[6] Points were assigned to patients based on their preoperative comorbidities, including age, cancer, COPD, congestive heart failure, ascites, end-stage renal disease, diabetes mellitus type 1, and diabetes mellitus type 2. Descriptive statistics were calculated using Chi-squared tests and one-way analysis of variance where appropriate. For initial assessment of the comorbidities to be assessed,[2,4,11,14,17,22,23,34] univariate logistic regressions were used. Factors that were significant under this analysis were included in a multivariable binary logistic regression analysis modeling the odds of any complication based on comorbidity factors. Any complication was defined as wound, cardiac, respiratory, renal, neurological, or septic/systemic complications in addition to deep vein thrombosis/pulmonary embolism, postoperative blood transfusion, urinary tract infection, extended LOS (3+ days), or reoperation.

Calculation of the CRS

The independent comorbidities included end-stage renal disease, history of hypertension, COPD, functional status, bleeding disorder, and disseminated cancer.[2,4,11,14,17,22,23,34] Each respective nonexponentiated coefficient from the multivariable model using these markers was used to calculate an integer risk score based on a

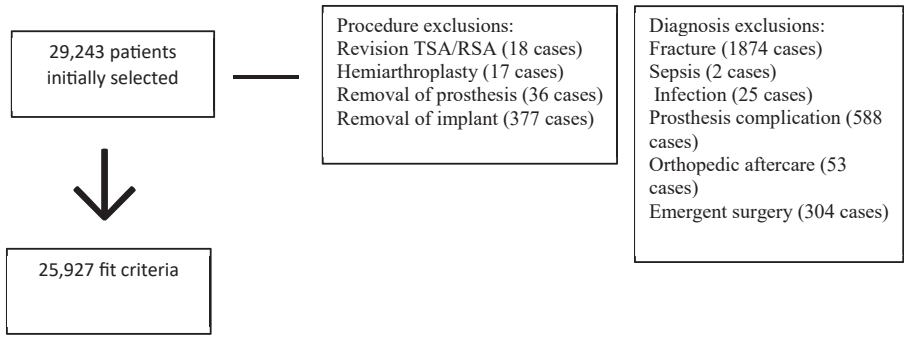

Figure 1 Patient selection. *TSA*, total shoulder arthroplasty; *RSA*, reverse shoulder arthroplasty.

simple calculation (coefficient$_x$/smallest coefficient). Model performance was assessed using the receiver operator characteristic analysis, specifically with the area under receiver operator curve (AUROC). Finally, complication rate by CRS was calculated for the cohort in this study. A cutoff of N $\geq$ 50 patients was used to determine which score values the complication rate was reported for; for scores under this N, an additional complication in 1 patient would change the estimated complication rate by more than 2%. A threshold of $P < .05$ was used to determine statistical significance. SPSS V27.0 was used (IBM Corporation, Armonk, NY, USA).

Results

Of the 29,243 surgical cases identified, a total of 25,927, or 88.67%, patients satisfied the criteria for analysis (Fig. 1). Patient exclusion criteria consisted of concurrent procedure exclusions including revision TSA/RSA (18 cases), hemiarthroplasty (17 cases), removal of prosthesis (36 cases), or removal of implant (377 cases) and diagnosis exclusions including fracture (1874 cases), sepsis (2 cases), infection (25 cases), prosthesis complication (588 cases), orthopedic aftercare (53 cases), and emergent surgery (304 cases). The average age was 69.2 (±9.5) years, and 46.2% of the cohort was composed of male and 53.8% of female patients.

Of these patients, 21,013 (81.05%) were White, 1215 (4.69%) were Black, 955 (3.68%) were Hispanic, 199 (0.76%) were Asian/Pacific Islander, and 2441 (9.41%) were of unknown/other race (Table I). There was a significant difference between patients of different racial/ethnic groups in terms of age ($P < .001$), mCCI ($P < .001$), ASA class ($P < .001$), preoperative functional status ($P = .005$), cigarette smoking ($P < .001$), steroid use ($P < .001$), bleeding disorders ($P = .002$), preoperative transfusions ($P = .007$), and hypertension requiring medical therapy ($P < .001$). The most common complications throughout the cohort included blood transfusion, readmission, and reoperation. There was also a significant difference between patients of different racial/ethnic groups in wound complications ($P < .001$), hospital readmission ($P < .001$), all complications combined except extended LOS ($P = .027$), and LOS of 3 or more days ($P < .001$; Table II).

Our final CRS model (Table III) contained 6 independent comorbidities, all of which were significant predictors of complications from our data set: end-stage renal disease ($P < .001$), hypertension on medical therapy ($P < .001$), COPD ($P < .001$), nonindependent functional status ($P < .001$), bleeding disorder ($P < .001$), and disseminated cancer ($P < .001$). The integer scores for these predictors ranged from 1 to 6, with a maximum total score of 21. This model was defined as the CRS. The AUROC (a measure of discriminative ability) for this model was 0.595, which indicates that there is a 59.5% chance of correctly predicting whether a given patient will have a complication using our model.

The AUROC for our novel CRS scoring system (0.595) indicates a fair discriminative ability to predict 30-day postoperative complications after SA (Fig. 2). This illustrates a similar discriminative ability compared to that of the ASA classification (0.604) and the modified CCI (0.597) as they were calculated in our data set. Other studies have also found similar AUROC values for ASA classification (0.584, 95% CI 0.578-0.589), mCCI (0.567, 95% CI 0.561-0.573), and mFI (0.534, 95% CI 0.529-0.539).[9,10,20,21] In this data set, the mean complication rate was 18.6%. In our data set, there was a stepwise increase in complication rate with increasing CRS (Table IV). Patients with a CRS of 2 had a complication rate of 29.6%, and 9.1% of the study population had a CRS of 2 or higher. Patients with a CRS of 0 had a complication rate of 12.3%.

Figure 3 shows the estimated complication rate by comorbidity score. The trend across comorbidity scores from 1 through 9 was close to linear, with a linear regression giving a slope of 9.3% and an R^2 of 0.9329. This means that each point increase in CRS correlates to an estimated 9.3% higher complication rate.

The mean CRS by patient race varied significantly (Table V). Most notably, Black patients had a higher average CRS (1.08, CI 1.03-1.13) than all other races (White 0.86, CI 0.85-0.87; Hispanic 0.90, CI 0.84-0.96; Asian/Pacific Islander 0.89, CI 0.78-1.00; Native American 0.75, CI 0.60-0.90; other/unknown 0.70, CI 0.67-0.73). The unknown/other racial group also illustrated a significantly lower CRS than all other racial groups (Table IV). There were no statistically significant differences in CRS among the other patient race groups.

Discussion

Current comorbidity indices have had a limited utility and ability to identify those most at risk of complications following SA. Our aim in this study was to develop a straightforward and effective tool capable of identifying those most at risk of postoperative complications after SA. The CRS described here is a tool which may be used to achieve this aim utilizing clinically relevant and readily available data points. The AUROC for our novel CRS scoring system was 0.676, indicating a fair discriminative ability to predict 30-day postoperative complications after SA. This demonstrates a similar discriminative ability to the most common comorbidity indices currently utilized, including ASA, mCCI, and mFI.[9,10,20,21]

Our novel CRS provides improved clinical utility relative to the aforementioned indices due to its straightforward scoring system, comparable discriminative ability, and easily identified variables. The ASA is a scale that relies on a physician's gestalt to describe a patient's physical status before surgery.[18] mCCI Is a tabulated comorbidity index (that uses a subset of variables from the original Charlson Comorbidity Index) developed to predict 1-year all-cause mortality.[19] Finally, mFI is a newer modified tabulated index (that

Table I
Descriptive statistics.

Variable	Race						*P* value
	White	Black	Hispanic	Asian/Pacific Islander	Native American	Unknown/other	
N	21013	1215	955	199	104	2441	
Age (mean, 95% CI)	69.5 (69.4-69.6)	64.8 (64.3-65.4)	68.2 (67.5-68.9)	68.7 (67.4-70.1)	64.5 (62.7-66.4)	69.3 (69.0-69.7)	**<.001**
CCI (mean, 95% CI)	2.79 (2.78-2.81)	2.57 (2.49-2.64)	2.81 (2.73-2.89)	2.82 (2.66-2.99)	2.27 (2.05-2.49)	2.74 (2.70-2.79)	**<.001**
ASA (mean, 95% CI)	2.56 (2.56-2.57)	2.71 (2.67-2.74)	2.54 (2.50-2.58)	2.48 (2.40-2.56)	2.61 (2.50-2.71)	2.45 (2.43-2.48)	**<.001**
Functional status (% independent)	98.1	97.3	96.7	96.4	98.1	98.5	**.005**
Smoker (%)	9.3	20.7	9.2	8.0	15.4	10.7	**<.001**
Steroid use (%)	4.8	5.9	6.3	10.1	9.6	4.3	**<.001**
Bleeding disorder (%)	2.5	2.3	2.6	1.0	1.9	1.2	**.002**
Preop transfusion (%)	0.1	0.3	0.2	0	0	0.0	**.007**
Weight loss >10% in past 6 mo (%)	0.2	0.4	0.2	0.5	0	0.1	.205
Hypertension requiring medication (%)	67.3	79.2	67.7	71.4	61.5	57.6	**<.001**
Disseminated cancer (%)	0.2	0.5	0.1	0.0	0.0	0.1	.123
BUN (mean, 95% CI)	18.9 (18.8-19.1)	17.1 (16.6-17.6)	17.9 (17.4-18.5)	18.6 (17.5-19.8)	15.9 (14.7-17.1)	18.2 (17.9-18.6)	**<.001**
Creatinine (mean, 95% CI)	.95 (.94-.95)	1.14 (1.08-1.21)	.93 (.89-.97)	.97 (.89-1.05)	.86 (.81-.91)	.92 (.90-.94)	**<.001**

CI, confidence interval; *CCI*, Charlson Comorbidity Index; *ASA*, American Society of Anesthesiologists; *BUN*, blood urea nitrogen.
Bold indicates statistical significance ($P < .05$).

Table II
Patient outcomes and complications.

Variable	Race						*P* value
	White	Black	Hispanic	Asian/Pacific Islander	Native American	Unknown/other	
Operative time (mean, 95% CI)	106 (106-107)	118 (115-121)	112 (109-115)	110 (104-116)	119 (109-128)	115 (113-116)	**<.001**
Wound complications (%)	0.3	0.4	0.2	0	1.9	0.6	**.001**
Respiratory (%)	0.5	0.7	0.8	0	0	0.7	.543
Cardiac (%)	0.3	0.2	0.1	0.5	0	0.2	.826
Renal (%)	0.1	0.1	0.2	0	0	0.1	.894
Neurologic (%)	0.1	0.1	0	0	0	0.1	.919
Systemic (%)	0.2	0.2	0.2	0	0	0.1	.867
DVT/PE (%)	0.5	0.7	0.4	0	0	0.6	.697
UTI (%)	0.7	0.4	0.6	0.5	0	0.7	.83
Blood transfusion (%)	1.6	2.1	2.6	3.0	1.0	1.5	.076
Readmission (%)	2.5	4.0	3.5	1.0	1.0	2.0	**.001**
Reoperation (%)	1.0	1.3	1.4	1.0	1.9	0.9	.648
All complications (excluding extended LOS) (%)	5.7	7.7	7.0	4.5	3.8	5.6	**.027**

CI, confidence interval; *LOS*, length of stay; *DVT/PE*, deep vein thrombosis/pulmonary embolism; *UTI*, urinary tract infection.
Bold indicates statistical significance ($P < .05$).

Table III
Development of CRS model.

Marker of support	Odds ratio	95% Confidence interval		*P* value	Coefficient	Raw	Score
		Lower	Upper				
End-stage renal disease	3.896	2.456	6.181	<.001	1.36	2.97	3.00
COPD	1.874	1.676	2.095	<.001	0.63	1.37	1.00
Hypertension treated with medication	1.581	1.471	1.699	<.001	0.46	1.00	1.00
Disseminated cancer	3.796	2.078	6.933	<.001	1.33	2.92	3.00
Nonindependent functional status	4.686	3.909	5.618	<.001	1.55	3.37	3.00
Bleeding disorder	1.992	1.673	2.371	<.001	0.69	1.50	2.00
Model performance	**AUROC**						Total score
CRS model	**0.595**						0-13
ASA classification	**0.604**						
Modified CCI	**0.597**						

CRS, comorbidity risk score; *AUROC*, area under receiver operator curve; *ASA*, American Society of Anesthesiologists; *COPD*, chronic obstructive pulmonary disease; *UTI*, urinary tract infection; *DVT/PE*, deep vein thrombosis/pulmonary embolism; *CCI*, Charlson Comorbidity Index.
The outcome variable was any wound, cardiac, respiratory, renal, neurologic, or septic complications, as well as DVT/PE, reoperation, readmission, blood transfusion, and UTI.
Bold indicates statistical significance ($P < .05$).

uses a subset of variables from the original Frailty Index) created to identify the decrease in physiologic reserves and multisystem impairments separate from chronologic age.[32] The use of mCCI and mFI is antiquated as most modern, national data sets do not collect the extensive variables required to calculate the CCI and FI.[20] Yi et al analyzed these indices in patients undergoing SA in the NSQIP database and found only mCCI and mFI to be associated with adverse events and each of these to only have a moderate ability to predict complications.[36] Thus, comparatively, the CRS provides a more easily applied, practical, and effective tool to identify those at increased risk of complications in the 30-day period following SA. With the increasing awareness of bundled payments, it is

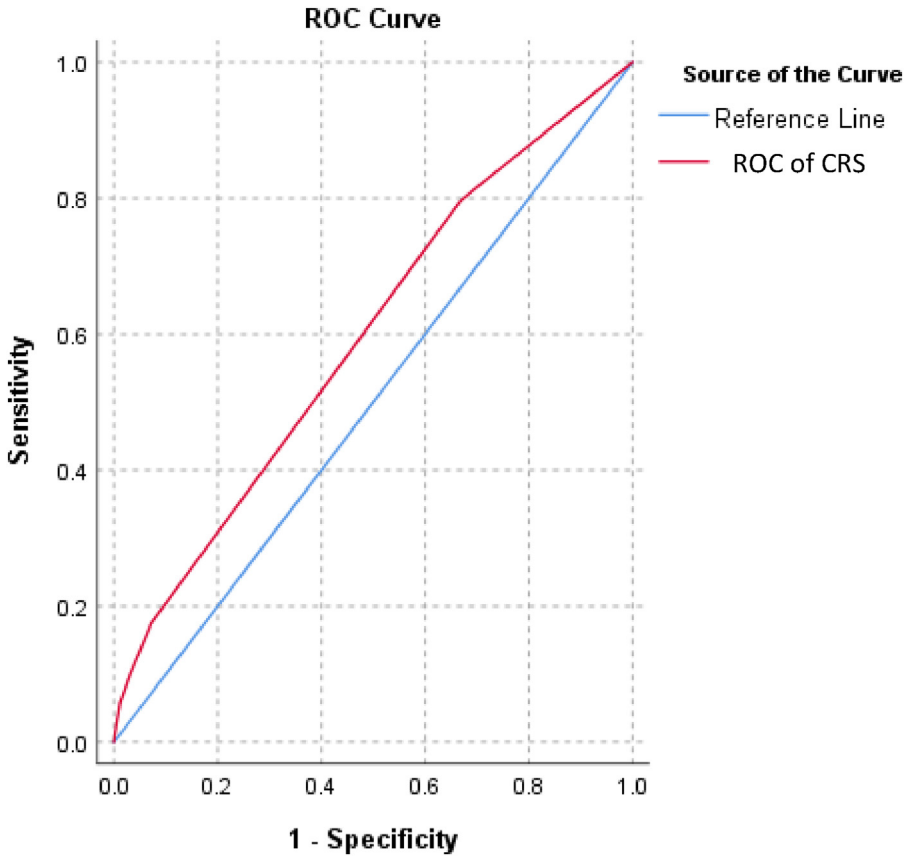

Figure 2 AUROC of comorbidity risk score (CRS). *AUROC*, area under receiver operator curve.

Table IV
Complication rate broken down by CRS score.

Score	Complication rate (%)	N total	N percent (%)
0	12.3	7960	30.7
1	19.2	15600	60.2
2	29.6	1249	4.8
3	33.1	592	2.3
4	51.9	420	1.6
5	57.3	75	0.3
6	47.6	21	0.1
7	77.8	9	0.0
9	100.0	1	0.0
Total	18.6	25927	100.0

CRS, comorbidity risk score.

advantageous to use a tool such as the CRS which can be easy calculated and documented by office administration without requiring physician time, input, and resources.

This study has also shed light on a potential disparity in the CRS between the various races. Black patients had a higher average CRS (1.08, CI 1.03-1.13, $P < .001$) than all other races (Table IV). An important trend identified in our data set was that a lower CRS for each race generally resulted in a lower rate of complications (Table VI). Thus, regardless of race, a lower CRS results in lower complication risk. Our results suggest that if the average CRS for each race was equal to the overall average (0.8537, CI 0.8011-0.8150, $P < .05$), then the average complication rate would decrease by approximately 2%. Although the average complication rate of each race would still be unequal, this could, ideally, mitigate some of the racial disparities observed and decrease the overall 30-day complication rate of SA. Our findings are consistent with previous studies that found various racial disparities in SA, including that of Singh et al, which found that from 1998 to 2011, Black patients had a lower utilization rate and longer median hospital stay than White patients after SA and that these disparities either remained the same or increased throughout this time. [8,25,29,31] Best et al found that Black patients had increased rates of complications and mortality compared to White patients from 2012 to 2018.[3] Our study further illustrates these disparities and how they persist in our novel CRS.

When considering the potential causes of the racial disparities identified in this study, it is worth noting that each of the comorbidities assessed has been studied for its relationship with the level of social support. In selecting these specific comorbidities that have been associated, in variable degrees, with social support, we have developed a strong prognostic indicator that is not inferior to other commonly used comorbidity scores currently described and utilized in the literature. Therefore, the possibility of social support potentially being a contributing factor to patient comorbidity load, and thus postoperative complication rate, cannot be eliminated. Although it is incredibly difficult to accurately assess a patient's level of social support without in-depth interviewing and surveys, the assessment methods currently utilized are prohibitively resource-intensive and/or subjective measures that may introduce bias.[12,16,27] The CRS provides an objective measure to serve as an additional data point in patient care. This commonality among each of these factors may be an area for future study to further develop the understanding of racial disparities as it relates to social support, medical comorbidities, and complications related to TSA.

There were several limitations to this study. First, its retrospective nature is bound to the limits of the database fidelity and

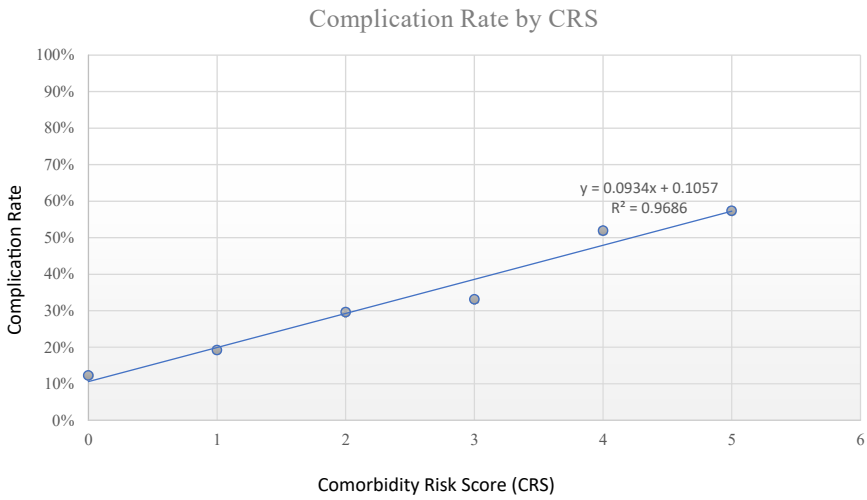

Figure 3 Estimated complication rate by CRS score. Complication rate by CRS with linear trendline, $R^2 = 0.9686$.

Table V
Mean comorbidity risk score by patient race.

Patient race	N	Mean	95% confidence interval		*P* value
			Lower bound	Upper bound	
White	21013	0.86	0.85	0.87	<.001
Black	1215	1.08	1.03	1.13	
Hispanic	955	0.90	0.84	0.96	
Asian/Pacific Islander	199	0.89	0.78	1.00	
Native American	104	0.75	0.60	0.90	
Unknown/other	2441	0.70	0.67	0.73	

Table VI
Complication rate broken down by patient race and comorbidity risk score.

Support score	White (%)	Black (%)	Hispanic (%)	Asian/Pacific Islander (%)	Native American (%)	Other (%)
0	11.7	17.9	13.3	16.7	2.6	14.3
1	18.6	22.1	17.8	14.6	18.3	24.9
2	29.2	39.5				25.6
3	33.1					42.9
4	51.4	58.5				64.3
5	53.7					85.7

Only categories with N < 40 have been included.

provides findings that cannot be established with the same degree of certainty as it would be in an ideal randomized control trial.[28] The NSQIP also collects complications within a 30-day postoperative period, thus long-term complications could not be included. Furthermore, the variations in complication rate at a given CRS for each race may indicate involvement of additional factors that cannot be discerned from the given database and should be subjected to further investigation. Also, while primary SA complication rates vary in the literature, the complication rate may be considered higher than that in other studies; however, this was calculated from a national standardized data set. The average complication rate following primary SA is approximately 15%.[15] The average CRS score in this study population was 0.8537 (CI 0.8011-0.8150, $P < .05$). This correlates to a complication rate of approximately 18.54%, which is similar to the complication rate noted in the literature. To identify patients at significantly increased risk, those above 2 standard deviations should be recognized as significantly different from the mean. Two standard deviations above the mean CRS are approximately 2.47, which, when rounded to the nearest CRS, correlates to at least a 29.6% complication rate and identifies approximately 9.1% of the database population to be at increased risk of postoperative complications within 30 days. Despite these limitations, utilizing a large database such as NSQIP allows the proper identification of an at-risk population for complications utilizing risk factors such as the novel CRS described.

Conclusion

This study proposes a novel, straightforward comorbidity score with significant clinical utility and similar accuracy in predicting 30-day complications compared to prior indices such as the ASA, mCCI, and mFI, thus introducing a useful assessment that can be employed to improve risk assessments and potential costs of care in the age of bundled payments. The racial disparities discovered offer

insight into the potential need to further explore social support as it relates to comorbidity burden and its influence on postoperative complications in patients undergoing SA.

Disclaimers:

Funding: The authors would like to thank the J. Robert Gladden Orthopaedic Society and Zimmer Biomet for their merit-based Research Grant which was used to support this research.
Conflicts of interest: The authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

References

1. Amen TB, Varady NH, Rajaee S, Chen AF. Persistent racial disparities in utilization rates and perioperative metrics in total joint arthroplasty in the U.S.: a comprehensive analysis of trends from 2006 to 2015. J Bone Joint Surg Am 2020;102:811-20. https://doi.org/10.2106/JBJS.19.01194.
2. Barton C, Effing TW, Cafarella P. Social support and social networks in COPD: a scoping review. COPD 2015;12:690-702. https://doi.org/10.3109/15412555.2015.1008691.
3. Best MJ, Aziz KT, McFarland EG, Martin SD, Rue JH, Srikumaran U. Worsening racial disparities in patients undergoing anatomic and reverse total shoulder arthroplasty in the United States. J Shoulder Elbow Surg 2021;30:1844-50. https://doi.org/10.1016/j.jse.2020.10.023.
4. Brasel KJ, Lim HJ, Nirula R, Weigelt JA. Length of stay: an appropriate quality measure? Arch Surg 2007;142:461-5. https://doi.org/10.1001/archsurg.142.5.461 [discussion 465-6].
5. Broida SE, Sweeney AP, Gottschalk MB, Woodmass JM, Wagner ER. Clinical outcomes of latissimus dorsi tendon transfer and superior capsular reconstruction for irreparable rotator cuff tears: a systematic review. Eur J Orthop Surg Traumatol 2022;32:1023-43. https://doi.org/10.1007/s00590-021-03046-5.
6. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis 1987;40:373-83.
7. Dunlop DD, Manheim LM, Song J, Sohn MW, Feinglass JM, Chang HJ, et al. Age and racial/ethnic disparities in arthritis-related hip and knee surgeries. Med Care 2008;46:200-8. https://doi.org/10.1097/MLR.0b013e31815cecd8.
8. Eichinger JK, Greenhouse AR, Rao MV, Gordon ER, Brinton D, Li X, et al. Racial and sex disparities in utilization rates for shoulder arthroplasty in the United States disparities in shoulder arthroplasty. J Orthop 2019;16:195-200. https://doi.org/10.1016/j.jor.2019.02.029.
9. Fernando DT, Berecki-Gisolf J, Newstead S, Ansari Z. Effect of comorbidity on injury outcomes: a review of existing indices. Ann Epidemiol 2019;36:5-14. https://doi.org/10.1016/j.annepidem.2019.06.004.
10. Fu MC, Ondeck NT, Nwachukwu BU, Garcia GH, Gulotta LV, Verma NN, et al. What associations exist between comorbidity indices and postoperative adverse events after total shoulder arthroplasty? Clin Orthop Relat Res 2019;477:881-90. https://doi.org/10.1097/CORR.0000000000000624.
11. Gonzalez-Saenz de Tejada M, Bilbao A, Baré M, Briones E, Sarasqueta C, Quintana JM, et al. CARESS-CCR Group. Association between social support, functional status, and change in health-related quality of life and changes in anxiety and depression in colorectal cancer patients. Psychooncology 2017;26:1263-9. https://doi.org/10.1002/pon.4303.
12. Hagiwara N, Slatcher RB, Eggly S, Penner LA. Physician racial bias and word use during racially discordant medical interactions. Health Commun 2017;32:401-8. https://doi.org/10.1080/10410236.2016.1138389.
13. He W, Goodkind D, Kowal P. An Aging World: 2015. In: Reports IP, editor. 95. Washington, DC: US Census Bureau; 2016.
14. Hernandez DC, Reitzel LR, Wetter DW, McNeill LH. Social support and cardiovascular risk factors among black adults. Ethn Dis 2014;24:444-50.
15. Kiet TK, Feeley BT, Naimark M, Gajiu T, Hall SL, Chung TT, et al. Outcomes after shoulder replacement: comparison between reverse and anatomic total shoulder arthroplasty. J Shoulder Elbow Surg 2015;24:179-85. https://doi.org/10.1016/j.jse.2014.06.039.
16. Ladin K, Emerson J, Berry K, Butt Z, Gordon EJ, Daniels N, et al. Excluding patients from transplant due to social support: results from a national survey of transplant providers. Am J Transplant 2019;19:193-203. https://doi.org/10.1111/ajt.14962.
17. Lewis ZH, Hay CC, Graham JE, Lin YL, Karmarkar AM, Ottenbacher KJ. Social support and actual versus expected length of stay in inpatient rehabilitation facilities. Arch Phys Med Rehabil 2016;97:2068-75. https://doi.org/10.1016/j.apmr.2016.06.005.
18. Mitchell I, Evans L, Rees T, Hardy L. Stressors, social support, and tests of the buffering hypothesis: effects on psychological responses of injured athletes. Br J Health Psychol 2014;19:486-508. https://doi.org/10.1111/bjhp.12046.
19. Mitchell PH, Powell L, Blumenthal J, Norten J, Ironson G, Pitula CR, et al. A short social support measure for patients recovering from myocardial infarction: the ENRICHD Social Support Inventory. J Cardiopulm Rehabil 2003;23:398-403. https://doi.org/10.1097/00008483-200311000-00001.
20. Ondeck NT, Bohl DD, Bovonratwet P, Anandasivam NS, Cui JJ, McLynn RP, et al. Predicting adverse outcomes after total hip arthroplasty: a comparison of demographics, the American Society of Anesthesiologists class, the modified Charlson comorbidity index, and the modified frailty index. J Am Acad Orthop Surg 2018;26:735-43. https://doi.org/10.5435/JAAOS-D-17-00009.
21. Ondeck NT, Bohl DD, Bovonratwet P, McLynn RP, Cui JJ, Shultz BN, et al. Discriminative ability of commonly used indices to predict adverse outcomes after poster lumbar fusion: a comparison of demographics, ASA, the modified Charlson Comorbidity Index, and the modified Frailty Index. Spine J 2018;18:44-52. https://doi.org/10.1016/j.spinee.2017.05.028.
22. Patel SS, Peterson RA, Kimmel PL. The impact of social support on end-stage renal disease. Semin Dial 2005;18:98-102. https://doi.org/10.1111/j.1525-139X.2005.18203.x.
23. Ratajová K, Blatný J, Poláčková Šolcová I, Meier Z, Horňáková T, Brnka R, et al. Social support and resilience in persons with severe haemophilia: an interpretative phenomenological analysis. Haemophilia 2020;26:e74-80. https://doi.org/10.1111/hae.13999.
24. Sanford Z, Taylor H, Fiorentino A, Broda A, Zaidi A, Turcotte J, et al. Racial disparities in surgical outcomes after spine surgery: an ACS-NSQIP analysis. Global Spine J 2019;9:583-90. https://doi.org/10.1177/2192568218811633.
25. Shahid H, Singh JA. Racial/ethnic disparity in rates and outcomes of total joint arthroplasty. Curr Rheumatol Rep 2016;18:20. https://doi.org/10.1007/s11926-016-0570-3.
26. Shao-Hsien L, Lapane KL. Scratching the surface: itching for evidence to reduce surgical health disparities in total shoulder arthroplasty. J Rheumatol 2020;47:490-2. https://doi.org/10.3899/jrheum.190796.
27. Sherbourne CD, Stewart AL. The MOS social support survey. Soc Sci Med 1991;32:705-14.
28. Shultz BN, Galivanche AR, Ottesen TD, Bovonratwet P, Grauer JN. The use of older versus newer data in the national surgical quality improvement program database influences the results of total hip arthroplasty outcomes studies. J Am Acad Orthop Surg Glob Res Rev 2019;3:e19.00108. https://doi.org/10.5435/JAAOSGlobal-D-19-00108.
29. Singh JA, Ramachandran R. Persisting racial disparities in total shoulder arthroplasty utilization and outcomes. J Racial Ethn Health Disparities 2015;2015:1-8. https://doi.org/10.1007/s40615-015-0138-3.
30. Singh JA, Ramachandran R. Racial disparities in total ankle arthroplasty utilization and outcomes. Arthritis Res Ther 2015;17:70. https://doi.org/10.1186/s13075-015-0589-2.
31. Singh JA, Sperling JW, Cofield RH. Ninety day mortality and its predictors after primary shoulder arthroplasty: an analysis of 4,019 patients from 1976-2008. BMC Musculoskelet Disord 2011;12:231. https://doi.org/10.1186/1471-2474-12-231.
32. Taylor SE. Social support: a review. In: Friedman MS, editor. The Handbook of Health Psychology. New York, NY: Oxford University Press; p. 189–214.
33. Tompson JD, Syed UA, Padegimas EM, Abboud JA. Shoulder arthroplasty utilization based on race - are black patients underrepresented? Arch Bone Jt Surg 2019;7:484-92.
34. Usta YY. Importance of social support in cancer patients. Asian Pac J Cancer Prev 2012;13:3569-72. https://doi.org/10.7314/apjcp.2012.13.8.3569.
35. Wagner ER, Farley KX, Higgins I, Wilson JM, Daly CA, Gottschalk MB. The incidence of shoulder arthroplasty: rise and future projections compared with hip and knee arthroplasty. J Shoulder Elbow Surg 2020;29:2601-9. https://doi.org/10.1016/j.jse.2020.03.049.
36. Yi BC, Gowd AK, Agarwalla A, Chen E, Amin NH, Nicholson GP, et al. Efficacy of the modified Frailty Index and the modified Charlson Comorbidity Index in predicting complications in patients undergoing operative management of proximal humerus fracture. J Shoulder Elbow Surg 2021;30:658-67. https://doi.org/10.1016/j.jse.2020.06.014.
37. Yu S, Mahure SA, Branch N, Mollon B, Zuckerman JD. Impact of race and gender on utilization rate of total shoulder arthroplasty. Orthopedics 2016;39:e538-44. https://doi.org/10.3928/01477447-20160427-14.