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Modified frailty index predicts medical complications, length of stay, readmission, and mortality following total shoulder arthroplasty

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Hypothesis: The purpose of this study was to evaluate the 5-factor modified frailty index (mFI-5) as a predictor of postoperative complications in patients undergoing total shoulder arthroplasty (TSA).

Methods: We conducted a retrospective analysis of the National Surgical Quality Improvement Program database for patients undergoing TSA between the years 2005 and 2017. The mFI-5 score, which includes the presence of comorbid diabetes, hypertension, congestive heart failure, chronic obstructive pulmonary disease, and functional status, was calculated for each patient. Multivariate logistic regression models were used to assess the relationship between the mFI-5 and postoperative complications.

Results: A total of 18,957 patients undergoing TSA were identified. The mFI-5 was a strong predictor of serious medical complications (cardiac arrest, myocardial infarction, septic shock, pulmonary embolism, postoperative dialysis, reintubation, and prolonged ventilator requirement), discharge to a facility, and readmission (odds ratio $\geq$ 1.309, $P \leq .001$). Length of stay also increased as the mFI-5 score increased ($P < .001$). However, among all the measured complications, the mFI-5 was the strongest predictor of mortality, with the risk more than doubling for each point increase in the mFI-5 score (odds ratio, 2.113; 95% confidence interval, 1.447-3.086; $P < .001$).

Conclusion: The mFI-5 predicts serious medical complications, increased length of stay, discharge to a facility, hospital readmission, and mortality in patients undergoing TSA. All of the variables within the mFI-5 are easily obtained through the patient history, allowing for a practical clinical tool that hospitals and surgeons can use to identify high-risk surgical candidates, inform preoperative counseling, and guide perioperative care to optimize patient outcomes.

Level of evidence: Basic Science Study; Validation of Classification Systems

Keywords: Shoulder arthroplasty; frailty index; complications; readmission; morbidity; outcomes

Over the past 20 years, the number of total shoulder arthroplasties (TSAs) performed each year has rapidly increased, with rates nearly tripling over the past decade.[7,16,22,23] Moreover, as the rate of TSA increases, so does the overall number of complications. Although outcomes of TSA are excellent, the rates of postoperative

This was a non-human subjects study, which did not require institutional review board approval.

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complications have ranged anywhere from 2.8% to 12% in recent studies.[1,3,5,6,8-10,17,18,35] When complications do occur, they can be devastating for the patient and costly to the health care system. Although numerous studies have shown that medical comorbidities increase the complication rates of TSA and various risk stratification models have successfully predicted adverse outcomes, no model has been widely adopted across all of orthopedics.[1,3,5,10,11,18,28]

Recently, several studies have used frailty, quantified as the modified frailty index (mFI), to effectively predict surgical complications and, moreover, better guide preoperative management.[31] The frailty index was originally developed by the Canadian Study of Health and Aging to serve as a marker of physiological decline. It has been validated as a risk stratification tool by successfully identifying patients at higher risk of postoperative complications across multiple surgical specialties, including orthopedics.[31] The original index identified more than 70 risk factors that were subsequently correlated to 11 comorbidities within the American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) database.[29,32] More recently, this index has been abbreviated to an mFI with 5 comorbidities: the 5-factor modified frailty index (mFI-5).[29,32] These 5 factors are congestive heart failure (CHF), diabetes mellitus (DM), chronic obstructive pulmonary disease (COPD) or current pneumonia, hypertension requiring medication, and non-independent functional status. One point is given for each of these comorbidities, and the total results in an mFI-5 score between 0 and 5.

Subsequent to this change, the mFI-5 has been shown to be an effective predictor of complications in patients undergoing total hip and knee arthroplasty and vertebral kyphoplasty, as well as patients with distal radial fractures.[31] However, it has yet to be evaluated in patients undergoing TSA. The aim of this study was to examine the discriminatory value of the mFI-5 in predicting morbidity and mortality in patients undergoing TSA. We hypothesized that the mFI-5 would successfully predict postoperative outcomes including surgical-site infections, life-threatening medical complications (represented by Clavien-Dindo grade IV [CDIV] complications), length of stay (LOS), adverse discharge, readmission, and mortality.

Materials and methods

This was a retrospective case-control study of the discriminatory value of the mFI-5 in detecting postoperative complications in patients undergoing TSA using the ACS NSQIP database. The NSQIP database is a nationally validated and risk-adjusted database of surgical data collected from more than 600 participating hospitals across the United States. In addition to preoperative data, the database records postoperative complications beginning on the day of surgery until 30 days postoperatively. Data are then deidentified and shared with participating institutions. Patients who underwent primary TSA between the years 2005 and 2017 were identified using Current Procedural Terminology (CPT) code 23472. Notably, both reverse TSA and anatomic TSA use the same CPT code, so the data were not able to be further stratified by the type of TSA. Throughout the design of this study, we utilized the checklist of Haider et al[11] for the evaluation of surgical database research.

Various patient demographic data were collected including age, sex, height, weight, American Society of Anesthesiologists (ASA) class, and wound class. Body mass index was then calculated from the height and weight data. Each patient's mFI-5 score was calculated by matching the NSQIP variables to the original Canadian Study of Health and Aging frailty index as outlined by Velanovich et al.[29,31,32] One point was assigned to each of the 5 comorbid variables: DM, CHF, COPD or current pneumonia, hypertension requiring medication, and non-independent functional status.

The presence of diabetes, CHF, hypertension, and COPD is defined by concomitant diagnoses in the patient's electronic medical records and is reported by surgical clinical reviewers, who capture the data through medical chart abstraction.[2] Specifically, in the NSQIP database, any patient with documented insulin resistance routinely taking antidiabetic agents for more than 2 weeks is defined as having a diagnosis of diabetes. Any patient whose diabetes is controlled by diet alone is excluded. CHF is defined in the NSQIP database as "newly diagnosed CHF within the previous 30 days or a diagnosis of chronic CHF with new signs or symptoms in the 30 days prior to surgery."[2] Common manifestations that fulfill this requirement are exercise intolerance, orthopnea, paroxysmal nocturnal dyspnea, elevated jugular venous pressure, cardiomegaly, or pulmonary vascular engorgement. Hypertension is reported when a diagnosis of hypertension is documented in the patient's chart within 30 days prior to the operative procedure and the patient has required long-term treatment (>2 weeks) with 1 or more antihypertensive medications.[2] For the diagnosis of COPD to be counted in the NSQIP database, 2 criteria must be met: The patient must have a historical or current diagnosis of COPD and must have at least 1 of the following: (1) a functional disability resulting from COPD such as dyspnea or an inability to perform activities of daily living, (2) a requirement for chronic bronchodilator therapy with oral or inhaled agents, (3) prior hospitalization for treatment of COPD, or (4) a forced expiratory volume in 1 second that is lower than 75% on a prior pulmonary function test.[2] Non-independent functional status is defined within the NSQIP database as requiring assistance for any activities of daily living within the 30 days preceding surgery.

Primary outcomes included any complication, life-threatening medical complications, surgical-site infection, adverse discharge, hospital readmission, mortality, and hospital LOS. "Any complication" was defined as a life-threatening medical complication, surgical-site infection, hospital readmission, or mortality that occurred within 30 days from surgery. Life-threatening medical complications were defined as CDIV complications, which included myocardial infarction, cardiac arrest, pulmonary embolism, postoperative dialysis, reintubation, and prolonged ventilator requirement.[8] Adverse discharge was defined as discharge of a patient anywhere but home, such as a skilled nursing facility or rehabilitation facility.

Table I Demographic data

Characteristic	Data
N	18,957
Average age, yr	69.2
Age, %	
18-39 yr	0.7
40-64 yr	28.5
65-74 yr	39.5
≥75 yr	31.3
Sex, %	
Female	56.1
Male	43.9
BMI group, %	
<18.5	0.7
Nonobese (18.5-29.9)	49.0
Obese I (30-34.9)	26.2
Obese II (35-39.9)	13.8
Obese III (≥40)	10.3
ASA class, %	
1	1.7
2	43.5
3	52.1
4	2.7

BMI, body mass index; *ASA*, American Society of Anesthesiologists.

Frequencies of baseline characteristics, comorbid conditions, and outcomes were calculated first. Baseline covariates were analyzed using the χ^2 test for categorical variables or the Student *t* test for continuous variables. Multivariate logistic regression models were then used to assess the predictive value of the mFI-5 in all patients. The α value was set at .05. All statistical analyses were performed using SPSS software (version 24; IBM, Armonk, NY, USA).

Results

From 2005 to 2017, a total of 18,957 patients who underwent primary TSA were identified from the NSQIP database and included in this study. Patient characteristics are outlined in Table I. The majority of the patients were women (56.1%), and the mean patient age was 69.2 years. Most patients had an ASA class of 3 or less (95.6%) and had a body mass index between 18.5 and 34.9. No patients were found to have an mFI-5 score greater than 4 points.

The rate of any complication among all patients was 4.3% (n = 18,957; Table II). The most common complications were readmission, at 2.8%, and life-threatening medical complications, at 1.0%. The risk of surgical-site infection and risk of mortality were 0.3% and 0.2%, respectively, whereas the risk of a non-homebound discharge was 11.4%. The frequencies of these complications were then calculated for all patients who scored 0 points on the mFI-5 (Table II). The rates of all complications except surgical-site infection were significantly lower in this group: any complication, 3.0%; CDIV complications, 0.7%; surgical-site infection, 0.3%; readmission, 1.9%; adverse discharge, 6.2%; and mortality, 0.1%.

Adjusted logistic regression analysis revealed that all measured outcomes except surgical-site infection increased concurrently with increasing mFI-5 score (Figs. 1 and 2). For each additional point on the mFI-5, the risk of any complication increased by 60.1% (odds ratio [OR], 1.601; 95% confidence interval [CI], 1.509-1.699; $P < .001$; Table III). Likewise, the risk of a CDIV complication increased by 39.5% (OR, 1.395; 95% CI, 1.155-1.686; $P = .001$), the risk of readmission increased by 45.0% (OR, 1.450; 95% CI, 1.298-1.620; $P < .001$), and the risk of an adverse discharge increased by 67.0% (OR, 1.670; 95% CI, 1.561-1.785; $P < .001$). The risk of surgical-site infection increased by 30.9%, although this was not statistically significant (OR, 1.309; 95% CI, 0.958-1.787; $P = .091$). However, the risk of mortality more than doubled (OR, 2.113; 95% CI, 1.447-3.086; $P < .001$) for each additional point in the mFI-5 score.

The average LOS for all patients undergoing TSA was 1.95 days. As the mFI-5 score increased, the average LOS successively increased (Fig. 2). Patients with an mFI-5 score of either 0 or 1 point fell below this total average, with the average LOS for these patient populations calculated to be 1.73 and 1.92 days, respectively ($P < .001$). Moreover, patients with mFI-5 scores greater than 1 point surpassed the average, with mFI-5 scores of 2, 3, and 4 points corresponding to LOSs of 2.23, 3.35, and 3.94 days, respectively ($P < .001$).

Discussion

As the number of TSAs performed continues to grow, so will the number of complications.[7,16,22,23] Therefore, it is imperative that patients preoperatively undergo risk stratification to predict potential negative outcomes. Our results demonstrate that the mFI-5 successfully predicts adverse outcomes including total complications, CDIV complications, readmission, adverse discharge, LOS, and mortality.

Numerous studies have repeatedly demonstrated that medical comorbidities negatively influence the outcomes of TSA.[3,5,14,17,18,20,28] In a study by Anthony et al,[3] the NSQIP database was retrospectively queried for comorbidities that predicted both major and minor complications within 30 days of TSA. After controlling for confounding variables, multivariate analysis showed that steroid use (OR, 3; 95% CI, 2-6), ASA class 4 (OR, 3; 95% CI, 1-7), preoperative hematocrit level lower than 38% (OR, 2; 95% CI, 1-3), and operative time greater than 2 hours (OR, 2; 95% CI, 1-3) were predictors of any complication whereas CHF was shown to be a risk factor for major morbidity or mortality (OR, 12; 95% CI, 1-106).[3] A similar study by Waterman et al[35] used the NSQIP database to show that cardiac disease, defined by the presence of CHF or a history

Table II Baseline complication rates for all patients as well as complication rates by mFI-5 score

	All TSA, %	mFI-5 score of 0 points, %	mFI-5 score of 1 point, %	mFI-5 score of 2 points, %	mFI-5 score of 3 points, %	mFI-5 score of 4 points, %
Any complication	4.3	3.0	4.1	6.4	9.2	17.6
CDIV complication	1.0	0.7	0.9	1.4	2.4	2.9
SSI	0.3	0.3	0.3	0.5	0.3	
Readmission	2.8	1.9	2.7	4.2	4.7	14.7
Mortality	0.2	0.1	0.2	0.3	1.8	
Adverse discharge	11.4	6.2	11.2	17.4	32.6	43.3

mFI-5, 5-factor modified frailty index; *TSA*, total shoulder arthroplasty; *CDIV*, Clavien-Dindo grade IV; *SSI*, surgical-site infection.
No patient scored 5 of 5 points on the mFI-5 scale, and no patient with a reported mortality or SSI scored greater than 3 of 5 points.

of myocardial infarction, was the most significant independent risk factor for mortality (OR, 85.31; 95% CI, 8.15-892.84). Other proven risk factors include hypertension, diabetes, obesity, age, pulmonary disease, renal failure, and functionally dependent status.[14,18,20] Moreover, the summation of medical comorbidities has been shown to increase the risk of postoperative complications more than each risk factor alone.[14]

Likewise, hospital LOS, adverse discharge, and unplanned readmission are all negatively affected by medical comorbidities.[14,18,20,34] Menendez et al[20] used the Nationwide Inpatient Sample (NIS) database to demonstrate that certain risk factors, including CHF and chronic pulmonary disorders, were related to a prolonged LOS after TSA. The NIS database has also been used to demonstrate that patients with an increasing number of comorbidities had a higher likelihood of a non-home-bound discharge.[14]

Medical comorbidities also play a significant adverse role in the total cost of TSA, as they greatly influence the cost of care beyond the surgical procedure itself, including the expenses associated with an extended LOS, use of skilled nursing facilities, and readmissions.[18,20,24,33] For instance, in 2017, a study by Sibia et al[27] reported that the cost of a day spent in an American hospital after total joint arthroplasty was anywhere between $1528 and $7272, and Virani et al[33] showed that readmission after TSA increased total costs by approximately $15,000.[25,31] The data in our

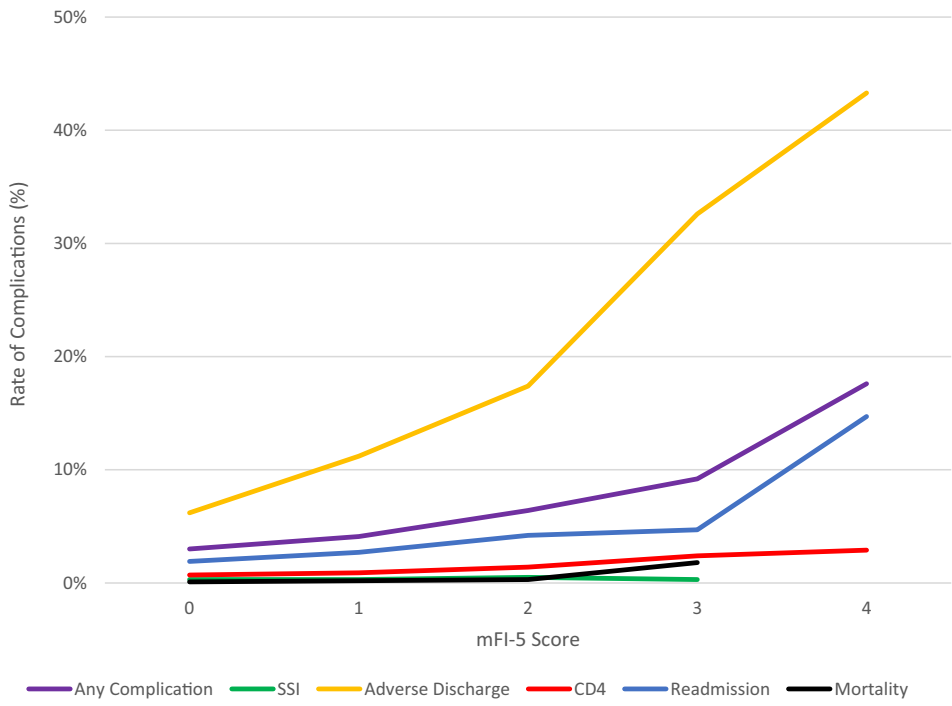

Figure 1 The rates of complications of total shoulder arthroplasty increased as the 5-factor modified frailty index (*mFI-5*) score increased. For mortality and surgical-site infection (*SSI*), no patients had an mFI-5 score greater than 3 points. No patients in the study had an mFI-5 score greater than 4 points. *CD4*, Clavien-Dindo grade IV complications.

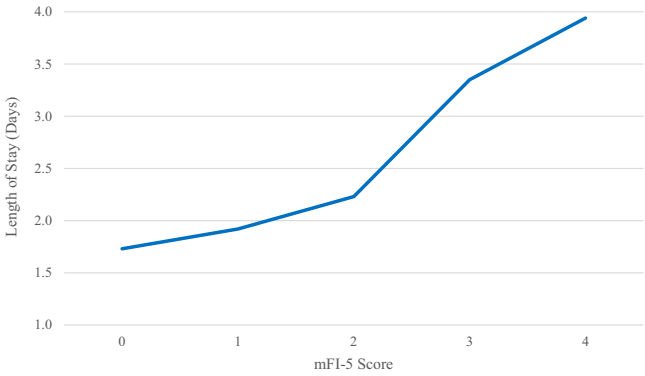

Figure 2 The length of stay after total shoulder arthroplasty increased as the 5-factor modified frailty index (*mFI-5*) score increased. No patients in the study had an mFI-5 score greater than 4 points.

study are consistent with such prior studies in that patients with a greater comorbidity burden or higher mFI score not only had a prolonged LOS but also had a much higher likelihood of discharge to a facility after TSA. For instance, patients with an mFI-5 score of 3 points averaged an extra day longer in the hospital compared with those who scored 2 points (3.35 days vs. 2.23 days, Fig. 2). Furthermore, the likelihood of a non-homebound discharge nearly doubled in patients with an mFI-5 score of 3 points vs. 2 points (32.6% vs. 17.4%), and the risk of mortality increased 6-fold (1.8% vs. 0.3%, Table II). These data not only inform patient-centered discussions on outcomes and expectations but also have a significant impact on surgeons and hospitals providing treatment to patients with greater medical complexity.[30]

Beyond the mFI, certain risk stratification models have previously been used to predict postoperative complications in TSA patients.[5,10,12,17] The Charlson Comorbidity Index, which assigns a score of 0 to 33 based on 14 different medical comorbidities, in addition to age, was shown in a study of 132 patients to be highly predictive of postoperative complications.[5] In addition, the Deyo Index, which assigns patients a score of 1 to 6 based on 17 diagnostic categories, was shown to be predictive of hospital mortality, postoperative complications, LOS, and hospital costs in a study of 28,434 patients that used the NIS database.[12] However, neither the Charlson Comorbidity Index nor the Deyo Index has been widely adopted across orthopedics. Furthermore, the lengthy number of comorbidities assessed by both of these models may lead to an extensive and expensive preoperative workup.

Finally, a patient's ASA class, which assesses the overall physical health status of a patient prior to surgery based on the level of systemic disease, has proved to be predictive of postoperative complications after TSA.[17,18,28] However, the ASA class can be subject to greater bias and therefore may be more difficult to explain to patients. Recent studies have called into question the high variability in ASA scores given the low to moderate inter-rater reliability that has been demonstrated in the orthopedic, pediatric, and general surgery populations.[4,13,19,21,26] For example, a study by Aronson et al[4] surveyed anesthesia providers with 10 different patient scenarios and found no inter-rater reliability in any of the scenarios, suggesting that the ASA score is more a matter of opinion on a patient's anesthetic risk rather than his or her surgical risk. However, a model that is widely adopted can be integrated into the electronic medical records to quickly and easily help facilitate an educated discussion with patients on their specific risk profile for postoperative complications. The mFI-5 is relatively easy to use and straightforward for patients to understand while still being sensitive enough to predict such complications.

Previous studies within orthopedics have validated both the 11-factor frailty index and, more recently, the mFI-5 for preoperative risk stratification.[31] These studies have successfully predicted outcomes of both elective and more urgent orthopedic procedures but, prior to this study, had not validated the use of the mFI-5 in TSA patients. The mFI-5 is a simple, clinically applicable tool that can easily be integrated into clinical practice. The 5 risk factors—CHF, DM, COPD or current pneumonia, hypertension requiring medication, and non-independent functional status—can easily be summated at a patient's bedside and discussed during a preoperative visit.

The limitations of this study are consistent with those of other database studies in that the data are dependent on the accuracy of coding and data entry. In addition, the NSQIP database is limited to 30 days postoperatively and therefore does not capture complications occurring beyond 30 days. Furthermore, any risk stratification tool that tallies up comorbidities risks giving all variables equal weight and does not take into account the degree of severity of each variable. For instance, a patient with diabetes well controlled with metformin will be given the same score as a patient with poorly controlled diabetes taking insulin. Finally, because patients were identified by CPT code, no

Table III ORs for mFI-5 by complication type

	OR	95% CI	*P* value
Any complication	1.601	1.509-1.699	<.001
CDIV complication	1.395	1.155-1.686	.001
SSI	1.309	0.958-1.787	.091
Readmission	1.450	1.298-1.620	<.001
Mortality	2.113	1.447-3.086	<.001
Adverse discharge	1.670	1.561-1.785	<.001

OR, odds ratio; *mFI-5*, 5-factor modified frailty index; *CI*, confidence interval; *CDIV*, Clavien-Dindo grade IV; *SSI*, surgical-site infection. The OR listed is for every 1-point increase in the mFI-5 score (ie, the odds for readmission increased by 45% for every 1-point increase in the mFI-5 score).

further stratification by type of TSA (anatomic or reverse) was possible with the data collected by NSQIP. Although several studies have shown there is little to no difference in postoperative complications between groups, the indications for each differs, resulting in slightly different patient populations.[15]

Conclusion

The mFI-5 predicts serious medical complications, increased LOS, discharge to a facility, hospital readmission, and mortality in patients undergoing TSA. All of the variables within the mFI-5 are easily obtained through the patient history, allowing for a practical clinical tool that hospitals and surgeons can use to identify high-risk surgical candidates, inform preoperative counseling, and guide perioperative care to optimize patient outcomes.

Disclaimer

The ACS NSQIP and the hospitals participating in the ACS NSQIP are the source of the data used herein; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors.

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References

1. Aldinger PR, Raiss P, Rickert M, Loew M. Complications in shoulder arthroplasty: an analysis of 485 cases. Int Orthop 2010;34:517-24. https://doi.org/10.1007/s00264-009-0780-7
2. American College of Surgeons National Surgical Quality Improvement Program. User guide for the 2013 participant use data file. https://www.facs.org/quality-programs/acs-nsqip/participant-use; 2014. Accessed March 10, 2019
3. Anthony CA, Westermann RW, Gao Y, Pugely AJ, Wolf BR, Hettrich CM. What are risk factors for 30-day morbidity and transfusion in total shoulder arthroplasty? A review of 1922 cases. Clin Orthop Relat Res 2015;473:2099-105. https://doi.org/10.1007/s11999-014-4107-7
4. Aronson WL, McAuliffe MS, Miller K. Variability in the American Society of Anesthesiologists physical status classification scale. AANA J 2003;71:265-74.
5. Chalmers PN, Gupta AK, Rahman Z, Bruce B, Romeo AA, Nicholson GP. Predictors of early complications of total shoulder arthroplasty. J Arthroplasty 2014;29:856-60. https://doi.org/10.1016/j.arth.2013.07.002
6. Chin PYK, Sperling JW, Cofield RH, Schleck C. Complications of total shoulder arthroplasty: are they fewer or different? J Shoulder Elbow Surg 2006;15:19-22. https://doi.org/10.1016/j.jse.2005.05.005
7. Day JS, Lau E, Ong KL, Williams GR, Ramsey ML, Kurtz SM. Prevalence and projections of total shoulder and elbow arthroplasty in the United States to 2015. J Shoulder Elbow Surg 2010;19:1115-20. https://doi.org/10.1016/j.jse.2010.02.009
8. Farng E, Zingmond D, Krenek L, SooHoo NF. Factors predicting complication rates after primary shoulder arthroplasty. J Shoulder Elbow Surg 2011;20:557-63. https://doi.org/10.1016/j.jse.2010.11.005
9. Fehringer EV, Mikuls TR, Michaud KD, Henderson WG, O'Dell JR. Shoulder arthroplasties have fewer complications than hip or knee arthroplasties in US veterans. Clin Orthop Relat Res 2010;468:717-22. https://doi.org/10.1007/s11999-009-0996-2
10. Floyd SB, Chapman CG, Thigpen CA, Brooks JM, Hawkins RJ, Tokish JM. Shoulder arthroplasty in the US Medicare population: a 1-year evaluation of surgical complications, hospital admissions, and revision surgery. JSES Open Access 2018;2:40-7. https://doi.org/10.1016/j.jses.2017.10.002
11. Haider AH, Bilimoria KY, Kibbe MR. A checklist to elevate the science of surgical database research. JAMA Surg 2018;153:505-7. https://doi.org/10.1001/jamasurg.2018.0628
12. Humphries W, Jain N, Pietrobon R, Socolowski F, Cook C, Higgins L. Effect of the Deyo score on outcomes and costs in shoulder arthroplasty patients. J Orthop Surg (Hong Kong) 2008;16:186-91. https://doi.org/10.1177/230949900801600212
13. Ihejirika RC, Thakore RV, Sathiyakumar V, Ehrenfeld JM, Obremskey WT, Sethi MK. An assessment of the inter-rater reliability of the ASA physical status score in the orthopaedic trauma population. Injury 2015;46:542-6. https://doi.org/10.1016/j.injury.2014.02.039
14. Jain NB, Guller U, Pietrobon R, Bond TK, Higgins LD. Comorbidities increase complication rates in patients having arthroplasty. Clin Orthop Relat Res 2005;(435)::232-8. https://doi.org/10.1097/01.blo.0000156479.97488.a2
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. Kim SH, Wise BL, Zhang Y, Szabo RM. Increasing incidence of shoulder arthroplasty in the United States. J Bone Joint Surg Am 2011;93:2249-54. https://doi.org/10.2106/JBJS.J.01994
17. Leschinger T, Raiss P, Loew M, Zeifang F. Total shoulder arthroplasty: risk factors for intraoperative and postoperative complications in patients with primary arthritis. J Shoulder Elbow Surg 2017;26:e71-7. https://doi.org/10.1016/j.jse.2016.08.001
18. Lovy AJ, Keswani A, Beck C, Dowdell JE, Parsons BO. Risk factors for and timing of adverse events after total shoulder arthroplasty. J Shoulder Elbow Surg 2017;26:1003-10. https://doi.org/10.1016/j.jse.2016.10.019
19. Mak PHK, Campbell RCH, Irwin MG, American Society of Anesthesiologists. The ASA Physical Status Classification: inter-observer consistency. American Society of Anesthesiologists. Anaesth Intensive Care 2002;30:633-40. https://doi.org/10.1177/0310057X0203000516
20. Menendez ME, Baker DK, Fryberger CT, Ponce BA. Predictors of extended length of stay after elective shoulder arthroplasty. J Shoulder Elbow Surg 2015;24:1527-33. https://doi.org/10.1016/j.jse.2015.02.014
21. Owens WD, Felts JA, Spitznagel EL. ASA physical status classifications: a study of consistency of ratings. Anesthesiology 1978;49:239-43.
22. Palsis JA, Simpson KN, Matthews JH, Traven S, Eichinger JK, Friedman RJ. Current trends in the use of shoulder arthroplasty in the United States. Orthopedics 2018;41:e416-23. https://doi.org/10.3928/01477447-20180409-05
23. Ricchetti ET, Abboud JA, Kuntz AF, Ramsey ML, Glaser DL, Williams GR. Total shoulder arthroplasty in older patients: increased perioperative morbidity? Clin Orthop Relat Res 2011;469:1042-9. https://doi.org/10.1007/s11999-010-1582-3

24. Rosas S, Sabeh KG, Buller LT, Law TY, Kalandiak SP, Levy JC. Comorbidity effects on shoulder arthroplasty costs analysis of a nationwide private payer insurance data set. J Shoulder Elbow Surg 2017;26:e216-21. https://doi.org/10.1016/j.jse.2016.11.044
25. Rosenthal E. As hospital prices soar, a stitch tops $500. *The New York Times*. http://www.myhss.org/downloads/board/regular_meetings/2013/RM_121213_NYTimes.pdf; 2013. Accessed January 20, 2019
26. Sankar A, Johnson SR, Beattie WS, Tait G, Wijeysundera DN. Reliability of the American Society of Anesthesiologists physical status scale in clinical practice. Br J Anaesth 2014;113:424-32. https://doi.org/10.1093/bja/aeu100
27. Sibia US, Turcotte JJ, MacDonald JH, King PJ. The cost of unnecessary hospital days for Medicare joint arthroplasty patients discharging to skilled nursing facilities. J Arthroplasty 2017;32:2655-7. https://doi.org/10.1016/j.arth.2017.03.058
28. 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
29. Subramaniam S, Aalberg JJ, Soriano RP, Divino CM. New 5-factor modified frailty index using American College of Surgeons NSQIP data. J Am Coll Surg 2018;226:173-81.e8. https://doi.org/10.1016/j.jamcollsurg.2017.11.005
30. Szekendi MK, Williams MV, Carrier D, Hensley L, Thomas S, Cerese J. The characteristics of patients frequently admitted to academic medical centers in the United States. J Hosp Med 2015;10:563-8. https://doi.org/10.1002/jhm.2375
31. Traven SA, Reeves RA, Sekar MG, Slone HS, Walton ZJ. New 5-factor modified frailty index predicts morbidity and mortality in primary hip and knee arthroplasty. J Arthroplasty 2019;34:140-4. https://doi.org/10.1016/j.arth.2018.09.040
32. Velanovich V, Antoine H, Swartz A, Peters D, Rubinfeld I. Accumulating deficits model of frailty and postoperative mortality and morbidity: its application to a national database. J Surg Res 2013;183:104-10. https://doi.org/10.1016/j.jss.2013.01.021
33. Virani NA, Williams CD, Clark R, Polikandriotis J, Downes KL, Frankle MA. Preparing for the bundled-payment initiative: the cost and clinical outcomes of total shoulder arthroplasty for the surgical treatment of glenohumeral arthritis at an average 4-year follow-up. J Shoulder Elbow Surg 2013;22:1601-11. https://doi.org/10.1016/j.jse.2012.12.028
34. Wang HT, Fafard J, Ahern S, Vendittoli P-A, Hebert P. Frailty as a predictor of hospital length of stay after elective total joint replacements in elderly patients. BMC Musculoskelet Disord 2018;19:14. https://doi.org/10.1186/s12891-018-1935-8
35. Waterman BR, Dunn JC, Bader J, Urrea L, Schoenfeld AJ, Belmont PJ Jr. Thirty-day morbidity and mortality after elective total shoulder arthroplasty: patient-based and surgical risk factors. J Shoulder Elbow Surg 2015;24:24-30. https://doi.org/10.1016/j.jse.2014.05.016