

**SHOULDER**

Modifiable risk factors increase length of stay and 90-day cost of care after shoulder arthroplasty



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Background: Baseline health conditions can negatively impact cost of care and risk of complications after joint replacement, necessitating additional care and incurring higher costs. Bundled payments have been used for hip and knee replacement and the Centers for Medicare & Medicaid Services (CMS) is testing bundled payments for upper extremity arthroplasty. The purpose of this study was to determine the impact of predefined modifiable risk factors (MRFs) on total encounter charges, hospital length of stay (LOS), related emergency department (ED) visits and charges, and related hospital readmissions within 90 days after shoulder arthroplasty.

Methods: We queried the electronic medical record (EPIC) for all shoulder arthroplasty cases under DRG 483 within a regional 7-hospital system between October 2015 and December 2019. Data was used to calculate mean LOS, total 90-day charges, related emergency department (ED) visits and charges, and related hospital readmissions after shoulder arthroplasty. Data for patients who had 1 or more MRFs, defined as anemia (hemoglobin < 10 g/dL), malnutrition (albumin < 3.4 g/dL), obesity (BMI > 40), uncontrolled diabetes (random glucose > 180 mg/dL or glycated hemoglobin > 8.0%), tobacco use (*International Classification of Diseases, Tenth Revision*, code indicating patient is a smoker), and opioid use (opioid prescription within 90 days of surgery), were evaluated as potential covariates to assess the relationship between MRFs and total encounter charges, LOS, ED visits, ED charges, and hospital readmissions.

Results: A total of 1317 shoulder arthroplasty patients were identified. Multivariable analysis demonstrated that anemia (+\$19,847, confidence interval [CI] \$15,743, \$23,951; $P < .001$), malnutrition (+\$5850, CI \$3712, \$7988; $P < .001$), and obesity (+\$2762, CI \$766, \$4758, $P = .007$) independently contributed to higher charges after shoulder arthroplasty. Mean LOS was higher in patients with anemia (5.0 ± 4.0 days vs. 2.2 ± 1.6 days, $P < .001$), malnutrition (3.7 ± 2.8 days vs. 2.2 ± 1.5 days, $P < .001$), and uncontrolled diabetes (2.8 ± 2.8 days vs. 2.3 ± 1.7 days, $P = .019$). Univariate risk factors associated with a significant increase in total 90-day encounter charges included anemia (+\$19,345, $n = 37$, $P < .001$), malnutrition (+\$6971, $n = 116$, $P < .001$), obesity (+\$2615, $n = 184$, $P = .011$), and uncontrolled diabetes (+\$4377, $n = 66$, $P = .011$). Univariate risk for readmission within 90 days was higher in patients with malnutrition (odds ratio 3.0, CI 1.8, 4.9; $P < .001$).

Conclusion: Malnutrition, obesity, and anemia contribute to significantly higher costs after shoulder arthroplasty. Medical strategies to optimize patients before shoulder arthroplasty are warranted to reduce total 90-day encounter charges, length of stay, and risk of readmission within 90 days of surgery. Optimizing patient health before shoulder surgery will positively impact outcomes and cost containment for patients, institutions, and payors after shoulder arthroplasty.

This study received approval from the SSM St Louis Internal Review Board.

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Recent efforts by the federal government and insurers include bundled payments to reduce costs and improve quality after common orthopedic procedures. Bundled payment models reimburse a predetermined amount per procedure to cover all services provided during the clinically defined episode of care, rather than the individual cost for each service rendered.¹² Hip and knee arthroplasty have shifted from a fee-for-service model to a fixed payment model. Under these models, hospitals and physicians face increasing financial repercussions for the cost of complications and readmissions during the 90 days following elective total joint arthroplasty (TJA).

Increased cost after TJA is driven primarily by post-acute care utilization including unplanned readmissions, emergency department (ED) visits, complications, and reoperations.⁹ Factors such as patient age, payor status, gender, race, and medical comorbidities are associated with increased complications, costs, and readmissions.¹³ These factors contribute to increased costs through longer length of stay (LOS), higher 90-day readmission rates, and need for secondary surgical procedures in the perioperative period.

The Centers for Medicare & Medicaid Services (CMS) is testing a 90-day bundled payment model for upper extremity arthroplasty. Under this pilot model, reimbursement would remain the same regardless of type of shoulder arthroplasty, comorbidity burden, or indication for surgery despite these factors having a significant impact on cost of care.⁸ However, bundled payment models for shoulder arthroplasty have demonstrated cost savings in a private practice bundled payment model for shoulder arthroplasty,¹² as well as for hip and knee arthroplasty. Identifying ways to reduce costs and improve outcomes becomes imperative for all stakeholders.

Modifiable risk factors (MRFs) represent a subset of medical comorbidities that can be positively impacted before elective TJA. The factors previously identified to increase costs in lower extremity TJA include anemia, malnutrition, obesity, uncontrolled diabetes, preoperative opioid use, and tobacco use.^{2,5,6,15} MRFs also may contribute to early revision. Kee et al⁷ found that more than 40% of patients at their institution undergoing early revision hip or knee arthroplasty had at least 1 MRF. In shoulder arthroplasty, factors associated with early revision include younger age, smoking, obesity, and male gender,¹⁸ with 2 of those factors potentially modifiable before initial shoulder arthroplasty.

The purpose of this study was to evaluate and quantify the impact of MRFs including anemia, malnutrition,

obesity, uncontrolled diabetes, preoperative opioid use, and preoperative tobacco use on 90-day charges after shoulder arthroplasty. Impact on LOS and readmission rates during the 90-day window also was examined. Identifying and quantifying costs associated with MRFs will allow physicians to identify strategies for preoperative optimization, with the goal of reducing costs and improving clinical outcomes regardless of bundle participation.

Patients and methods

All patients admitted for shoulder arthroplasty (DRG 483) between October 2015 and December 2019 were included in the study and were identified from the electronic medical record (EMR) covering a 7-hospital system (10 surgeons) in a Midwestern metropolitan region. No patients were excluded from this retrospective cohort study and IRB approval was obtained prior to data collection. The DRG 483 includes both elective joint arthroplasty and arthroplasty for acute fracture. Utilizing MRFs and definitions previously identified by Schroer et al,¹⁵ patients who had 1 or more MRFs were identified, defined as the following: anemia (hemoglobin < 10 g/dL), malnutrition (albumin < 3.4 g/dL), obesity (body mass index [BMI] > 40), uncontrolled diabetes mellitus (DM; random glucose > 180 mg/dL or glycated hemoglobin > 8%), tobacco use (*International Classification of Diseases, Tenth Revision*, code indicating patient is a smoker), and opioid use (opioid prescription within 90 days of surgery).

Outcome measures

The primary outcome measure was surgery-related 90-day charges after elective shoulder arthroplasty. Secondary outcomes included LOS, related ED visits, and hospital readmission within 90 days from surgery. Other factors examined were ED charges and readmission charges. Charges were determined using ChargeMaster, which is a software within the EMR that applies a standardized list of charges for a given procedure, product, or service. The ChargeMaster price represents the estimated cost for labor, facility use, and technology and includes the cost of covering underinsured/uninsured care. This does not directly correlate with the payment received by the institution but is a standardized list of charges.

Statistical analysis

Clinical characteristics and baseline demographics for the study population were described using counts and frequencies (%). We examined univariate associations between MRFs and the following outcomes: ED charges, readmission charges, total

encounter charges (linear regression), LOS (Poisson regression), 90-day readmission, and ED visit (logistic regression). Subsequently, we built multivariable models for the 2 primary outcomes, total encounter charges and LOS. We included in our models only those variables that were (1) modifiable, (2) statistically significant, or (3) confounders. A confounder was defined as any variable that, when added to the model, altered any of the effect sizes by >15%. Model appropriateness and fit were assessed using a specification link test for single-equation models and inspection of residuals and outliers. A *P* value of <.05 was considered statistically significant, and all confidence intervals (CIs) were 95%. Missing data were not imputed, and only patients with data for the variable in question were analyzed. All statistical analysis was performed using Stata, version 16.0 (StataCorp, College Station, TX, USA).

We calculated power based on the available 1317 patients. To compare differences in total charges, for those with anemia vs. those without, for example, we assumed a 2-sided Type I error rate of .05; mean costs of \$36,647 for the cohort and of \$52,229 for patients with anemia, and a rate of anemia of 1.8%.¹⁵ Given these parameters, we had >99% power to detect an effect of this size. For LOS, we calculated the effect size we could detect, given 1317 participants. Assuming 80% power, a 2-sided Type I error rate of .05, and a 10% correlation between covariates, we would be able to detect a relative risk of 1.36 for a 1-day increase in LOS.

Results

A total of 1317 shoulder arthroplasty patients were identified and all were included in the analysis, except for variables where data were missing. Clinical characteristics of the study population are shown in [Table I](#).

We present the multivariable results in [Tables II](#) and [III](#). Total encounter charges were statistically significantly higher in patients with anemia, malnutrition, and obesity ([Table II](#), [Fig. 1](#)). Multivariable analysis to examine the independent effects of MRFs on LOS revealed that increased LOS was significantly associated with anemia and malnutrition. Mean LOS among unaffected individuals was 2.2-2.3 days, but was statistically significantly longer for patients with anemia, malnutrition, or uncontrolled diabetes ([Table IV](#)).

We present the results of univariate analyses for each of the outcomes in [Supplementary Tables S1-S6](#). With respect to total encounter charges, anemia, malnutrition, obesity, and uncontrolled diabetes had univariate association with higher cost ([Supplementary Table S1](#)).

In univariate analysis, LOS was statistically significantly higher for patients with anemia and uncontrolled diabetes ([Supplementary Table S2](#)). Malnutrition was the only factor found to have univariate association with readmission related to the arthroplasty within 90 days, indicating a 3-fold increase in risk of readmission ([Supplementary Table S3](#)). We found statistically significant univariate associations between readmission charges and malnutrition ([Supplementary Table S4](#)).

Table I Modifiable risk factors in the patient population

Variable	n	Count (%)
Anemia	1079	37 (3.4)
Malnutrition	905	116 (12.8)
Obesity	1309	184 (14.1)
Uncontrolled diabetes	1108	66 (6.0)
Smoking	1317	146 (11.1)
Opioid use	1317	427 (32.4)

None of the MRFs examined were associated with ED visits (*P* > .05 for all) or ED charges related to the arthroplasty ([Supplementary Tables S5 and S6](#)).

Discussion

Anemia, malnutrition, and obesity had significant independent effects on total encounter charges after shoulder arthroplasty. Identifying these factors preoperatively in patients undergoing shoulder arthroplasty will allow surgeons and institutions to implement strategies to reduce cost. Quantifying the MRF that could lead to financial disincentives within a bundled payment model will allow potential optimization of patients with medical comorbidities and may be effective in reducing cost for the entire episode of care.⁸

Although malnutrition is not routinely identified or addressed preoperatively, it had an outsized impact across all parameters evaluated in the current study, including significant association with higher 90-day charges, readmission, and longer LOS after shoulder arthroplasty. Garcia et al⁴ found a 7.6% prevalence of malnutrition in patients undergoing shoulder arthroplasty, and a significantly increased risk of blood transfusion, longer hospital stay, and death within 30 days of surgery. The effect on charges and costs was not reported in their study. In addition to higher cost, malnutrition has been associated with higher postoperative complications and delayed wound healing after TJA,² which was not directly evaluated in our study. There is also evidence that nutritional intervention positively affects outcomes after TJA,¹⁶ outlining an avenue to

Table II Independent effects of modifiable risk factors on total encounter charges (n = 882)

Variable	β (95% CI) [*]	<i>P</i> value [†]
Anemia	19,847 (15,743, 23,951)	<.001
Malnutrition	5850 (3712, 7988)	<.001
Obesity	2762 (766, 4758)	.007

Values are in US dollars.

^{*} β can be interpreted as the adjusted change in ED charges per unit change in the independent variable.

[†] *P* value was obtained using linear regression, mutually adjusting for all variables presented.

Table III Independent effects of modifiable risk factors on length of stay (n = 885)

Variable	RR (95% CI) [*]	P value [†]
Anemia	2.2 (1.9, 2.6)	<.001
Malnutrition	1.5 (1.3, 2.6)	<.001

RR, relative risk; CI, confidence interval.

^{*} RR can be interpreted as the risk of 1 increased day in length of stay for each independent variable.

[†] P value was obtained using Poisson regression, mutually adjusting for all variables presented.

modify this risk without cancelation or delay of scheduled procedures.

Anemia was the least prevalent MRF in the study population but was associated with higher LOS and total 90-day encounter charges. Anemia is multifactorial and can result from iron deficiency, renal disease, occult gastrointestinal bleeding, bone marrow disorders, or hereditary factors. Despite its multiple etiologies, anemia is amenable to management and modification preoperatively, including iron supplementation, treatment with medication such as epoetin alpha, transfusion, and/or identification and correction of the underlying cause. Although transfusion risk after shoulder arthroplasty is low,³ anemia can potentially affect cost and LOS in this patient population.

Although obesity was the least costly MRF in terms of overall additional effect on charges, the prevalence of obesity in the US population and the increased risks

demonstrated after hip and knee arthroplasty demand that BMI be evaluated and addressed preoperatively. Anakwenze et al¹ examined complication rates by BMI and were unable to identify increased risk for aseptic revision, 1-year mortality, or 3-year deep infection. Superobese patients (defined as BMI >50) were found to have significantly increased complication rates after shoulder arthroplasty.¹⁹ Because obesity is multifactorial and difficult to modify, it has become a de facto limiter for access to hip and knee arthroplasty, with many surgeons and institutions applying strict BMI cutoffs for TJA. As bundled payment models become the norm, this also may limit access to shoulder arthroplasty for this patient population.

Although uncontrolled diabetes, smoking history, and opioid use did not have an independent effect on charges, they still represent MRFs that increase costs in univariate analysis. Uncontrolled diabetes was associated with increased LOS and total 90-day encounter charges in this cohort, similar to other reports.^{10,11} Evidence exists that delaying surgery in patients with elevated glycated hemoglobin may reduce the rate of complications and improve outcomes after TJA.⁶ Our study suggests that targeting these patients for improved glycemic control before surgery also may reduce LOS and costs after shoulder arthroplasty. Similarly, although smoking was not identified as an MRF contributing to increased charges, LOS, or readmission after shoulder arthroplasty in this cohort, patients with smoking history who undergo shoulder arthroplasty have significantly increased readmission, revision within 90 days, wound complications, instability of the prosthesis, as

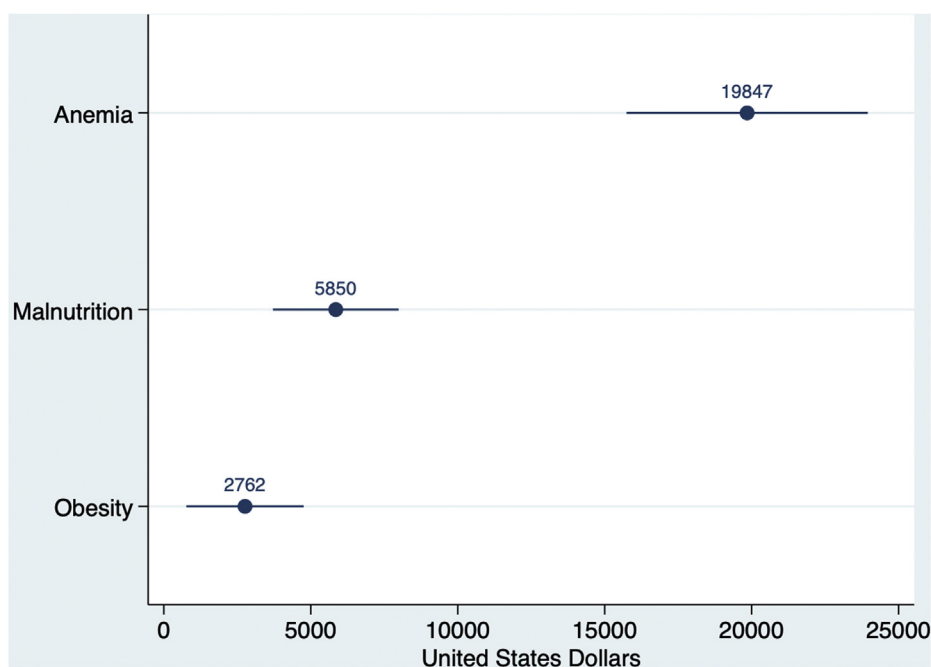


Figure 1 Graph indicating the independent effect of modifiable risk factors (anemia, malnutrition, and obesity, mutually adjusted) on increase in total encounter charges over the mean.

Table IV Average LOS according to comorbidities

Variable	Affected group		Unaffected group		P value*
	n	Mean LOS \pm SD	n	Mean LOS \pm SD	
Anemia	37	5 \pm 4.0	1042	2.2 \pm 1.6	<.001
Malnutrition	116	3.7 \pm 2.8	789	2.2 \pm 1.5	<.001
Obesity	184	2.4 \pm 2.4	1125	2.2 \pm 1.6	.158
Uncontrolled diabetes	66	2.8 \pm 2.8	1042	2.3 \pm 1.7	.019
Smoking	146	2.1 \pm 1.8	1171	2.3 \pm 1.7	.244
Opioid use	427	2.3 \pm 1.7	890	2.2 \pm 1.7	.407

LOS, length of stay.

* P values were obtained using univariate linear regression.

well as pneumonia, sepsis, and myocardial infarction postoperatively.¹⁷ The impact on charges and costs was not quantified in that study, but larger studies are needed to confirm this risk and quantify the increased charges or costs associated with smoking.

This study has several limitations. First, we note that charges, rather than billing or collections, were used to evaluate the financial effects of MRFs after shoulder arthroplasty. Charges do not directly reflect dollar amounts billed or collected, but they are a part of a standard network accounting system and allow for unbiased evaluation of the financial impact of MRFs after shoulder arthroplasty. A second limitation is that not all patients had data for all of the MRFs measured, which limited the population analyzed for each variable. Because missing data can result in selection bias, this is always a concern. However, we believe the majority of missing data is missing at random and, therefore, should not impact the validity of the results, although the statistical power is reduced. The effect of smoking on these outcomes does not reflect factors related to smoking such as product used and smoking behavior, as we used an *International Classification of Diseases, Tenth Revision*, code to identify smokers. Patients may be subject to misclassification; however, we would expect this misclassification to be nondifferential, if present. A final limitation is the relatively short-term assessment of cost of care. Longer follow-up may identify additional risk factors for increased cost, including reoperation and early revision. A recent study suggested that early failure of shoulder prostheses requiring reoperation tended to occur within 2 years, and later failures occurred at an average rate of 1.1% per year.¹⁴

The strengths of the study include the longitudinal nature of the data, which permitted us to evaluate outcomes occurring after surgery, the large sample size, and the ability to generalize widely to patients within the greater metropolitan region and similar populations. Data for all patients undergoing total shoulder arthroplasty in the 7-hospital system were included where available and none was excluded.

Conclusion

To our knowledge, this study is the first to quantify charges associated with MRFs after shoulder arthroplasty, with a focus on those factors amenable to pre-operative management. Ameliorating the conditions associated with MRFs prior to shoulder arthroplasty has the potential to reduce costs and improve outcomes, resulting in benefit for patients, physicians, institutions, and payors.

Disclaimer

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Supplementary Data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jse.2021.08.010>.

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