Risk Factors for In-Hospital Myocardial Infarction After Shoulder Arthroplasty

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Abstract

As cardiovascular complications are associated with significant morbidity and mortality in patients who have arthroplasty, it is important to analyze risk factors for perioperative cardiac morbidity after shoulder arthroplasty.

Using the Nationwide Inpatient Sample, we stratified patients who underwent shoulder arthroplasty into those who had an acute myocardial infarction after arthroplasty and a larger cohort of patients who did not. The top 4 predictors for acute myocardial infarction after shoulder arthroplasty were congestive heart failure, angina pectoris, complicated diabetes mellitus, and male sex. Other pertinent factors were older age, Caucasian ethnicity, and primary diagnosis of proximal humerus fracture.

It is prudent for surgeons and patients to understand the degree to which perioperative cardiac morbidity affects surgical recovery.

The incidence of shoulder arthroplasty in the United States is increasing annually,[1-3] and the majority of these operations occur in older patients.[4-6] Elderly patients with cardiovascular, pulmonary, cerebral, renal, and hepatic disease are increasingly susceptible to numerous surgical complications.[4] Myocardial infarction (MI) is a complication that occurs in 0.7% of noncardiac surgeries. This figure increases to 1.1% in patients with coronary artery disease.[7-11] Perioperative MI increases morbidity and mortality,[8] and perioperative cardiac morbidity is the leading cause of death after anesthesia and surgery.[12] The financial effects of perioperative cardiac morbidity and mortality must also be considered. A 2009 claims analysis study estimated charges associated with a perioperative MI at $15,000 and the cost of cardiac death at $21,909.[13]

Cardiovascular complications are associated with a significant degree of morbidity and mortality in patients who undergo arthroplasty.[14-16] Although studies have elucidated 30- and 90-day morbidity and mortality rates after shoulder arthroplasty, in hip and knee arthroplasty[17-19] little has been done to determine predictors of perioperative MI in a representative database of patients. Given the increasing incidence of shoulder arthroplasty in the United States, the elective nature of this procedure, and the percentage of the US population with cardiovascular risk factors,[20] it is important to establish predictors of perioperative MI to ensure patients and physicians have the necessary resources to make informed decisions.

We conducted a study to examine the risk factors for perioperative MI in a large cohort of patients admitted for shoulder arthroplasty to US hospitals. We wanted to evaluate the association between perioperative MI and shoulder arthroplasty with respect to demographics, primary diagnosis, medical comorbidities, and perioperative complications. Specifically, we tested the null hypothesis that, among patients undergoing shoulder arthroplasty, and accounting for confounding variables, there would be no difference in risk factors for patients who have a perioperative MI.

Materials and Methods

This study was exempt from approval by our institutional review board. All data used in this project were deidentified before use.

Nationwide Inpatient Sample (NIS)

The Nationwide Inpatient Sample (NIS), an annual survey of hospitals, is conducted by the Healthcare Cost and Utilization Project (HCUP) and sponsored by the Agency for Healthcare Research and Quality (AHRQ). This database is the largest publicly available all-payer inpatient discharge database in the United States.[21] Sampling 8 million hospital stays each year, NIS includes information from a representative batch of 20% of US hospitals. In 2011, 46 states and 1045 hospitals contributed information to the database, representing 97% of the US population.[22] This large sample allows researchers to analyze a robust set of medical conditions and uncommon treatments. The survey, conducted each year since 1988, includes demographic, clinical, and resource use data.[23] Discharge weight files are provided by NIS to arrive at valid national estimates.

This database is particularly useful because it provides information on up to 25 medical diagnoses and 15 procedures, which are recorded with *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) codes. Researchers can use this database to analyze patient and hospital characteristics as well as inpatient outcomes.[24,25] Numerous studies have

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used NIS to address pertinent queries across the medical landscape.[22,26]

Patient Selection and Analysis

We used NIS to isolate a population of 422,371 adults (≥18 years old) who underwent total shoulder arthroplasty (TSA) or hemi–shoulder arthroplasty (HSA) between January 1, 2002 and December 31, 2011. We then placed the patients in this population into 1 of 2 cohorts. The first cohort had an acute MI during the perioperative period after TSA, and the second, larger cohort did not have an acute MI after TSA. Acute MI was identified using *ICD-9-CM* code 410.xx. To identify a population of shoulder arthroplasty patients, we included discharges with an *ICD-9-CM* procedure code of 81.80 or 81.88 (both TSA) or 81.81 (HSA) in the sample. We then considered the degree to which each of 5 variables—primary diagnosis, age, sex, race, and select medical comorbidities—was predictive of in-hospital MI after TSA.

Statistical Analysis

Given the large sample used in this study, normal distribution of data was assumed. Using bivariate analysis, Pearson χ^2 test for categorical data, and independent-samples *t* test for continuous data, we compared the nonacute MI and acute MI groups. Multivariable binary logistic regression analyses allowed us to isolate the extent that primary diagnosis, age, sex, race, and medical comorbidities were predictors of acute MI after shoulder arthroplasty. Statistical significance was set at $P < .05$. SPSS Version 22.0 (SPSS, Chicago, Illinois) was used for all statistical analyses and data modeling.

Results

Between January 1, 2002 and December 31, 2011, an estimated total of 422,371 patients underwent shoulder arthroplasty (59.3% TSA, 40.7% HSA). Of these patients, 1174 (0.28%) had a perioperative MI, and 421,197 (99.72%) did not (**Table 1**). Patients with a primary diagnosis of proximal humerus fracture (33.8% vs 16.6%; $P < .001$) or rotator cuff arthropathy (10.1% vs 9.9%; $P < .001$) were more likely than patients with other diagnoses to have an in-hospital MI.

Our review of the demographics found that patients who underwent shoulder arthroplasty and had a perioperative MI were likely older (75±8.9 years vs 69±11 years; $P < .001$), Caucasian (94.2% vs 91.9%; $P = .002$), male (43.2% vs 39.7%; $P = .013$), in the highest median household income bracket of $63,000 or

Table 1. Demographic and Provider-Related Characteristics in Patients With and Without Myocardial Infarction (MI)

	Patients			
Parameter	All	No MI	MI	*P*
Weighted N (%)	422,371 (100)	421,197 (99.72)	1174 (0.28)	
Mean (SD) age, y	69 (11)	69 (11)	75 (8.9)	<.001
Age group, %				<.001
<45 y	3.0	3.0	0	
45-64 y	29.0	29.0	14.1	
65-84 y	33.7	33.7	31.3	
>85 y	34.3	34.3	54.6	
Sex, %				.013
Female	60.3	60.3	56.8	
Male	39.7	39.7	43.2	
Race, %				.002
White	91.9	91.9	94.2	
Black	3.1	3.1	1.2	
Hispanic	2.9	2.9	2.5	
Other	2.2	2.2	2.1	
Household income, %				<.001
$1-$38,999	20.7	20.7	20.4	
$39,000-$47,999	27.1	27.1	26.1	
$48,000-$62,999	26.6	26.6	22.7	
≥$63,000	25.6	25.6	30.8	
Insurance status, %				<.001
Medicare	66.3	66.3	80.9	
Medicaid	2.6	2.6	0.9	
Private	26.4	26.4	13.4	
Other	4.7	4.7	4.9	
Primary diagnosis, %				<.001
Osteoarthrosis	61.3	61.4	40.4	
Proximal humerus fracture	16.6	16.6	33.8	
Avascular necrosis	3.4	3.4	0	
Rheumatoid arthritis	1.4	1.4	0.4	
Nonunion of humerus fracture	2.3	2.3	1.2	
Rotator cuff arthropathy	9.9	9.9	10.1	
Other	5.1	5.0	14.0	
Hospital size, %				.042
Small	15.1	15.1	12.7	
Medium	23.7	23.7	25.6	
Large	61.2	61.2	61.8	
Hospital teaching status, %				.084
Nonteaching	54.4	54.4	51.9	
Teaching	45.6	45.6	48.1	
Hospital location, %				.002
Urban	88.5	88.5	91.4	
Rural	11.5	11.5	8.6	
Type of arthroplasty, %				<.001
Total shoulder arthroplasty	59.3	59.4	45	
Hemi–shoulder arthroplasty	40.7	40.6	55	
Mean (SD) length of stay, d	2.7 (2.5)	2.7 (2.5)	9.4 (7.9)	<.001

more (30.8% vs 25.6%; P < .001), and using Medicare (80.9% vs 66.3%; P < .001). They were more likely to be treated in a medical center of medium size (25.6% vs 23.7%; P = .042) or larger (61.8% vs 61.2%; P = .042). MIs occurred more often in urban environments (91.4% vs 88.5%; P = .002) and in HSA patients (55% vs 40.6%; P < .001), resulting in longer hospital stays (9.4±7.9 days vs 2.7±2.5 days; P < .001) and higher probability of death (6.5% vs 0.1%; P < .001).

We then analyzed the 2 cohorts for medical comorbidities (**Table 2**). Patients in the MI cohort presented with a significantly higher incidence of congestive heart failure, previous MI, angina pectoris, chronic lung disease, hypertension, diabetes, renal failure, fluid and electrolyte disorders, pulmonary circulatory disease, coagulopathy, and deficiency anemia (P < .001) but not liver disease and obesity. Bivariate analysis of perioperative outcomes (**Table 3**) indicated that these patients also had a statistically higher rate of numerous other complications: pulmonary embolism (4.9% vs 0.2%; P < .001), pneumonia (15.1% vs 1.2%; P < .001), deep venous thrombosis (2.6% vs 0.2%; P < .001), cerebrovascular event (1.6% vs 0.1%; P < .001), acute renal failure (15.1% vs 1.2%; P < .001), gastrointestinal complication (1.2% vs 0.3%; P < .001), mechanical ventilation (1.2% vs 0.3%; P < .001), transfusion (33.4% vs 8.8%; P < .001), and nonroutine discharge (73.3% vs 36.0%; P < .001).

Multivariable logistic regression analysis was performed to determine independent predictors of perioperative MI after shoulder arthroplasty (**Table 4**). Patients with a primary diagnosis of proximal humerus fracture (odds ratio [OR], 1.38; 95% confidence interval [CI], 1.15-1.65; P < .001) were more likely than patients with a primary diagnosis of osteoarthritis to have an MI. The odds of postoperative MI increased with age (OR, 1.04 per year; 95% CI, 1.03-1.05; P < .001) and were higher in males (OR, 1.72; 95% CI, 1.52-1.96; P < .001). Compared with Caucasians, African Americans (OR, 0.19; 95% CI, 0.09-0.40; P < .001) were less likely to have an in-hospital MI after shoulder arthroplasty. After shoulder arthroplasty, the odds of MI in the perioperative period increased with each subsequent day of care (OR, 1.10; 95% CI, 1.10-1.11; P < .001).

Regarding independent comorbidities, multivariable logistic regression analysis also determined that history of congestive heart failure (OR, 4.86; 95% CI, 4.20-5.61; P < .001), angina pectoris (OR, 2.90; 95% CI, 2.02-4.17; P < .001), complicated diabetes (OR, 1.96; 95% CI, 1.49-2.57; P < .001), renal failure (OR, 1.42; 95% CI, 1.17-1.72; P < .001), fluid and electrolyte disorders (OR, 1.42; 95% CI, 1.21-1.67; P < .001), and deficiency anemia (OR, 1.62; 95% CI, 1.40-1.88; P < .001) were significant predictors of perioperative MI after shoulder arthroplasty.

Discussion

Results of other studies have elucidated 30- and 90-day mortality rates and postoperative complications after shoulder arthroplasty, but, relative to hip and knee arthroplasty,[17-19] little has been done to determine predictors of perioperative MI in a large sample of shoulder arthroplasty patients. Given the increasing rates of shoulder arthroplasty[1-3] and the demographics of this population,[4-6] it is likely that postoperative cardiovascular events will increase in frequency. We found that, in order of decreasing significance, the top 4 risk predictors for acute MI after shoulder arthroplasty were congestive heart failure, angina pectoralis, complicated diabetes mellitus, and male sex. Other pertinent risk factors included older age, Caucasian ethnicity, and a primary diagnosis of proximal humerus fracture. The rate of acute MI in patients who were older than 75 years when they underwent HSA for proximal humerus fracture was 0.80%.

Table 2. Comorbidities in Patients With and Without Myocardial Infarction (MI)

	Patients, %			
Parameter	All	No MI	MI	*P*
Congestive heart failure	4.0	3.9	32.6	<.001
Previous myocardial infarction	4.0	4.0	7.7	<.001
Angina pectoris	0.6	0.6	2.9	<.001
Chronic lung disease	16.6	16.6	23.5	<.001
Hypertension	62.9	62.9	70.5	<.001
Uncomplicated diabetes mellitus	17.4	17.4	21.7	<.001
Complicated diabetes mellitus	1.6	1.6	6.0	<.001
Liver disease	1.0	1.0	0.90	.668
Obesity	10.3	10.3	10.6	.680
Renal failure	3.3	3.3	14.5	<.001
Fluid and electrolyte disorders	6.9	6.8	23.6	<.001
Pulmonary circulatory disease	0.9	0.9	4.9	<.001
Coagulopathy	1.3	1.3	3.0	<.001
Deficiency anemia	9.2	9.1	23.5	<.001

Table 3. Complications in Patients With and Without Myocardial Infarction (MI)[a]

	Patients, %		
Parameter	All	No MI	MI
Death	0.1	0.1	6.5
Pulmonary embolism	0.3	0.2	4.9
Pneumonia	1.3	1.2	15.1
Deep venous thrombosis	0.2	0.2	2.6
Cerebrovascular event	0.1	0.1	1.6
Acute renal failure	1.2	1.2	15.1
Gastrointestinal complication	0.3	0.3	1.2
Mechanical ventilation	0.3	0.3	1.2
Transfusion	8.9	8.8	33.4
Nonroutine discharge	36.1	36.0	73.3

[a]All *P*s < .001.

Demographics

We found that patients who had an acute MI after shoulder arthroplasty were likely older, male, and Caucasian. Age and male sex are well-established risk factors for increased cardiac complications after arthroplasty.[27-29] Previous studies have indicated that the rate of cardiac events increases in arthroplasty patients older than 65 years.[19,28,29] In our study, more than 50% of the patients who had an acute perioperative MI were older than 85 years. Less explainable is the increased occurrence of acute MI in Caucasian patients and wealthy patients, given that minorities in the United States have higher rates of cardiovascular disease.[30] Shoulder arthroplasty is an elective procedure, more likely to be undertaken by Caucasians. Therefore, at-risk minority groups and financially challenged groups may be less likely to have this procedure.

Table 4. **Multivariable Logistic Regression Model of Predictors of Acute Myocardial Infarction After Shoulder Arthroplasty[a]**

Predictor	OR	95% CI Lower	95% CI Upper	*P*
Hemi–shoulder arthroplasty (reference: total shoulder arthroplasty)	1.08	0.94	1.26	.284
Age, per 1-year increase	1.04	1.03	1.05	<.001
Male sex (reference: female)	1.72	1.52	1.96	<.001
Race (reference: white)				
Black	0.19	0.09	0.40	<.001
Hispanic	0.63	0.42	0.94	.024
Other	0.92	0.61	1.38	.678
Insurance status (reference: private insurance)				
Medicare	1.09	0.90	1.32	.395
Medicaid	0.33	0.14	0.77	.010
Other	1.70	1.25	2.33	.001
Days of care, per 1-day increase	1.10	1.10	1.11	<.001
Comorbidities (reference: absence of disease)				
Congestive heart failure	4.86	4.20	5.61	<.001
Previous myocardial infarction	1.35	1.08	1.68	.009
Angina pectoris	2.90	2.02	4.17	<.001
Chronic lung disease	1.13	0.98	1.31	.091
Hypertension	1.16	1.008	1.33	.039
Uncomplicated diabetes mellitus	1.13	0.98	1.32	.100
Complicated diabetes mellitus	1.96	1.49	2.57	<.001
Liver disease	0.64	0.33	1.22	.175
Obesity	1.05	0.86	1.28	.619
Renal failure	1.42	1.17	1.72	<.001
Fluid and electrolyte disorders	1.42	1.21	1.67	<.001
Pulmonary circulatory disease	1.44	1.07	1.94	.018
Coagulopathy	0.73	0.50	1.08	.115
Deficiency anemia	1.62	1.40	1.88	<.001
Primary diagnosis (reference: osteoarthrosis)				
Proximal humerus fracture	1.38	1.15	1.65	<.001
Avascular necrosis[b]	—	—	—	—
Rheumatoid arthritis	0.85	0.36	1.97	.698
Nonunion of humerus fracture	0.53	0.31	0.91	.022
Rotator cuff arthropathy	1.32	1.08	1.63	.008
Other	2.02	1.63	2.51	<.001

Abbreviations: CI, confidence interval; OR, odds ratio.
[a]Model fit: area under receiver operating characteristic (ROC) = 0.87; Nagelkerke R^2 = 0.17. Statistical significance set at $P < .05$.
[b]OR could not be calculated because of small number of events.

Primary Diagnosis

In this series, patients with a primary diagnosis of proximal humerus fracture were more likely to have an in-hospital MI. This finding is consistent with previous studies indicating a higher rate of complications for proximal humerus fracture patients than for shoulder arthroplasty patients.[31,32] Given that more than 75% of patients who present with a proximal humerus fracture are older than 70 years, it would be prudent to examine operative indications after this diagnosis,[33] particularly as benefit from surgery for fractures has not been definitively demonstrated.[34-37]

Comorbidities

Many of the patients in our MI cohort presented with congestive heart failure, angina pectoris, complicated diabetes, renal failure, fluid and electrolyte disorders, or deficiency anemia. This is in keeping with other studies indicating that preexisting cardiovascular morbidity increases the rate of MI after various forms of arthroplasty.[7-11] Patients in our MI cohort were also susceptible to a variety of post-MI perioperative complications, including pulmonary embolism, pneumonia, deep venous thrombosis, cerebrovascular event, acute renal failure, gastrointestinal complication, mechanical ventilation, transfusion, and nonroutine discharge, and their incidence of death was higher. These findings are consistent with reports that postoperative cardiovascular complications increase the degree of morbidity and mortality in arthroplasty patients.[14-16] It is also worth noting that the odds of MI in the perioperative period increase with each subsequent day of care. This is understandable given that patients presenting with numerous comorbidities are at increased risk for perioperative complications[38] resulting in hospital readmission.[39]

The literature indicates that MI occurs as a complication in 0.7% of patients who undergo noncardiac surgery,[7] though some series have shown it is more prevalent after arthroplasty procedures.[28,40] MI significantly increases the rate of perioperative morbidity and mortality,[8] and perioperative cardiac morbidity is a leading cause of death after anesthesia and surgery.[12] Furthermore, the most common cause of death after lower extremity arthroplasty is cardiovascular-related.[41,42] In patients who presented for elective hip arthroplasty, cardiorespiratory disease was

one of the main risk factors (with older age and male sex) shown to increase perioperative mortality.[43]

Perioperative cardiovascular complications increase postoperative morbidity and mortality.[12] The rate of cardiovascular complications after shoulder arthroplasty ranges from 0.8% to 2.6%, and the incidence of MI hovers between 0.3% and 0.9%.[17,19,28,40,44] A recent study in 793 patients found that, over a 30-day period, cardiovascular complications accounted for more than one-fourth of all complications.[17] Singh and colleagues[19] analyzed cardiopulmonary complications after primary shoulder arthroplasty in a total of 3480 patients (4019 arthroplasties) and found this group had a 90-day cardiac morbidity (MI, congestive heart failure, arrhythmia) rate of 2.6%. In that study, a Deyo-Charlson index of 1 or more was a significant independent risk factor for cardiac complications following surgery. Scores on this weighted index of 17 comorbidities are used to assess the complexities of a patient population. Given the severity of cardiovascular perioperative complications, it is important to preoperatively identify high-risk population groups and sufficiently study and optimize patients before shoulder arthroplasty.

There is much debate about the effectiveness of perioperative β-blockers in reducing perioperative cardiac morbidity and mortality.[45-48] Such a discussion is outside of the scope of this article, but it may be prudent to seek a cardiology consultation for patients presenting with risk factors for perioperative MI. β-Blockers may prove useful in reducing cardiac morbidity in high-risk patients after noncardiac surgery.[45,49]

Many limitations are inherent in studies that use a nationally represented database such as NIS, which we used in this study. It is highly likely that NIS does not capture all potential postoperative complications, as this database is very large and subject to errors in data entry and clinical coding. In addition, detailed clinical information (eg, severity of certain comorbid diseases before shoulder arthroplasty, details about the intraoperative course) was not readily available for analysis. Another limitation, which may have led to an underestimate of complication rates, was our not being able to obtain information about postdischarge complications.

Despite these limitations, NIS and other databases have helped researchers answer questions about low-incidence conditions and generalize findings to a national population. In the present study, we analyzed 2 cohorts, patients with and without acute MI after shoulder arthroplasty, to determine predictors for and complications of postarthroplasty MI. We identified numerous predictors for acute MI: congestive heart failure, angina pectoris, complicated diabetes, renal failure, fluid and electrolyte disorders, and deficiency anemia prior to arthroplasty. As perioperative MI is associated with significant morbidity,[14-16] it would be wise to screen patients for such comorbid conditions, assess the severity of these conditions, and offer shoulder arthroplasty with prudence.

Conclusion

The top 4 predictors for acute MI after shoulder arthroplasty were congestive heart failure, angina pectoralis, complicated diabetes mellitus, and male sex. Other pertinent risk factors included older age, Caucasian ethnicity, and primary diagnosis of proximal humerus fracture. Surgeons and patients must be aware of predictors for adverse surgical outcomes such as perioperative MI and understand the extent to which these events increase perioperative morbidity and mortality.

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References

1. 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(8):1115-1120.
2. Kim SH, Wise BL, Zhang Y, Szabo RM. Increasing incidence of shoulder arthroplasty in the United States. *J Bone Joint Surg Am*. 2011;93(24):2249-2254.
3. Kurtz SM, Lau E, Ong K, Zhao K, Kelly M, Bozic KJ. Future young patient demand for primary and revision joint replacement: national projections from 2010 to 2030. *Clin Orthop*. 2009;467(10):2606-2612.
4. Boettcher WG. Total hip arthroplasties in the elderly. Morbidity, mortality, and cost effectiveness. *Clin Orthop*. 1992;(274):30-34.
5. Greenfield S, Apolone G, McNeil BJ, Cleary PD. The importance of coexistent disease in the occurrence of postoperative complications and one-year recovery in patients undergoing total hip replacement. Comorbidity and outcomes after hip replacement. *Med Care*. 1993;31(2):141-154.
6. Kreder HJ, Williams JI, Jaglal S, Hu R, Axcell T, Stephen D. Are complication rates for elective primary total hip arthroplasty in Ontario related to surgeon and hospital volumes? A preliminary investigation. *Can J Surg*. 1998;41(6):431-437.
7. Botto F, Alonso-Coello P, Chan MT, et al. Myocardial injury after noncardiac surgery: a large, international, prospective cohort study establishing diagnostic criteria, characteristics, predictors, and 30-day outcomes. *Anesthesiology*. 2014;120(3):564-578.
8. Mangano DT, Browner WS, Hollenberg M, London MJ, Tubau JF, Tateo IM. Association of perioperative myocardial ischemia with cardiac morbidity and mortality in men undergoing noncardiac surgery. The Study of Perioperative Ischemia Research Group. *N Engl J Med*. 1990;323(26):1781-1788.
9. Tarhan S, Moffitt EA, Taylor WF, Giuliani ER. Myocardial infarction after general anesthesia. *JAMA*. 1972;220(11):1451-1454.
10. Landesberg G, Mosseri M, Zahger D, et al. Myocardial infarction after vascular surgery: the role of prolonged stress-induced, ST depression-type ischemia. *J Am Coll Cardiol*. 2001;37(7):1839-1845.
11. van Waes JA, Nathoe HM, de Graaff JC, et al. Myocardial injury after noncardiac surgery and its association with short-term mortality. *Circulation*. 2013;127(23):2264-2271.
12. Mangano DT. Perioperative cardiac morbidity. *Anesthesiology*. 1990;72(1):153-184.
13. Fleisher LA, Corbett W, Berry C, Poldermans D. Cost-effectiveness of differing perioperative beta-blockade strategies in vascular surgery patients. *J Cardiothorac Vasc Anesth*. 2004;18(1):7-13.
14. Aynardi M, Pulido L, Parvizi J, Sharkey PF, Rothman RH. Early mortality after modern total hip arthroplasty. *Clin Orthop*. 2009;467(1):213-218.
15. Gangireddy C, Rectenwald JR, Upchurch GR, et al. Risk factors and clinical impact of postoperative symptomatic venous thromboembolism. *J Vasc Surg*. 2007;45(2):335-341.
16. Baser O, Supina D, Sengupta N, Wang L, Kwong L. Impact of postoperative venous thromboembolism on Medicare recipients undergoing total hip replacement or total knee replacement surgery. *Am J Health Syst Pharm*. 2010;67(17):1438-1445.
17. 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*. 2010;468(3):717-722.
18. Farmer KW, Hammond JW, Queale WS, Keyurapan E, McFarland EG. Shoulder arthroplasty versus hip and knee arthroplasties: a comparison of outcomes. *Clin Orthop*. 2007;(455):183-189.
19. Singh JA, Sperling JW, Cofield RH. Cardiopulmonary complications after primary shoulder arthroplasty: a cohort study. *Semin Arthritis Rheum*. 2012;41(5):689-697.
20. Go AS, Mozaffarian D, Roger VL, et al; American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Heart disease and stroke statistics—2014 update: a report from the American Heart Association. *Circulation*. 2014;129(3):e28-e292.
21. Lin CA, Kuo AC, Takemoto S. Comorbidities and perioperative complications in HIV-positive patients undergoing primary total hip and knee arthroplasty. *J Bone Joint Surg Am*. 2013;95(11):1028-1036.
22. Maynard C, Sales AE. Changes in the use of coronary artery revascularization procedures in the Department of Veterans Affairs, the National Hospital Discharge Survey, and the Nationwide Inpatient Sample, 1991–1999. *BMC Health Serv Res*. 2003;3(1):12.
23. Griffin JW, Novicoff WM, Browne JA, Brockmeier SF. Obstructive sleep apnea as a risk factor after shoulder arthroplasty. *J Shoulder Elbow Surg*. 2013;22(12):e6-e9.
24. Hambright D, Henderson RA, Cook C, Worrell T, Moorman CT, Bolognesi MP. A comparison of perioperative outcomes in patients with and without rheumatoid arthritis after receiving a total shoulder replacement arthroplasty. *J Shoulder Elbow Surg*. 2011;20(1):77-85.
25. Odum SM, Troyer JL, Kelly MP, Dedini RD, Bozic KJ. A cost-utility analysis comparing the cost-effectiveness of simultaneous and staged bilateral total knee arthroplasty. *J Bone Joint Surg Am*. 2013;95(16):1441-1449.
26. Ponce BA, Menendez ME, Oladeji LO, Soldado F. Diabetes as a risk factor for poorer early postoperative outcomes after shoulder arthroplasty. *J Shoulder Elbow Surg*. 2014;23(5):671-678.
27. Alfonso DT, Toussaint RJ, Alfonso BD, Strauss EJ, Steiger DT, Di Cesare PE. Nonsurgical complications after total hip and knee arthroplasty. *Am J Orthop*. 2006;35(11):503-510.
28. Mantilla CB, Horlocker TT, Schroeder DR, Berry DJ, Brown DL. Frequency of myocardial infarction, pulmonary embolism, deep venous thrombosis, and death following primary hip or knee arthroplasty. *Anesthesiology*. 2002;96(5):1140-1146.
29. Singh JA, Jensen MR, Harmsen WS, Gabriel SE, Lewallen DG. Cardiac and thromboembolic complications and mortality in patients undergoing total hip and total knee arthroplasty. *Ann Rheum Dis*. 2011;70(12):2082-2088.
30. Kurian AK, Cardarelli KM. Racial and ethnic differences in cardiovascular disease risk factors: a systematic review. *Ethn Dis*. 2007;17(1):143-152.
31. Zhang AL, Schairer WW, Feeley BT. Hospital readmissions after surgical treatment of proximal humerus fractures: is arthroplasty safer than open reduction internal fixation? *Clin Orthop*. 2014;472(8):2317-2324.
32. Schairer WW, Zhang AL, Feeley BT. Hospital readmissions after primary shoulder arthroplasty. *J Shoulder Elbow Surg*. 2014;23(9):1349-1355.
33. de Kruijf M, Vroemen JP, de Leur K, van der Voort EA, Vos DI, Van der Laan L. Proximal fractures of the humerus in patients older than 75 years of age: should we consider operative treatment? *J Orthop Traumatol*. 2014;15(2):111-115.
34. Hauschild O, Konrad G, Audige L, et al. Operative versus non-operative treatment for two-part surgical neck fractures of the proximal humerus. *Arch Orthop Trauma Surg*. 2013;133(10):1385-1393.
35. Hanson B, Neidenbach P, de Boer P, Stengel D. Functional outcomes after nonoperative management of fractures of the proximal humerus. *J Shoulder Elbow Surg*. 2009;18(4):612-621.
36. Handoll HH, Ollivere BJ, Rollins KE. Interventions for treating proximal humeral fractures in adults. *Cochrane Database Syst Rev*. 2012;12:CD000434.
37. Court-Brown CM, Cattermole H, McQueen MM. Impacted valgus fractures (B1.1) of the proximal humerus. The results of non-operative treatment. *J Bone Joint Surg Br*. 2002;84(4):504-508.
38. Chalmers PN, Gupta AK, Rahman Z, Bruce B, Romeo AA, Nicholson GP. Predictors of early complications of total shoulder arthroplasty. *J Arthroplasty*. 2014;29(4):856-860.
39. Mahoney A, Bosco JA 3rd, Zuckerman JD. Readmission after shoulder arthroplasty. *J Shoulder Elbow Surg*. 2014;23(3):377-381.
40. Khan SK, Malviya A, Muller SD, et al. Reduced short-term complications and mortality following Enhanced Recovery primary hip and knee arthroplasty: results from 6,000 consecutive procedures. *Acta Orthop*. 2014;85(1):26-31.
41. Paavolainen P, Pukkala E, Pulkkinen P, Visuri T. Causes of death after total hip arthroplasty: a nationwide cohort study with 24,638 patients. *J Arthroplasty*. 2002;17(3):274-281.
42. Sharrock NE, Cazan MG, Hargett MJ, Williams-Russo P, Wilson PD Jr. Changes in mortality after total hip and knee arthroplasty over a ten-year period. *Anesth Analg*. 1995;80(2):242-248.
43. Parvizi J, Johnson BG, Rowland C, Ereth MH, Lewallen DG. Thirty-day mortality after elective total hip arthroplasty. *J Bone Joint Surg Am*. 2001;83(10):1524-1528.
44. Morris MJ, Molli RG, Berend KR, Lombardi AV Jr. Mortality and perioperative complications after unicompartmental knee arthroplasty. *Knee*. 2013;20(3):218-220.
45. Lindenauer PK, Pekow P, Wang K, Mamidi DK, Gutierrez B, Benjamin EM. Perioperative beta-blocker therapy and mortality after major noncardiac surgery. *N Engl J Med*. 2005;353(4):349-361.
46. Wijeysundera DN, Beattie WS, Wijeysundera HC, Yun L, Austin PC, Ko DT. Duration of preoperative beta-blockade and outcomes after major elective noncardiac surgery. *Can J Cardiol*. 2014;30(2):217-223.
47. Andersson C, Merie C, Jorgensen M, et al. Association of beta-blocker therapy with risks of adverse cardiovascular events and deaths in patients with ischemic heart disease undergoing noncardiac surgery: a Danish nationwide cohort study. *JAMA Int Med*. 2014;174(3):336-344.
48. Bakker EJ, Ravensbergen NJ, Poldermans D. Perioperative cardiac evaluation, monitoring, and risk reduction strategies in noncardiac surgery patients. *Curr Opin Crit Care*. 2011;17(5):409-415.
49. Auerbach AD, Goldman L. Beta-blockers and reduction of cardiac events in noncardiac surgery: scientific review. *JAMA*. 2002;287(11):1435-1444.