Risk Factors for 30-Day Complications After Thumb CMC Joint Arthroplasty: An American College of Surgeons National Surgery Quality Improvement Program Study

HAND
2019, Vol. 14(3) 357–363
© The Author(s) 2017
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/1558944717744341
hand.sagepub.com

Kalpit N. Shah¹, Steven F. Defroda¹, Bo Wang¹, and Arnold-Peter C. Weiss¹

Abstract

Background: The first carpometacarpal (CMC) joint is a common site of osteoarthritis, with arthroplasty being a common procedure to provide pain relief and improve function with low complications. However, little is known about risk factors that may predispose a patient for postoperative complications. **Methods:** All CMC joint arthroplasty from 2005 to 2015 in the prospectively collected American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database were identified. Bivariate testing and multiple logistic regressions were performed to determine which patient demographics, surgical variables and medical comorbidities were significant predictors for complications. These included wound related, cardiopulmonary, neurological and renal complications, return to the operating room (OR) and readmission. **Results:** A total of 3344 patients were identified from the database. Of those, 45 patients (1.3%) experienced a complication including wound issues (0.66%), return to the OR (0.15%) and readmission (0.27%) amongst others. When performing bivariate analysis, age over 65, American Society of Anesthesiologists (ASA) Class, diabetes and renal dialysis were significant risk factors. Multiple logistic regression after adjusting for confounding factors demonstrated that insulin-dependent diabetes and ASA Class 4 had a strong trend while renal dialysis was a significant risk factor. **Conclusions:** CMC arthroplasty has a very low overall complication rate of 1.3% and wound complication rate of 0.66%. Diabetes requiring insulin and ASA Class 4 trended towards significance while renal dialysis was found to be a significant risk factors in logistic regression. This information may be useful for preoperative counseling and discussion with patients who have these risk factors.

Keywords: thumb CMC arthroplasty, surgical complications, readmission, reoperation, NSQIP

Introduction

Osteoarthritis (OA) of the carpometacarpal (CMC) joint is fairly common in the United States with an incidence of 6.6 in 100 adults between age 40 and 49 years, and 36.4 in 100 adults over age 80 suffering from symptomatic, radiographic OA.^{5,30,31} Carpometacarpal joint arthritis causes pain, deformity, and loss of function.²⁷ Gervis and Froimson were the first to describe surgical treatment for trapeziometacarpal arthritis.^{7,8} Eaton and Littler described their trapeziectomy with tendon interposition technique in 1973.⁶ Despite numerous other described techniques, ligament reconstruction, tendon interposition (LRTI) is typically regarded as the standard to which new procedures addressing CMC arthritis should be compared.^{9,12,21}

Carpometacarpal arthroplasty is generally regarded as a safe outpatient procedure. Due to the high variability in surgical technique and the widespread acceptance of CMC arthroplasty as an outpatient procedure, most studies to date focus on long-term outcomes and complications.²⁸ While short-term outcomes tend to be overlooked, Lipira et al reported on 30-day complications following all hand surgery

¹Brown University, Department of Orthopaedic Surgery, Providence, RI, USA

Corresponding Author:

Kalpit N. Shah, Department of Orthopaedic Surgery, Warren Alpert School of Medicine, Brown University, 593 Eddy Street, Providence, RI 02903, USA.

Email: kalpit210@gmail.com

cases from 2006 to 2011. The study included over 300 Current Procedural Terminology (CPT) codes and 10 000 patients, and found a 2.5% 30-day complication rate, with surgical site infection being the most common complication (1.1%).¹³ Specifically, they found the rate of complication in outpatient cases to be even lower (1.4% overall, 0.9% infection).¹³ Similarly, a study by Menendez et al evaluated surgical site complications after common outpatient hand surgery and found surgical site infection to be 0.33% in the first 30 days.¹⁶ Specifically, they noted surgical site infection rate of 0.49% after CMC arthroplasty.¹⁶ In our study, we sought to quantify all complications (surgical and systemic) after CMC arthroplasty, as the authors believe that this can be a procedure in which pain, swelling, wound dehiscence, and infection are possible in the early postoperative period.²⁷

Knowledge of complications following CMC arthroplasty is important to allow surgeons to properly counsel their patients regarding their postoperative course, as well as to properly screen patients prior to intervention. The aim of this study was to determine patient risk factors for 30-day complications after CMC arthroplasty, as reported in the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database. The NSQIP database has been previously utilized to study short-term postoperative complications in a number of orthopedic procedures,^{1,2,4,10,11,14,15,22,23,29} but it has not been utilized for CMC arthroplasty. We hypothesized that regardless of medical comorbidity, patients would have equivalent complication rates in the immediate postoperative period.

Materials and Methods

Source Data

To study complications following thumb CMC joint arthroplasty, the ACS-NSQIP database was utilized. This database represents a high-quality, prospectively collected surgical database encompassing approximately 750 medical centers from January 2006 to December 2015, making it well suited for our study. To maintain database quality, hospitals are excluded from ACS-NSQIP if their interobserver disagreement rate between clinical reviewers is greater than 5% or if their 30-day follow-up rate is less than 80%. Finally, this database provides a highly accurate account of patient demographics, medical comorbidities, postoperative admissions, complications, and rate of reoperation, which has been validated for a large number of orthopedic procedures to date.^{1,2,14,15,17,18,23,25,26,29} An institutional review board (IRB) approval was not obtained as this data set was de-identified data available from the American College of Surgeons to all participating institutions.

Data Collection

All cases from January 2006 to December 2015 with the CPT codes 25447 ("Interposition arthroplasty, intercarpal or carpometacarpal joints") and 25445 ("Arthroplasty with prosthetic replacement, trapezium") were included. Procedures with additional CPT codes were excluded. To assess potential patient risk factors for complications, reoperation, and readmission, a number of variables were collected and analyzed. These included demographic data such as age, sex, race, body mass index (BMI), smoking status, alcohol use, and functional status. Portion of a patient's medical history such as preoperative lab values and a variety of medical comorbidities were also investigated. Finally, surgical data such as the principal anesthesia used during surgery (regional, monitored anesthesia care [MAC], or general), American Society of Anesthesiologists (ASA) class ranging from 1 (healthy patient) to 4 (potentially life threatening medical disease), anesthesia time, resident involvement, and inpatient versus outpatient setting were also evaluated for their role as significant predictor variables. Within the NSQIP database, cases in which both general anesthesia and a regional block were utilized were classified as general anesthesia (ie, the principal anesthesia). For each patient, information on individual medical comorbidities was collected, and preoperative Charlson Comorbidity Index (CCI) scores were subsequently calculated for each patient as a global measure of health status.³

The primary outcome variable assessed was 30-day complication following thumb CMC arthroplasty. Complications included wound complications (surgical site and deep infection or wound dehiscence), respiratory complications, cardiac complications, renal complications, neurological complications, return to the operating room for a related event, and readmission to the hospital for reasons related to the surgery. Multiple continuous variables were converted to categorical variables for univariate analysis to assess their contribution as a predictor variable. These included age (>60, >65, and >70), diabetic status (yes with insulin, yes without insulin, or no), and BMI (<18.5, 18.5-25, 25-30, and >30). For the purposes of multiple variable regressions, age was treated as a categorical factor (<65 or >65), diabetes was treated as a categorical variable and the rest as continuous variables. The following medical comorbidities were included in the NSQIP database but were not included in the data analysis as these were not present in any patients undergoing thumb CMC arthroplasty: ventilator dependence, current pneumonia, presence of ascites or esophageal varices, vascular claudication at rest, coma, central nervous system tumors, chemotherapy, or radiotherapy.

Statistical Analysis and Modeling

We initially examined the distribution of different complications occurred among patients in our study. Then, we

compared demographic, comorbidity, and operative data between the patient groups with complications (cases) and without complications (controls). *T* tests were used to compare the means of continuous variables and the Pearson chi-square tests were used to determine the association between categorical variables and postoperative complications. All variables with a *P* value less than .10 in the bivariate analyses were included in a multiple logistic regression analysis to adjust for confounders. The group of patients without a known complication was used as the reference group in the multivariable analysis, and a *P* value of .05 or less was considered to be a statistically significant independent predictor of postoperative complication. A receiver operating characteristic curve was plotted to validate this multivariable model, and the area under the curve was .63 (95% confidence interval [CI], 0.55-0.72). All analyses were done in R 3.3.1.

Results

A total of 3344 patients from the ACS-NSQIP database from the years 2006 to 2015 were identified as having undergone a thumb CMC joint arthroplasty. Within 30 days after the surgery, 45 patients (1.3%) developed 54 complications (Table 1). There were 5 cases (0.15%) where the patient returned to the operation room. Difference in demographic risk factors was evaluated between the patients with and without a postoperative complication (Table 2). Bivariate analyses were performed for these variables and those with a *P* < 0.1 were included in the multiple logistic regression. There was no difference in the distribution of sex, race, BMI, current smoking status, and current alcohol use.

Bivariate analyses of comorbidity data (Table 3) showed that the distributions of ASA Classification and diabetes are significantly different among patients with and without complications. Notably, among patients who developed complications, the percentage of ASA class 4—Life Threat (6%) was multiple times of those of other categories (<2%, *P* = .04), and the percentage of patients who have diabetes requiring insulin (4.3%) was significantly higher than those of patients with no diabetes or does not require insulin (<1.5%, *P* = .05). Moreover, patients with complications are much more likely to have been on dialysis (25.0%) than those who did not have complications (1.3%, *P* = .004). There is no statistical evidence that patients with and without complications had different rates of peripheral vascular disease, steroid usage, chemotherapy, or radiation therapy.

Bivariate analyses of operative data (Table 4) showed that the surgical time, general anesthesia, and resident involvement were not different between the 2 groups of patients.

Table 1. Complications Profile of 3344 Patients from 2006 to 2015.

Complications distribution (30 days prospective)	n	%
Wound complications		
Superficial infection	18	0.54
Deep infection	2	0.06
Dehiscence	2	0.06
Organ/space SSI	0	0
Respiratory complications		
Pneumonia	2	0.06
Pulmonary embolism	1	0.03
Reintubation	1	0.03
Ventilator >48 h	1	0.03
Cardiac complications		
Cardiac arrest	0	0
Myocardial infarction	2	0.06
Renal complications		
Acute renal failure	0	0
UTI	9	0.27
Neurologic complications		
CVA	1	0.03
Coma	0	0
Peripheral nerve injuries	0	0
Hematologic complications		
DVT	0	0
Systemic complications		
Sepsis	0	0
Septic shock	0	0
Clostridium difficile colitis	0	0
Return to operation room	5	0.15
Readmission	9	0.27
Blood transfusion	0	0
Death	1	0.03
Total overall number of complications	54	—
Total number of patients with a complication	45	1.3

Note. SSI = surgical site infection, UTI = urinary tract infection, CVA = cerebrovascular accident; DVT = deep vein thrombosis.

Multiple logistic regression model (Table 5) was constructed based on the ACS-NSQIP sample data to determine the significant independent predictors for postoperative complications. After adjusting for confounding variables, diabetes requiring insulin (odds ratio [OR]: 2.62, *P* = .06) and ASA class 4—Life Threat (OR: 10.13, *P* = .07) were identified as independent risk factors approaching significance, while dialysis usage (OR: 20.63, *P* < .001) was identified as a significant risk factor for developing complications after thumb CMC joint arthroplasty surgery.

Table 2. Analysis of Demographic Variables Versus Complications.

Demographics	Patients without complications n = 3299	Patients with complications n = 45	P value
Age			.15
Mean (SD)	62 (9)	65 (11)	
Age group: 65 plus (%)			.09
No	1978 (99.0)	20 (1.0)	
Yes	1321 (98.1)	25 (1.9)	
Sex (%)			.38
Male	785 (99.0)	8 (1.0)	
Female	2512 (98.5)	37 (1.5)	
Race (%)			.55
White	2701 (97.8)	35 (2.2)	
Black or African American	75 (97.4)	2 (2.6)	
Asian	28 (100)	0 (0)	
Other/unknown	495 (98.4)	8 (1.6)	
Ethnicity: Hispanic (%)			1.00
No	2683 (98.7)	34 (1.3)	
Yes	96 (99.0)	1 (1.0)	
Body mass index			.10
Underweight (<18.5)	60 (98.4)	1 (1.6)	
Normal (18.5-25)	710 (98.2)	13 (1.8)	
Overweight (25-30)	1088 (99.4)	7 (0.6)	
Obese (>30)	1441 (98.4)	24 (1.6)	
Smoker (%)			.52
Yes	461 (98.3)	8 (1.7)	
No	2838 (98.7)	37 (1.3)	
Alcohol use (%)			1.00
Yes	31 (96.8)	1 (3.2)	
No	790 (98.2)	14 (1.8)	
Functional status (%)			.25
Independent	3251 (98.7)	44 (1.3)	
Partially dependent	16 (94.1)	1 (5.9)	

Discussion

We evaluated the ACS-NSQIP database to study complications, reoperations, and readmissions in patients who had undergone a thumb CMC arthroplasty. Historically, elective hand surgery has a very low complication rate, which presents a unique challenge to prospectively evaluate surgical procedures for potential complications and identify risk factors associated with its development.

We were able to identify 3344 patients undergoing surgical intervention to address CMC arthritis and noted 30-day complications across a variety of domains, reoperations, and readmissions. Given the large number of patients included, we were able to analyze the data for potential risk factors that may put the patient at an increased risk for experiencing an acute adverse event. Twenty-two patients (0.67%) developed a surgical site infection or had

Table 3. Analysis of Comorbidities Versus Complications.

Comorbidities	Patients without complications	Patients with complications	P value
ASA Classification (%)			.04
1—No disturb	211 (99.5)	1 (0.5)	
2—Mild disturb	2073 (98.9)	24 (1.1)	
3—Severe disturb	982 (98.2)	18 (1.8)	
4—Life threat	31 (94.0)	2 (6.0)	
Diabetes (%)			.05
No	2961 (98.8)	37 (1.2)	
Insulin	110 (95.7)	5 (4.3)	
Oral	17 (100)	0 (0)	
Noninsulin	211 (98.6)	3 (1.4)	
Hypertension requiring medication (%)			.45
No	1740 (98.8)	21 (1.2)	
Yes	1559 (98.5)	24 (1.5)	
Peripheral vascular disease (%)			1.00
No	814 (98.2)	15 (1.8)	
Yes	7 (100)	0 (0)	
Previous cardiac surgery (%)			.31
No	802 (98.3)	14 (1.7)	
Yes	19 (95.0)	1 (5.0)	
History of angina (%)			1.00
No	819 (98.2)	15 (1.8)	
Yes	2 (100)	0 (0)	
Congestive heart failure (%)			1.00
No	3297 (98.7)	45 (1.3)	
Yes	2 (100)	0 (0)	
Cerebrovascular accident or transient ischemic attack (%)			1.00
No	821 (98.2)	15 (1.8)	
Yes	48 (98.0)	1 (2.0)	
Bleeding disorder (%)			.22
No	3237 (98.7)	43 (1.3)	
Steroid use (%)			.19
No	3192 (98.7)	42 (1.3)	
Yes	107 (97.3)	3 (2.7)	
Dialysis use (%)			.004
No	3293 (98.7)	43 (1.3)	
Yes	6 (75.0)	2 (25.0)	
Chemotherapy or radiation therapy (%)			1.00
No	821 (98.2)	15 (1.8)	
Yes	1 (100)	0 (0)	

Note. ASA = American Society of Anesthesiologists.

wound-healing issues. It must be noted that 18 patients of the 22 patients with surgical site infection were noted to have superficial infection whose treatment often varies

Table 4. Analysis of Operative Data Versus Complications.

Operative variables	Patients without complications	Patients with complications	P value
Wound classification (%)			1.00
Clean	3281 (98.6)	45 (1.6)	
Not clean	18 (100)	0 (0)	
Wound closure (%)			1.00
All layers fully closed	1537 (98.3)	26 (1.7)	
Not fully closed	2 (100)	0 (0)	
Surgical time			.95
Mean (SD)	76 (38)	75 (36)	
Anesthesia (%)			.87
General	2268 (98.6)	32 (1.6)	
Other	1024 (98.7)	13 (1.3)	
Anesthesia time			.23
Mean (SD)	115 (54)	105 (35)	
Resident involvement (%)			.41
No resident	582 (98.5)	9 (1.5)	
Other	238 (97.5)	6 (2.5)	
Inpatient vs outpatient (%)			1.00
Inpatient	83 (98.8)	1 (1.2)	
Outpatient	3208 (98.4)	52 (1.6)	
Previous surgery within 30 days (%)			1.00
No	822 (98.2)	15 (1.8)	
Yes	2 (100)	0 (0)	
Days from hospital admission to operation			.17
Mean (SD)	0.003 (0.13)	0 (0)	

depending on the provider preference. Nonoperative management with oral antibiotics and observation is often utilized. These patients with a superficial infection account for roughly 49% of patients with complications. Although they were included in our study as a complication, they represent a minor event and would further reduce the overall complication rate if excluded. Five patients (0.15%) returned to the operating room, and 9 patients (0.27%) had to be readmitted after the surgery. A total of 45 patients (1.3%) experienced some form of complication after a CMC arthroplasty. Age over 65 was associated with a trend toward increased complication rate, while ASA class, diabetes requiring insulin use, and renal disease requiring dialysis were significant risk factors for complications under a univariate analysis. Under a logistic regression, renal disease requiring dialysis ($P = .004$) was a risk factor that continued to be significantly associated with complications. However, it must be noted that insulin use ($P = .06$) and ASA class 4 ($P = .07$) were trending toward significance, but they do not achieve the customary significant P value of .05, an arbitrarily established cutoff value for statistical significance.²⁰ We believed a more inclusive approach to patient counseling and setting expectations may benefit the surgeon.

Table 5. Logistic Regression Analysis With Multiple Predictors.

Potential predictors	Odds ratio	95% confidence interval		P value
		Lower	Upper	
Age over 65				
No (reference)	—	—	—	—
Yes	1.12	0.60	2.14	.73
Diabetes				
No (reference)	—	—	—	—
Insulin	2.62	0.84	6.69	.06
Noninsulin	0.91	0.21	2.64	.88
Oral (no case of complication)	—	—	—	—
ASA Classification				
1—No disturb (reference)	—	—	—	—
2—Mild disturb	2.33	0.48	41.83	.41
3—Severe disturb	3.33	0.64	61.19	.28
4—Life threat	10.13	0.89	229.60	.07
Dialysis				
No (reference)	—	—	—	—
Yes	20.63	2.82	99.89	.0004

Note. ASA = American Society of Anesthesiologists.

There have been some recent database analyses published that looked at complications after hand and wrist surgery. Lipira et al did a comprehensive analysis of complications that develop after any hand surgery (208 CPT codes included).¹³ As mentioned earlier, they found a low surgical site complication rate of 2.5% in their group. Besides that, their common complications included death (0.3%), urinary tract infection (UTI; 0.3%), hemorrhage requiring transfusion (0.3%), and sepsis and septic shock (0.3%). In this study, with the exception of UTI (0.27%), we did not see similar systemic complications. This likely stems from the difference in patient populations—Given that all hand surgery-related CPT codes were included in the article by Lipira et al, many nonelective surgeries are likely to have been captured. This may have included patients who are at a higher risk for the observed complication compared with this study's elective-only patient population.

Menendez et al similarly looked at the California State Ambulatory Surgery database for surgical site infections following the 7 most common hand surgery procedures.¹⁶ They report an overall infection rate of 0.33%, and infection after thumb basal joint arthroplasty to be 0.49%. We found a similar wound complication rate after basal joint arthroplasty of 0.67%, although we included wound dehiscence in our group, which could be contributing to the slightly higher rate we found. In addition, their database relies on billing data, which may not have captured all incidents of infections secondary to inaccurate coding, failure to document due to

financial incentives or fear of retribution²⁴ and if the patient had an infection that was treated nonoperatively as only visits to the emergency department for infection or if the infection necessitated another operation or hospital stay were recorded. As the data collection for the ACS-NSQIP database is done prospectively, all incidents of nonoperative and operative infections are theoretically collected providing a more complete representation of outcomes. The authors of that study also tried to find risk factors for surgical site infections included in their study. They were able to show a difference based on patient insurance; however, age, sex, smoking status, obesity, and diabetes were not significant. In our study, we were able to identify increasing age, insulin dependence, ASA class, and renal disease as predictors for all complications. Menendez et al did not perform subanalysis on basal joint arthroplasties, and their only complication was infection compared with the comprehensive set included in this study. This made it difficult to directly compare the risk factors associated with complications.

A recent study by Naram et al evaluated complications after thumb joint arthroplasty with a goal of comparing trapeziectomy with ligament reconstruction and tendon interposition with trapeziectomy alone.¹⁹ Of the 200 operations (176 patients) included in the study, they reported a complication rate of 35%. However, the complications reported were much more detailed than can be found in the NSQIP database. For example, parasthesias, swelling, and clinical outcomes specific to thumb basal joint arthroplasty such as subsidence were included as complications. When isolating just infections requiring antibiotics or surgical intervention, they report a rate of 5.5%, which is significantly higher than the rate reported in this study. This difference may be attributed to the significantly lower sample size than this study and due to differences in the surgeon preference and threshold for what warrants antibiotics or surgical intervention.

This study contains some limitations. The complications collected in the NSQIP database primarily include surgical and systemic complications but not all outcomes that may interest a hand surgeon, namely, improvement or presence of postoperative pain, hardware complications treated nonoperatively or complications that manifested after 30 days, and functional assessments such as grip strength, range of motion, or other patient-reported outcome measures. Many surgeons chose to immobilize patients for 4 weeks postoperatively; complications that may manifest after this period of immobilization may not be captured by this database. Some of the complications identified by the database are related to the patient comorbidities and not necessarily to the surgical procedure. However, the goal of this study was not to identify only complications related to CMC arthroplasty but rather all complications that may affect a patient undergoing CMC arthroplasty. Although the database captures both outpatient and inpatient centers, it does not

collect data from stand-alone ambulatory surgery centers where a sizable portion of these surgeries may be performed. It is possible that the patient population that undergoes surgery at an ambulatory surgery center may be different than those who have their procedure performed in an inpatient or outpatient setting. Patients who had missing data were excluded from the analysis and may represent a source of bias. Although the patient sample sizes are relatively large, it is possible that due to the low number for some of the complications, the comparison may be underpowered.

We hope that this study will allow surgeons to have a better informed discussion with their patients regarding risks and benefits of a thumb CMC joint arthroplasty based on the patients' comorbidities and other risk factors. This study may also be used to establish benchmarks for outcomes and complications across institutions.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5).

Statement of Informed Consent

Informed consent was not obtained as this was a de-identified database study that is open to use by participating institutions.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: One of the authors, A-PCW, has a conflict of interest that is unrelated to this project with Extremity Medical Inc. A-PCW also has a patent that may be related to this article, but it did not affect the results of this project. The rest of the authors have no conflicts of interest.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

1. Basques BA, Gardner EC, Varthi AG, et al. Risk factors for short-term adverse events and readmission after arthroscopic meniscectomy: does age matter? *Am J Sports Med.* 2015;43(1):169-175. doi:10.1177/0363546514551923.
2. Belmont P Jr, Goodman G, Waterman B, et al. Thirty-day postoperative complications and mortality following total knee arthroplasty: incidence and risk factors among a national sample of 15,321 patients. *J Bone Joint Surg Am.* 2014;96(1):20-26.

3. Charlson ME, Pompei P, Ales KL, et al. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis.* 1987;40(5):373-383.
4. Cvetanovich GL, Chalmers PN, Verma NN, et al. Risk factors for short-term complications of anterior cruciate ligament reconstruction in the United States. *Am J Sports Med.* 2016;44(3):618-624. doi:10.1177/0363546515622414.
5. Dillon CF, Hirsch R, Rasch EK, et al. Symptomatic hand osteoarthritis in the United States: prevalence and functional impairment estimates from the third U.S. National Health and Nutrition Examination Survey, 1991-1994. *Am J Phys Med Rehabil.* 2007;86(1):12-21.
6. Eaton RG, Littler JW. Ligament reconstruction for the painful thumb carpometacarpal joint. *J Bone Joint Surg Am.* 1973;55(8):1655-1666.
7. Froimson AI. Tendon arthroplasty of the trapeziometacarpal joint. *Clin Orthop Relat Res.* 1970;70:191-199.
8. Gervis WH. Osteoarthritis of the trapeziometacarpal joint treated by excision of the trapezium. *Proc R Soc Med.* 1947;40(9):492.
9. Gillis J, Calder K, Williams J. Review of thumb carpometacarpal arthritis classification, treatment and outcomes. *Can J Plast Surg.* 2011;19(4):134-138.
10. Haughom BD, Schairer WW, Hellman MD, et al. Does resident involvement impact post-operative complications following primary total knee arthroplasty? an analysis of 24,529 cases. *J Arthroplasty.* 2014;29(7):1468-1472.e2.
11. Haughom BD, Schairer WW, Hellman MD, et al. Resident involvement does not influence complication after total hip arthroplasty: an analysis of 13,109 cases. *J Arthroplasty.* 2014;29(10):1919-1924.
12. Kriegs-Au G, Petje G, Fojtl E, et al. Ligament reconstruction with or without tendon interposition to treat primary thumb carpometacarpal osteoarthritis. *J Bone Joint Surg Am.* 2005;87(suppl 1):78-85.
13. Lipira AB, Sood RF, Tatman PD, et al. Complications within 30 days of hand surgery: an analysis of 10,646 patients. *J Hand Surg Am.* 2015;40(9):1852-1859.e3.
14. Martin CT, Gao Y, Pugely AJ, et al. 30-day morbidity and mortality after elective shoulder arthroscopy: a review of 9410 cases. *J Shoulder Elbow Surg.* 2013;22(12):1667-1675.e1.
15. Martin CT, Pugely AJ, Gao Y, et al. Risk factors for thirty-day morbidity and mortality following knee arthroscopy: a review of 12,271 patients from the national surgical quality improvement program database. *J Bone Joint Surg Am.* 2013;95(14):e981-e110.
16. Menendez ME, Lu N, Unizony S, et al. Surgical site infection in hand surgery. *Int Orthop.* 2015;39(11):2191-2198.
17. Namba RS, Inacio MCS, Paxton EW. Risk factors associated with deep surgical site infections after primary total knee arthroplasty: an analysis of 56,216 knees. *J Bone Joint Surg Am.* 2013;95(9):775-782.
18. Namba RS, Inacio MCS, Paxton EW. Risk factors associated with surgical site infection in 30,491 primary total hip replacements. *J Bone Joint Surg Br.* 2012;94(10):1330-1338.
19. Naram A, Lyons K, Rothkopf DM, et al. Increased complications in trapeziectomy with ligament reconstruction and tendon interposition compared with trapeziectomy alone. *Hand.* 2016;11(1):78-82.
20. Nuzzo R. Scientific method: statistical errors. *Nature.* 2014;506(7487):150-152.
21. Sakai N. Interposition arthroplasty using trapezium tendon ball for osteoarthritis of the carpometacarpal joint of the thumb. *Tech Hand Up Extrem Surg.* 2006;10(2):68-72.
22. Shields E, Iannuzzi JC, Thorsness R, et al. Perioperative complications after hemiarthroplasty and total shoulder arthroplasty are equivalent. *J Shoulder Elbow Surg.* 2014;23(10):1449-1453.
23. Shields E, Thirukumaran C, Thorsness R, et al. An analysis of adult patient risk factors and complications within 30 days after arthroscopic shoulder surgery. *Arthroscopy.* 2015;31(5):807-815.
24. Simborg DW. DRG creep: a new hospital-acquired disease. *N Engl J Med.* 1981;304(26):1602-1604.
25. SooHoo NF, Farnig E, Lieberman JR, et al. Factors that predict short-term complication rates after total hip arthroplasty. *Clin Orthop Relat Res.* 2010;468(9):2363-2371.
26. SooHoo NF, Lieberman JR, Ko CY, et al. Factors predicting complication rates following total knee replacement. *J Bone Joint Surg Am.* 2006;88(3):480-485.
27. Vermeulen GM, Slijper H, Feitz R, et al. Surgical management of primary thumb carpometacarpal osteoarthritis: a systematic review. *J Hand Surg Am.* 2011;36(1):157-169.
28. Wajon A, Vinycomb T, Carr E, et al. Surgery for thumb (trapeziometacarpal joint) osteoarthritis. *Cochrane Database Syst Rev.* 2015;23(2):CD004631.
29. Waterman BR, Dunn JC, Bader J, et al. Thirty-day morbidity and mortality after elective total shoulder arthroplasty: patient-based and surgical risk factors. *J Shoulder Elbow Surg.* 2015;24(1):24-30.
30. Wilder FV, Barrett JP, Farina EJ. Joint-specific prevalence of osteoarthritis of the hand. *Osteoarthritis Cartilage.* 2006;14(9):953-957. doi:10.1016/j.joca.2006.04.013.
31. Zhang Y, Niu J, Kelly-Hayes M, et al. Prevalence of symptomatic hand osteoarthritis and its impact on functional status among the elderly: the Framingham Study. *Am J Epidemiol.* 2002;156(11):1021-1027.