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Factors Associated with In-hospital Pulmonary Embolism Following Shoulder Arthroplasty

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Abstract

Background—Despite pulmonary embolism (PE) being a feared complication after shoulder arthroplasty, little is known about its perioperative associated factors.

Materials and Methods—We used the Nationwide Inpatient Sample to gather a sample of 422,372 patients who underwent shoulder arthroplasty between 2002 and 2011. This population was divided into two cohorts based on those who experienced perioperative PE (0.25%) and those who did not. Demographics were compiled for both cohorts. Multivariable logistic regression analysis was used to account for confounding variables and determine significant predictors of perioperative PE.

Results—After adjusting for patient demographic and clinical variables in multivariable regression modeling, the top 4 independent predictors for PE were primary diagnosis of proximal humerus fracture, deficiency anemia, congestive heart failure, and chronic lung disease. Other pertinent risk factors included increasing age, obesity, fluid and electrolyte abnormalities, undergoing TSA rather than HA, and subsequent days of post-operative care.

Conclusions—Knowledge of these factors might help in preoperative counseling and prove useful for implementation of quality improvement strategies to reduce its occurrence. Surgeons may consider initiating thromboprophylaxis in patients with any of the aforementioned comorbidities.

Keywords

nationwide inpatient sample; shoulder arthroplasty; pulmonary embolism; perioperative complications

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IRB Status:

As NIS contains only de-identified information and is publicly available, IRB approval was not required for this study.

Level of evidence: Level III, Database Analysis Case Control Design, Epidemiology Study

Introduction

The demand for shoulder arthroplasty has experienced substantial growth during the past decade, even more so than hip and knee replacements.¹² Despite its increasing popularity and demonstrated cost-effectiveness, shoulder arthroplasty is not free of risk, especially given the increasing age and comorbidity burden of surgical candidates. In particular, pulmonary embolism (PE) constitutes a severe medical complication after shoulder arthroplasty.

The Centers for Disease Control and Prevention (CDC) estimate that nearly 280,000 people are hospitalized for PE each year and 12% die within one month of diagnosis.^{3,34} PE has been deemed “the most preventable cause of hospitalization. In 2008, the Centers for Medicare and Medicaid Services (CMS) included PE in their list of “never events”, for which related costs of treatment were no longer reimbursed. Pulmonary emboli put enormous financial strain on the United States healthcare system and economy. A recent analysis approximates that the total annual healthcare cost for a single PE is close to \$17,000, which is dwarfed by concomitant disability claims and productivity loss experienced by employers.²⁰

A PE has been recognized as a major complication in almost all types of surgery, including orthopaedics.^{16,25,32} Perioperative PE are associated with significant morbidity and mortality in arthroplasty patients. The majority of PE focus in the orthopedic literature concerns hip or knee arthroplasty as PE rates in lower extremity arthroplasties may be as high as 0.4–0.8% for unilateral knee, and 1.5% for hip.^{5,17,36} In addition to shoulder arthroplasty being a less common procedure than lower extremity arthroplasty, the rates of PE are lower ranging from 0.2%–0.54%.¹⁸ Together this may account for less literature concerning PE associated with shoulder arthroplasty. To our knowledge, no study has investigated risk factors for PE using a large, nationally representative sample. In light of the increasing frequency of elective shoulder arthroplasty, the detrimental outcomes and financial consequences associated with PE in shoulder arthroplasty it may be beneficial to establish predictors of perioperative PE in order to better allocate resources and insure that patients and physicians can make more informed decisions.

This purpose of this study is to use nationally representative data to identify perioperative factors associated with the development of in-hospital PE after shoulder arthroplasty.

Materials and Methodology

This study was exempt from approval by our institutional review board; all data utilized in this project was de-identified prior to use.

The Nationwide Inpatient Sample (NIS)

The Nationwide Inpatient Sample (NIS), sponsored by the Agency for Healthcare Research and Quality (AHRQ), is an annual survey of hospital discharges conducted by the Healthcare Cost and Utilization Project (HCUP). Currently, this database is the largest publicly available, all-payer, inpatient discharge database in the United States.¹⁴ The first

NIS was available in 1988 and hospital participation in the program has increased each year. The annual sample is a 20% stratification from all participating community hospitals which excludes federal, military, and psychiatric institutions. Each year discharge weight files are available to allow for valid national estimates. In 2011, the sample drawn from over eight million hospital stays in 1,000 non-federal hospitals represented 97% of the US population after weighting.⁹

The large sample population provided by the NIS allows researchers to analyze trends in healthcare aspects such as costs, quality, and outcomes.⁹ Moreover, its emphasis on demographic, clinical and resource data bestows upon the NIS the unique ability to draw correlations and conclusions using rare conditions and special patient populations. It includes information on up to 25 diagnosis and 15 procedures for each hospital stay. This information is recorded using the *International Classification of Diseases, 9th Revision, Clinical Modification* (ICD-9-CM) codes. A number of recent studies have used this database to address the effect that patient and hospital characteristics can have on inpatient outcomes in a myriad of medical conditions.^{13,27,31}

Patient Selection and Analysis

Our study population consisted of adults (≥ 18 years old) undergoing shoulder arthroplasty between January 1, 2002 and December 31, 2011. Discharges with a procedure code (ICD-9-CM) for total (81.80, 81.88) or partial (81.81) shoulder arthroplasty were identified and included in the analysis. We then categorized this population into one of two cohorts: (1) patients without a diagnosis of a postoperative PE (pulmonary embolism: ICD-9-CM 415.1) and (2) patients who had a diagnosis code for PE listed during their hospital stay. We then analyzed the extent to which the following variables could predict an in-hospital PE following shoulder arthroplasty: (1) primary diagnosis, (2) age, (3) gender, (4) race, (5) and select medical comorbidities.

Statistical Analysis

Due to the large weighted sample size, normal distribution of the data was assumed. Pearson's chi-square test was employed for analysis of categorical data, and independent-samples T test for continuous data. Multivariable logistic regression modeling was used to determine factors independently associated with the development of an in-hospital PE. All predictor variables were included simultaneously in the regression model. We used the area under the receiver-operating characteristic (ROC) curve to evaluate the discriminatory ability of our model. Statistical significance was set at $P < 0.05$. SPSS Version 22.0 (SPSS®, IBM®, Chicago, IL, USA) was used for all statistical analyses and data modeling.

Results

During the 10-year study period, an estimated total of 422,372 patients underwent shoulder arthroplasty. Of these patients, 59.3% underwent total shoulder arthroplasty (TSA) and 40.7% underwent hemiarthroplasty (HA). The frequency of in-hospital PE was 0.25%, or 2.5 events per 1000 shoulder arthroplasties (Table I).

Patients with an in-hospital diagnosis of PE were more likely older (72 ± 11 years vs 69 ± 11 years, $P < 0.001$), black (3.6% vs 3.1%; $P = 0.038$) or Hispanic (4.2% vs 2.9%; $P = 0.038$), female (67.5% vs 60.3%; $P < 0.001$), and insured under Medicare (73.8% vs 66.3%; $P < 0.001$) or Medicaid (3.8% vs 2.6%; $P < 0.001$). In addition, perioperative PEs were more frequent in medium (27.8% vs 23.7%; $P < 0.001$) and large-sized (62.8% vs 61.2%; $P < 0.001$) hospitals based on bed size standards set by HCUP, and in teaching institutions (48.9% vs 45.6%; $P = 0.030$).

We then analyzed these two cohorts for the presence of medical comorbidities (Table II). Patients in the PE cohort presented with a significantly higher incidence of congestive heart failure (12.5% vs 4%; $P < 0.001$), chronic lung disease (24.5% vs 16.6%; $P < 0.001$), uncomplicated diabetes mellitus (22.2% vs 17.4%; $P < 0.001$), obesity (12.5% vs 10.3%; $P = 0.018$), renal failure (5.1% vs 3.3%; $P = 0.002$), fluid and electrolyte disorder (19.5% vs 6.8%; $P < 0.001$), coagulopathy (3.3% vs 1.3%; $P < 0.001$), and deficiency anemia (23.4% vs 9.2%; $P < 0.001$).

In the bivariate analysis of perioperative outcomes, the presence of PE was associated with a significantly higher incidence of mortality and other complications (Table 3): myocardial infarction (5.4% vs 0.3%; $P < 0.001$), pneumonia (12.5% vs 1.2%; $P < 0.001$), deep venous thrombosis (11.0% vs 0.2%; $P < 0.001$), cerebrovascular event (0.5% vs 0.1%; $P = 0.001$), acute renal failure (6.4% vs 1.2%; $P < 0.001$), gastrointestinal complication (2.6% vs 0.3%; $P < 0.001$), mechanical ventilation (2.6% vs 0.3%; $P < 0.001$), transfusion (24.9% vs 8.8%; $P < 0.001$) and non-routine discharge (72.4% vs 36.0%; $P < 0.001$).

In multivariable logistic regression analysis (Table IV), patients with a primary diagnosis of proximal humerus fracture (odds ratio [OR] 2.43; 95% confidence interval [CI], 2.02–2.92; $P < 0.001$) were more likely to suffer a PE in comparison to those with a primary diagnosis of osteoarthritis; and patients undergoing TSA were more likely to have a PE than those undergoing HA (OR 1.33; 95% CI, 1.20–1.56; $P < 0.001$). Also, analysis shows the odds of postoperative PE increased with each decade of life (OR 1.10; 95% CI, 1.04–1.17; $P < 0.001$). Finally, the odds of having a PE in the perioperative period increased with each subsequent day of inpatient care following shoulder arthroplasty (OR, 1.12; 95% CI, 1.11–1.13; $P < 0.001$). Other predictors independently associated with PE included chronic congestive heart failure (OR 1.49; 95% CI, 1.20–1.84; $P < 0.001$), chronic lung disease (OR 1.40; 95% CI, 1.21–1.62; $P < 0.001$), obesity (OR 1.31; 95% CI, 1.08–1.58; $P = 0.006$), fluid and electrolyte disorders (OR 1.33; 95% CI, 1.12–1.59; $P = 0.001$), and deficiency anemia (OR 1.84; 95% CI, 1.57–2.15; $P < 0.001$).

Discussion

Although the rate of PE in hospitalized patients has not increased over the years, it is still reasonable to assume that the increasing rate of shoulder arthroplasty will be accompanied by a rise in the incidence of perioperative PE.^{12,27} Thromboprophylaxis and post-operative anticoagulant therapy have been shown to reduce PE in many types of surgery; but as seen in other surgical complications, this accomplishment has possibly been offset by the morbid demographics and comorbidities in patients who commonly undergo joint arthroplasty.^{2,8,22}

In this study, we found that the top 4 independent predictors of perioperative PE after shoulder arthroplasty were primary diagnosis of proximal humerus fracture (OR 2.4), deficiency anemia (OR 1.8), congestive heart failure (OR 1.5), and chronic lung disease (OR 1.4). Additional risk factors for PE included advancing age, obesity, fluid and electrolyte abnormalities, undergoing TSA rather than HA, and subsequent days of post-operative care.

Demographics

We found that the rate of perioperative PE prior to discharge was 0.25% following shoulder arthroplasty. A recent study by Navarro et al in 2574 patients undergoing shoulder arthroplasty conveys the prevalence of PE within 90 days of shoulder arthroplasty to be 0.54%.¹⁸ Another study of 3,480 patients by Singh et al showed that 0.9–1.2% of shoulder arthroplasties resulted in PE within 90 days.²⁹ The higher rates presented by these two studies may show that many perioperative PE occur after the patient has been discharged. A review of the literature by Willis et al asserts that the rate of perioperative PE in shoulder arthroplasty ranges from 0.2% to 2%.³⁵ Our finding falls within this range. A study by Lyman et al used a cohort of similar size to ours and published comparable results of 0.23%.¹⁵

In agreement with previous studies, advanced age was associated with higher rates of PE after shoulder arthroplasty.⁴ Univariate analysis of our demographic data indicates a higher prevalence of perioperative PE after shoulder arthroplasty in females; but after accounting for confounding demographic variables and comorbidities, it seems that gender is not an independent predictor of this complication. Studies concerning the lower extremity have shown that the female gender is an independent risk factor for perioperative PE in hip and knee arthroplasty.⁴ One study by Griffin et al has found female gender to be an independent risk factor for mortality from perioperative PE in shoulder arthroplasty.⁸ Our data is in agreement with past studies showing that a greater number of females than males undergo shoulder arthroplasty. This reality offset by the greater risk of PE in men than women may be a likely reason that there is no relationship between gender and perioperative PE.²³ Several studies have alluded to hormone replacement therapy in post-menopausal women as a risk factor for PE; surgeons should keep this in mind when performing procedures on the elderly female demographic.²⁴

Primary Diagnosis

Proximal humerus fracture (PHFx) was associated with greater than a two fold increase risk of PE. Previous studies have defined fractures, surgery, and immobilization as risk factors for thromboembolic events, all of which are present in patients undergoing surgical intervention for PHFx.^{1,10,18} This is in concurrence with an institutional analysis which indicated a 5.1% incidence rate of PE after shoulder arthroplasty for PHFx.³⁰ It is apparent that surgeons should maintain a high level of suspicion when these patients present with respiratory difficulty, hypoxia, and tachycardia.¹¹ While it is not typical for shoulder arthroplasty patients to receive thromboprophylaxis, these findings support providing anticoagulation for arthroplasties following PHFx.

A recent study by Shields et al asserts that patient characteristics, not procedure type, are predictive variables in shoulder arthroplasty outcomes.²⁶ Another study concurs with Shields and reports similar complication rates between TSA and HSA. Trofa et al argue against similar complication rates.³³ Their study found that patients undergoing TSA have a higher rate of complications than those undergoing HA. Some may stress that modern studies concerning this argument may be flawed by the FDA approval of the reverse total shoulder arthroplasty (RSA) in 2004. The RSA is a salvage surgery indicated for failed primary arthroplasties and excessive rotator cuff injury, which commonly occurs in the older, morbid population. All of the studies presented here, along with ours, accounted for comorbidities and patient characteristics in order to account for confounding variables that may accompany the RSA. Our findings concur with Trofa and indicate that TSA is independently associated inpatient PE.

Comorbidities

We found several associations between the development of in-hospital PE and a number of pre-existing comorbidities: congestive heart failure, chronic lung disease, obesity, fluid and electrolyte disorders, and deficiency anemia. The relationship of these comorbidities with PE has been well established in the hip and knee arthroplasty literature. A recent study Parvizi et al have concluded that increased BMI, chronic obstructive pulmonary disorder, atrial fibrillation, and anemia were all independent risk factors for PE after total joint arthroplasty.²¹ Two other recent studies show that a higher score on the Deyo-Charlson Comorbidity Index serves as an independent risk factor for PE after total knee replacements and shoulder arthroplasty. The Deyo-Charlson Index is a validated comorbidity assessment that includes diseases relevant to our study like: cardiac, pulmonary, renal, diabetic, and hepatic diseases.²⁸ These studies are in agreement with our findings that aforementioned comorbidities are independent predictors of PE in shoulder arthroplasty, and they help support this correlation into the realm of shoulder arthroplasty. It can also be noted that the finding in this paper supports an investigation by Heit et al which insists that patients with chronic liver disease have a reduced risk for venous thromboemboli.¹⁰

Limitations are numerous in studies using a large, nationally representative database such as the NIS. Given the large amount of data and the complexity of the ICD-9 (procedure and diagnoses) codes used by the NIS, it is highly likely that hospital employed coders make errors in data entry.¹⁹ These faults are evident in an analysis of an institution's spinal fusion surgeries which discovered that 21% of diagnosis codes (ICD-9) entered by hospital employees failed to match the diagnosis noted in the chart by the surgeon.⁷ These inaccuracies in clinical coding may lead to underestimations or misclassifications of postoperative complications which could have effected our study. Reverse TSA only became a unique code in October 2010; therefore, we do not know the true proportion of reverse vs. anatomic TSA in our population. We were also inhibited by the lack of pre-operative clinical details (type of anesthesia, blood loss, medications, surgery length, etc.) available for analysis.⁷ Moreover, the NIS is based off information found in hospital discharge bills; therefore, we were unable to identify complications the patient may have experienced after discharge. Therefore, failure to account for pre-operative patient disposition and post-operative PE could also have led to an underestimation of complication

rates. The NIS also lacks the sequence of events during inpatient stay, so we could not determine if each PE was a result of shoulder arthroplasty or some other procedure the patient underwent during their stay.¹⁹ It also was impossible to determine readmissions since patients are de-identified. Finally, although our findings represent statistically significant associations, causality between predictors and PE cannot be established.

Conclusions

The purpose of this study was to employ a nationally representative large database to analyze the perioperative factors associated with PE following shoulder arthroplasty. The top four predictors for PE were primary diagnosis of proximal humerus fracture, deficiency anemia, congestive heart failure, and chronic lung disease. Other pertinent risk factors included advancing age, obesity, fluid and electrolyte abnormalities, undergoing TSA rather than HA, and subsequent days of post-operative care. In light of a scarcity of evidence for or against anticoagulation in shoulder arthroplasty, our results may be used by surgeons in preoperative discussions with patients so that they may be adequately informed of their risk. While more studies may be necessary to develop a strict algorithm for anticoagulation, surgeons may strongly consider initiating prophylaxis in patients with any of the aforementioned comorbidities, particularly if the patient's history is contributory (e.g. obesity or previous thromboembolic event). Guidelines for thromboembolism prophylaxis are readily available and multiple effective options may be used.⁶

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References

1. Anderson FA Jr, Spencer FA. Risk factors for venous thromboembolism. *Circulation*. 2003 Jun 17; 107(23 Suppl 1):I9–16.10.1161/01.CIR.0000078469.07362.E6 [PubMed: 12814980]
2. Bot AG, Menendez ME, Neuhaus V, Ring D. The influence of psychiatric comorbidity on perioperative outcomes after shoulder arthroplasty. *J Shoulder Elbow Surg*. 2014 Apr; 23(4):519–27.10.1016/j.jse.2013.12.006 [PubMed: 24630546]
3. Centers of Disease Control. Venous thromboembolism in adult hospitalizations—United States, 2007–2009. *MMWR Morb Mortal Wkly Rep*. 2012 Jun 8; 61(22):401–4. [PubMed: 22672974]
4. Chalmers PN, Gupta AK, Rahman Z, Bruce B, Romeo AA, Nicholson GP. Predictors of early complications of total shoulder arthroplasty. *J Arthroplasty*. 2014 Apr; 29(4):856–60.10.1016/j.arth.2013.07.002 [PubMed: 23927910]
5. Dahl OE, Gudmundsen TE, Bjørnå BT, Solheim DM. Risk of clinical pulmonary embolism after joint surgery in patients receiving low-molecular-weight heparin prophylaxis in hospital: a 10-year prospective register of 3,954 patients. *Acta Orthop Scand*. 2003 Jun; 74(3):299–304.10.1080/00016470308540844 [PubMed: 12899550]
6. Geerts WH, Bergqvist D, Pineo GF, Heit JA, Samama CM, Lassen MR, et al. Prevention of venous thromboembolism: American College of Chest Physicians Evidence-Based Clinical Practice Guidelines (8th Edition). *Chest*. 2008 Jun; 133(6 Suppl):381S–453S.10.1378/chest.08-0656 [PubMed: 18574271]

7. Gologorsky Y, Knightly JJ, Lu Y, Chi JH, Groff MW. Improving discharge data fidelity for use in large administrative databases. *Neurosurg Focus*. 2014 Jun;36(6):E2.10.3171/2014.3.FOCUS1459 [PubMed: 24881634]
8. Griffin JW, Hadeed MM, Novicoff WM, Browne JA, Brockmeier SF. Patient age is a factor in early outcomes after shoulder arthroplasty. *J Shoulder Elbow Surg*. 2014 Dec; 23(12):1867–71.10.1016/j.jse.2014.04.004 [PubMed: 24957847]
9. HCUP Databases. Healthcare Cost and Utilization Project (HCUP). Agency for Healthcare Research and Quality; Rockville, MD: Jul. 2014 www.hcup-us.ahrq.gov/nisoverview.jsp
10. Heit JA, Silverstein MD, Mohr DN, Petterson TM, O'Fallon WM, Melton LJ 3rd. Risk factors for deep vein thrombosis and pulmonary embolism: a population-based case-control study. *Arch Intern Med*. 2000 Mar 27; 160(6):809–15. [PubMed: 10737280]
11. Hoxie SC, Sperling JW, Cofield RH. Pulmonary embolism after operative treatment of proximal humeral fractures. *J Shoulder Elbow Surg*. 2007 Nov-Dec;16(6):782–3.10.1016/j.jse.2006.12.004 [PubMed: 17531514]
12. Kim SH, Wise BL, Zhang Y, Szabo RM. Increasing incidence of shoulder arthroplasty in the United States. *J Bone Joint Surg Am*. 2011 Dec 21; 93(24):2249–54.10.2106/JBJS.J.01994 [PubMed: 22258770]
13. Kurtz SM, Ong KL, Lau E, Bozic KJ. Impact of the economic downturn on total joint replacement demand in the United States: updated projections to 2021. *J Bone Joint Surg Am*. 2014 Apr 16; 96(8):624–30.10.2106/JBJS.M.00285 [PubMed: 24740658]
14. 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 Jun 5; 95(11):1028–36.10.2106/JBJS.L.00269 [PubMed: 23780541]
15. Lyman S, Sherman S, Carter TI, Bach PB, Mandl LA, Marx RG. Prevalence and risk factors for symptomatic thromboembolic events after shoulder arthroplasty. *Clin Orthop Relat Res*. 2006 Jul; 448:152–6.10.1097/01.blo.0000194679.87258.6e [PubMed: 16826110]
16. Martino MA, Borges E, Williamson E, Siegfried S, Cantor AB, Lancaster J, et al. Pulmonary embolism after major abdominal surgery in gynecologic oncology. *Obstet Gynecol*. 2006 Mar; 107(3):666–71.10.1097/01.AOG.0000200046.28199 [PubMed: 16507939]
17. Memtsoudis SG, Besculides MC, Gaber L, Liu S, González Della Valle A. Risk factors for pulmonary embolism after hip and knee arthroplasty: a population-based study. *Int Orthop*. 2009 Dec; 33(6):1739–45.10.1007/s00264-008-0659-z [PubMed: 18925395]
18. Navarro RA, Inacio MC, Burke MF, Costouros JG, Yian EH. Risk of thromboembolism in shoulder arthroplasty: effect of implant type and traumatic indication. *Clin Orthop Relat Res*. 2013 May; 471(5):1576–81.10.1007/s11999-013-2829-6 [PubMed: 23392993]
19. Noskin GA, Rubin RJ, Schentag JJ, Kluytmans J, Hedblom EC, Smulders M, et al. The burden of *Staphylococcus aureus* infections on hospitals in the United States: an analysis of the 2000 and 2001 Nationwide Inpatient Sample Database. *Arch Intern Med*. 2005 Aug 8–22; 165(15):1756–61.10.1001/archinte.165.15.1756 [PubMed: 16087824]
20. Page RL, Ghushchyan V, Gifford B, Read RA, Raut M, Bookhart BK, et al. Hidden Costs Associated With Venous Thromboembolism: Impact of Lost Productivity on Employers and Employees. *J Occup Environ Med*. 2014 Sep; 56(9):979–85.10.1097/JOM.0000000000000208 [PubMed: 25046319]
21. Parvizi J, Huang R, Raphael IJ, Arnold WV, Rothman RH. Symptomatic pulmonary embolus after joint arthroplasty: stratification of risk factors. *Clin Orthop Relat Res*. 2014 Mar; 472(3):903–12.10.1007/s11999-013-3358-z [PubMed: 24264881]
22. Rao G, Zikria EA, Miller WH, Samadani SR, Ford WB. Incidence and prevention of pulmonary embolism after coronary artery surgery. *Vasc Surg*. 1975 Jan-Feb;9(1):37–45. [PubMed: 1079102]
23. Robert-Ebadi H, Le Gal G, Carrier M, Couturaud F, Perrier A, Bounameaux H, et al. Differences in clinical presentation of pulmonary embolism in women and men. *J Thromb Haemost*. 2010 Apr; 8(4):693–8.10.1111/j.1538-7836.2010.03774.x [PubMed: 20096004]
24. Rosendaal FR, Helmerhorst FM, Vandenbroucke JP. Oral contraceptives, hormone replacement therapy and thrombosis. *Thromb Haemost*. 2001 Jul; 86(1):112–23. [PubMed: 11486996]

25. Saleem A, Markel DC. Fatal pulmonary embolus after shoulder arthroplasty. *J Arthroplasty*. 2001 Apr; 16(3):400–3. [PubMed: 11307142]
26. Shields E, Iannuzzi JC, Thorsness R, Noyes K, Voloshin I. Perioperative complications after hemiarthroplasty and total shoulder arthroplasty are equivalent. *J Shoulder Elbow Surg*. 2014 Oct; 23(10):1449–53.10.1016/j.jse.2014.01.052 [PubMed: 24751531]
27. Silverstein MD, Heit JA, Mohr DN, Petterson TM, O’Fallon WM, Melton LJ 3rd. Trends in the incidence of deep vein thrombosis and pulmonary embolism: a 25-year population-based study. *Arch Intern Med*. 1998 Mar 23; 158(6):585–93. [PubMed: 9521222]
28. 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 Dec; 70(12):2082–8.10.1136/ard.2010.148726 [PubMed: 22021865]
29. Singh JA, Sperling JW, Cofield RH. Cardiopulmonary complications after primary shoulder arthroplasty: a cohort study. *Semin Arthritis Rheum*. 2012 Apr; 41(5):689–97.10.1016/j.semarthrit.2011.09.003 [PubMed: 22055539]
30. Sperling JW, Cofield RH. Pulmonary embolism following shoulder arthroplasty. *J Bone Joint Surg Am*. 2002 Nov; 84-A(11):1939–41. No doi. [PubMed: 12429752]
31. Spolverato G, Ejaz A, Hyder O, Kim Y, Pawlik TM. Failure to rescue as a source of variation in hospital mortality after hepatic surgery. *Br J Surg*. 2014 Jun; 101(7):836–46.10.1002/bjs.9492 [PubMed: 24760705]
32. Stein PD, Matta F. Pulmonary embolism and deep venous thrombosis following bariatric surgery. *Obes Surg*. 2013 May; 23(5):663–8.10.1007/s11695-012-0854-2 [PubMed: 23404239]
33. Trofa D, Rajaei SS, Smith EL. Nationwide trends in total shoulder arthroplasty and hemiarthroplasty for osteoarthritis. *Am J Orthop (Belle Mead NJ)*. 2014 Apr; 43(4):166–72. No doi. [PubMed: 24730001]
34. White RH. The epidemiology of venous thromboembolism. *Circulation*. 2003 Jun 17; 107(23 Suppl 1):I4–8.10.1161/01.CIR.0000078468.11849.6 [PubMed: 12814979]
35. Willis AA, Warren RF, Craig EV, Adler RS, Cordasco FA, Lyman S, et al. Deep vein thrombosis after reconstructive shoulder arthroplasty: a prospective observational study. *J Shoulder Elbow Surg*. 2009 Jan-Feb; 18(1):100–6.10.1016/j.jse.2008.07.011 [PubMed: 19095183]
36. Zahir U, Sterling RS, Pellegrini VD, Forte ML. Inpatient pulmonary embolism after elective primary total hip and knee arthroplasty in the United States. *J Bone Joint Surg Am*. 2013 Nov 20.95(22):e175.10.2106/JBJS.L.00466 [PubMed: 24257675]

TABLE 1

Demographic and Provider-Related Characteristics in Patients With and Without PE

Parameter	All patients	No PE	PE	P
Weighted N (%)	422,372 (100)	421,314 (99.72)	1,058 (0.25)	
Average age (yr $\pm$ SD)	69 $\pm$ 11	69 $\pm$ 11	72 $\pm$ 11	<0.001
Age group, yr (%)				
<45	3.0	3.0	1.4	
45–64	29.0	29.0	22.3	
65–84	33.7	33.7	30.8	<0.001
>85	34.3	34.3	45.4	
Sex (%)				
Female	60.3	60.3	67.5	
Male	39.7	39.7	32.5	<0.001
Race				
White	91.9	91.9	90.5	
Black	3.1	3.1	3.6	
Hispanic	2.9	2.9	4.2	0.038
Other	2.2	2.2	1.7	
Household income (%)				
\$1–\$38,999	20.7	20.7	20.6	
\$39,000–\$47,999	27.1	27.1	26.5	
\$48,000–\$62,999	26.6	26.6	24.6	0.179
\$63,000	25.6	25.6	28.3	
Insurance status (%)				
Medicare	66.3	66.3	73.8	
Medicaid	2.6	2.6	3.8	
Private	26.4	26.4	17.7	<0.001
Other	4.7	4.7	4.7	
Primary diagnosis (%)				
Osteoarthritis	61.3	61.4	40.2	
Proximal humerus fracture	16.6	16.6	39.4	
Avascular necrosis	3.4	3.4	1.2	
Rheumatoid arthritis	1.4	1.4	1.3	<0.001
Non-union of humerus fracture	2.3	2.3	1.4	
Rotator cuff arthropathy	9.9	9.9	5.6	
Other	5.1	5.0	10.9	
Hospital size (%)				
Small	15.1	15.1	9.4	
Medium	23.7	23.7	27.8	<0.001
Large	61.2	61.2	62.8	
Hospital teaching status (%)				
Non-teaching	54.4	54.4	51.1	0.030

Parameter	All patients	No PE	PE	P
Teaching	45.6	45.6	48.9	
Hospital location (%)				
Urban	88.5	88.5	88.3	0.824
Rural	11.5	11.5	11.7	
Type of arthroplasty (%)				
Total	59.3	59.4	47.6	<0.001
Partial	40.7	40.6	52.4	
Length of stay (days $\pm$ SD)	2.7 $\pm$ 2.5	2.7 $\pm$ 2.5	9.5 $\pm$ 9.1	<0.001

TABLE 2

Comorbidities in Patients With and Without PE

Parameter (%)	All patients	No PE	PE	<i>P</i>
Congestive heart failure	4.0	4.0	12.5	<0.001
Ischemic heart disease	4.0	4.5	2.7	0.006
Chronic lung disease	16.6	16.6	24.5	<0.001
Hypertension	62.9	62.9	65.1	0.154
Uncomplicated diabetes mellitus	17.4	17.4	22.2	<0.001
Complicated diabetes mellitus	1.6	1.7	0.9	0.046
Liver disease	1.0	1.0	0.9	0.665
Obesity	10.3	10.3	12.5	0.018
Renal failure	3.3	3.3	5.1	0.002
Fluid and electrolyte disorders	6.9	6.8	19.5	<0.001
Coagulopathy	1.3	1.3	3.3	<0.001
Deficiency anemia	9.2	9.2	23.4	<0.001

TABLE 3

Complications in Patients With and Without PE

Parameter (%)	All patients	No PE	PE	P
Death	0.1	0.1	5.3	<0.001
Myocardial infarction	0.3	0.3	5.4	<0.001
Pneumonia	1.3	1.2	12.5	<0.001
Deep venous thrombosis	0.2	0.2	11.0	<0.001
Cerebrovascular event	0.1	0.1	0.5	0.001
Acute renal failure	1.2	1.2	6.4	<0.001
Gastrointestinal complication	0.3	0.3	2.6	<0.001
Mechanical ventilation	0.3	0.3	2.6	<0.001
Transfusion	8.9	8.8	24.9	<0.001
Non-routine discharge	36.1	36.0	72.4	<0.001

TABLE 4

Multivariable Logistic Regression Model of Predictors of Pulmonary Embolism after Shoulder Arthroplasty

Predictor	95% CI			P
	OR	Lower	Upper	
Age, per 10-year increase	1.1 0	1.04	1.17	0.001
Female sex (reference: male)	0.9 8	0.85	1.13	0.776
Race (reference: white)				
Black	1.1 3	0.80	1.60	0.503
Hispanic	0.9 1	0.64	1.28	0.576
Other	0.7 1	0.44	1.14	0.156
Insurance status (reference: private insurance)				
Medicare	1.1 1	0.92	1.33	0.284
Medicaid	1.3 7	0.93	2.00	0.108
Other	1.1 9	0.86	1.64	0.286
Days of care, per 1-day increase	1.1 2	1.11	1.13	<0.001
TSA (reference: HSA)	1.3 3	1.13	1.56	<0.001
Comorbidities (reference: absence of disease)				
Congestive heart failure	1.4 9	1.20	1.84	<0.001
Ischemic heart disease	0.4 5	0.30	0.68	<0.001
Chronic lung disease	1.4 0	1.21	1.62	<0.001
Hypertension	1.0 9	0.947	1.25	0.234
Uncomplicated diabetes mellitus	1.1 1	0.95	1.30	0.193
Complicated diabetes mellitus	0.3 3	0.17	0.65	0.001
Liver disease	0.3 5	0.17	0.72	0.004
Obesity	1.3 1	1.08	1.58	0.006
Renal failure	0.6 7	0.50	0.91	0.011
Fluid and electrolyte disorders	1.3 3	1.12	1.59	0.001
Coagulopathy	1.0 8	0.73	1.60	0.694
Deficiency anemia	1.8 4	1.57	2.15	<0.001
Primary diagnosis (reference: osteoarthritis)				

Predictor	OR	95% CI		P
		Lower	Upper	
Proximal humerus fracture	2.4 3	2.02	2.92	<0.001
Avascular necrosis	0.6 4	0.36	1.14	0.13
Rheumatoid arthritis	1.6 8	0.99	2.86	0.056
Non-union of humerus fracture	0.8 5	0.50	1.44	0.536
Rotator cuff arthropathy	0.7 8	0.59	1.02	0.072
Other	1.6 4	1.27	2.11	<0.001

OR, odds ratio; CI, confidence interval; statistical significance set at $p < 0.05$

Model fit: area under the ROC curve=0.84; Nagelkerke R-square= 0.11