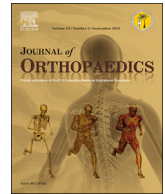




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A higher altitude is an independent risk factor for venous thromboembolisms following total shoulder arthroplasty

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ABSTRACT

Introduction: High altitudes lead to physiological changes that may predispose to venous thromboembolisms (VTE) including deep vein thrombosis (DVT) and pulmonary embolism (PE). No prior study has evaluated if there is also a higher risk of VTEs after total shoulder arthroplasties (TSAs) performed at higher elevations compared to lower elevations. The purpose of this study was to identify if undergoing TSA at a higher altitude center (> 4000 feet above sea level) is an independent risk factor for a postoperative VTE.

Methods: A retrospective review was performed from 2005 to 2014 using the Medicare Standard Analytical Files of the Pearl Diver database (Pearl Diver Technologies, West Conshohocken, PA, USA). The inclusion criteria for the study group consisted of all patients in the database undergoing primary TSAs at an altitude above 4000 feet. Patients were queried using the International Classification of Disease 9th revision codes (ICD-9). All patients undergoing primary TSA were queried using ICD-9 procedure code 81.80. Patients were filtered using the zip codes of the hospitals where the procedure occurred and were separated into high (> 4,000 ft) and low (< 100 ft) altitudes. Patients undergoing TSA in altitudes < 100 ft represented the control group. Patients with a history of VTE, DVT, PE, and coagulation disorders were excluded from the study. Patients in the study group were randomly matched 1:1 according to age, gender, and comorbidities. Two mutually exclusive cohorts were formed and rates of VTE, DVT, and PE were analyzed and compared. Statistical analysis was performed using the programming language R (University of Auckland, New Zealand). An alpha value less than 0.05 was considered statistically significant.

Results: In the first 30 postoperative days, patients undergoing TSA at a higher altitude experienced a significantly **higher** rate of PEs (odds ratio [OR], 39.5; $P = < 0.001$) when compared to similar patients at lower altitudes. This trend was also present for PE (OR, 2.02; $P < 0.03$) at 90 days postoperatively.

Conclusion: TSAs performed at higher altitudes (> 4000 feet) have a **higher** rate of acute postoperative PEs in the first 30 days and 90 days postoperatively when compared to matched patients receiving the same surgery at a lower altitude (< 100 feet). TSA patients at high altitude should be counseled on these increased risks.

1. Introduction

Venous thromboembolism (VTE) is a well recognized complication of Total Hip and Total Knee Arthroplasties (THA and TKA),¹ however considered to be a rare complication after Total Shoulder Arthroplasty (TSA). Deep Venous Thrombosis (DVT) rates can be as high as 40–60% and Pulmonary Embolism (PE) rates can be as high as 1–3% after THA and TKAs.² However, VTE rates after TSA have been shown to be between 0.2% and 16.0%.³ In contrast to THAs and TKAs which have established guidelines published by the AAOS and ACCP,^{4,5} TSAs lack

formally published guidelines or protocols for post-operative VTE prophylaxis. Thus, the routine use of chemical prophylaxis following TSA is rare.

Most orthopedic surgeons properly optimize high risk patients at increased risk for VTEs, which includes those with: obesity (BMI 30), tobacco use, hypertension, diabetes mellitus, and hyperlipidemia.⁶ One risk factor for post-operative VTEs that has been demonstrated in other orthopedic procedures is altitude, with the assumption that higher altitudes may increase risk for VTE. While this has been evaluated for post-operative orthopedic patients undergoing acute air travel, the

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impact of high altitude has not been investigated in TSA patients.⁷

Higher altitudes lead to physiologic changes that may predispose to VTE including DVT and pulmonary embolism (PE). Several studies have demonstrated an increase in factors contributing to Virchow's Triad (hypercoagulability, venous stasis, and vessel wall injury) at high altitudes.^{8–10} Prior studies have noted increased rates of VTE in patients undergoing arthroscopic knee and shoulder surgery at high altitude centers (> 4000 feet) compared to low altitude centers (< 100 feet).^{11–13} To date, no paper has evaluated if there is also a higher risk of VTEs for TSA procedures performed at higher elevations compared to lower elevations.

The purpose of this study is evaluate whether high altitude is a potentially modifiable risk factor following TSA by comparing the rates of deep vein thrombosis (DVT), pulmonary embolisms (PE) and VTEs in patients undergoing TSA at a high and low altitude centers. Our hypothesis is that patients undergoing TSA at higher altitudes will have higher incidence of VTEs than patients at lower altitudes.

2. Materials and methods

A retrospective study was done utilizing the national provider database Pearl Diver (Pearl Diver Technologies, Inc. Fort Wayne, Indiana), which is compliant with the Health Insurance Portability and Accountability Act. Pearl Diver is a publicly available database that holds the records of over 23 million patients. The International Classification of Disease, ninth edition (ICD-9) codes for total shoulder arthroplasty (TSA, 81.80) and reverse shoulder arthroplasty (RSA, 81.88) facilitated a selective query of the entire Medicare population was performed from 2005 to 2014.

Patients were stratified into two groups based on the altitude of the hospital. Those who had the procedure in areas with high altitude > 4000 feet were defined as the “high altitude group” and the control group which had the procedure at < 100 feet, were defined as the “low altitude group”. 5-digit zip codes provided through the Zip-Codes database (Datasheet LLC, Hopewell Junction, NY, USA) provided the geographic locations of the U.S. mainland with respect to altitude (Fig. 1). An assumption was made that zip code of procedure was the

same as zip code of recuperation for these patients. Our exclusion criteria included those patients with a prior history of deep venous thrombosis (DVT) and/or pulmonary embolism (PE), as well as patients with a prior history of a hypercoagulable state or with any unspecified coagulation defect (ICD-9 codes 298.81, 289.82, and 286.9).

Using Boolean operations, patients in the high altitude group were match controlled with patients in the low altitude group. Patients were matched based on comorbidities which are known to lead to thromboembolic events, including BMI > 30, tobacco use, hypertension, diabetes, and hyperlipidemia.⁶

The matching process is done 1:1 based on age, sex, and the five comorbidities known to be associated with increased risk of post-operative VTE as noted above. Rates of DVT and PE were assessed in both groups within 30-days and 90-days of the above stated procedures. Descriptive and statistical analysis was performed by the programming language R (University of Auckland, New Zealand).

Statistical analysis included calculating odds ratios (OR) and 95% Confidence Intervals (CI) using binary logistic regression. Analyses where one group contained an event rate of zero were performed using Fisher's Exact Test, and the odds ratio manually calculated using a 2 × 2 table. Risk ratios (RR) were calculated from odds ratios and event prevalence in the low-altitude group. Number needed to harm (NNH) was calculated from event incidence in both groups. Statistical significance was defined as $p < 0.05$.

3. Results

A total of 37,819 TSA patients met all inclusion criteria before breakdown by zip code. 7754 patients had their procedures performed at an altitude of greater than or equal to 4000 feet and formed the high-altitude study group. 30,065 patients had their procedures performed at an altitude of less than or equal to 100 feet and formed the low-altitude study group. Of these, 13,964 age- and gender-matched patients (Table 1) were identified for inclusion in this study.

For patients undergoing TSA, the overall VTE rate within 30 days was 0.27%; the overall DVT rate within 30 days was 0.0% and the overall PE rate within the same time frame was 0.27% (Table 2). Within

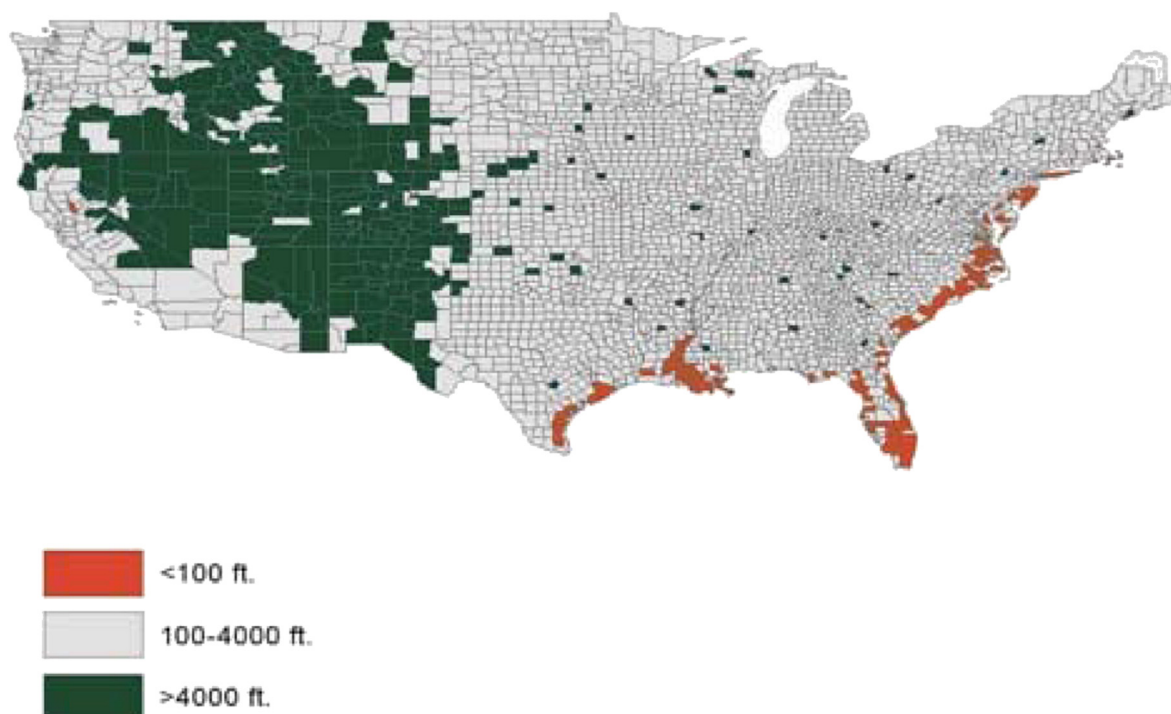


Fig. 1. Geographic United States with varying altitudes used in the study.

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