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## ORIGINAL ARTICLE

# High altitude is an independent risk factor for venous thromboembolism following arthroscopic rotator cuff repair: a matched case-control study in Medicare patients

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**Background:** Although the risk of venous thromboembolism (VTE) following elective shoulder arthroscopy is low, the large volume of procedures performed each year yields a significant annual burden of patients with thromboembolic complications. The purpose of this study was to evaluate the association of high procedural altitude with the incidence of postoperative VTE following arthroscopic rotator cuff repair.

**Methods:** A Medicare database was queried for all patients undergoing arthroscopic rotator cuff repair from 2005 to 2012. All patients with procedures performed at an altitude of 4000 feet or higher were grouped into the “high-altitude” study cohort. Patients with procedures performed at an altitude of 100 feet or lower were then matched to patients in the high-altitude cohort on the basis of age, gender, and medical comorbidities. The rate of VTE was then assessed for both the high-altitude and matched low-altitude cohorts within 90 days postoperatively.

**Results:** The rates of combined VTE (odds ratio [OR], 2.6;  $P < .0001$ ), pulmonary embolism (OR, 4.3;  $P < .0001$ ), and lower extremity deep venous thrombosis within 90 days (OR, 2.2;  $P = .029$ ) were all significantly higher in patients with procedures performed at high altitude compared with matched patients with the same procedures performed at low altitude.

**Conclusions:** Procedural altitude  $>4000$  feet is associated with significantly increased rates of postoperative VTE, including deep venous thrombosis and pulmonary embolism, compared with age-, gender-, and comorbidity-matched patients undergoing the same procedures at altitudes  $<100$  feet.

**Level of evidence:** Level III; Case Control Study; Treatment Study

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**Keywords:** Rotator cuff repair; VTE; high altitude; complications; DVT; PE

This study meets exempt criteria of the University of Virginia Institutional Review Board for Health Sciences Research.

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The epidemiology and prophylaxis of venous thromboembolism (VTE) following major orthopedic procedures, such as total joint arthroplasty and hip fracture surgery, have been extensively discussed within the modern orthopedic and hematology literature.<sup>1,11,13</sup> Significantly less literature and attention have been directed toward risk stratification and prevention of VTE following arthroscopic procedures such as

rotator cuff repair.<sup>20</sup> Furthermore, a recent study by Schick et al reported that including their study, only 71 cases of VTE following shoulder arthroscopy had been reported in the literature. Whereas the rate of VTE following arthroscopic rotator cuff repair is substantially lower than the rate after other major orthopedic procedures, the total burden of patients who incur VTE events following rotator cuff repair is not insignificant, given the large number of procedures performed annually, and it will likely rise alongside the increasing number of rotator cuff repairs being performed each year.<sup>8,10,24</sup>

In contrast to lower extremity total joint arthroplasty, no clear recommendations exist for chemoprophylaxis after shoulder arthroscopy, and thus it is critical to identify risk factors for the development of VTE after arthroscopic shoulder procedures to guide evidence-based prophylaxis strategies.<sup>13</sup> Although general risk factors for postoperative VTE have been well documented, the inherently low rate of VTE following shoulder arthroscopy has prevented the isolation of risk factors specific to shoulder arthroscopy.<sup>20</sup>

Procedural altitude has not been previously systematically evaluated as a risk factor for VTE following orthopedic surgery. The lower ambient oxygen concentration at higher altitudes can lead to hypoxia, which in turn causes increased platelet aggregation and activation of blood coagulation factors, resulting in a prothrombotic state.<sup>4,16</sup> Whereas the relationship between high altitude–related hypoxia and the development of VTE has been relatively well studied in air travelers and mountaineers, it has yet to be evaluated as a possible risk factor for VTE after orthopedic surgery.<sup>5,16</sup> Given the thousands of patients undergoing arthroscopic rotator cuff repairs at high altitudes yearly in the United States alone, it is of clinical significance to determine whether these patients are at increased risk of thromboembolic complications postoperatively.

The purpose of this study was to employ a national database of Medicare patients to evaluate the association of high procedural altitude with the incidence of postoperative VTE, including lower extremity deep venous thrombosis (DVT), upper extremity DVT, and pulmonary embolism (PE), following arthroscopic rotator cuff repair. Our hypothesis was that the incidence of postoperative VTE would be significantly higher in patients undergoing arthroscopic rotator cuff repair at altitudes >4000 feet compared with matched control patients undergoing the same arthroscopic shoulder procedures at altitudes below 100 feet.

## Materials and methods

The PearlDiver patient records database ([www.pearldiverinc.com](http://www.pearldiverinc.com), Fort Wayne, IN, USA), a for-fee insurance-based patient records database, was used for the study. The database consists of several separate private insurers and a Medicare database with procedural volumes and patient demographics for patients with *International Classification of Diseases, Ninth Revision* (ICD-9) diagnoses and procedures or *Current Procedural Terminology* (CPT) codes. The data obtained are anonymous, and thus the authors' Institutional Review Board deemed this study exempt. The data for this study

were derived from the Medicare database within PearlDiver, which contains >100 million individual patients records from 2005 to 2012. The Medicare data contained within the database are the complete 100% Medicare Standard Analytical File, indexed and reorganized to allow patient tracking over time among other advantages.

The goal study population was patients who underwent arthroscopic rotator cuff repair, with or without subacromial decompression or a biceps tenodesis. The database was first queried for all patients who fit this criterion using CPT code 29827 (arthroscopic rotator cuff repair). Patients with any concomitant open or arthroscopic shoulder procedures, other than subacromial decompression or biceps tenodesis, were then subsequently excluded from this cohort using CPT codes, including patients with rotator cuff repair performed as part of a shoulder arthroplasty procedure, open or mini-open rotator cuff repair, open or arthroscopic synovectomy, and open or arthroscopic extensive débridement. Patients who underwent a concomitant lysis of adhesions or manipulation under anesthesia were also excluded.

Additional exclusion criteria included patients with a personal history of VTE, including a diagnosis or history of DVT or PE before the date of their arthroscopic rotator cuff repair. Patients with a diagnosis of a primary or secondary hypercoagulable state (ICD-9 289.81 and 289.82, respectively) were excluded, as were patients with any unspecified coagulation defect (ICD-9 286.9). Patients who underwent subsequent contralateral arthroscopic rotator cuff repair were counted only once for whichever surgery occurred first. Patients who underwent subsequent ipsilateral arthroscopic rotator cuff repair (revision repair) were also counted only once, for only the index procedure.

After the application of these inclusion and exclusion criteria, the resulting arthroscopic rotator cuff repair cohort was then broken down by the hospital or surgery center ZIP code in which the procedure was performed. Only patients in hospitals or surgery centers that performed at least 50 arthroscopic rotator cuff repairs during the 8-year study period were included. The altitude of the hospital or surgery center within each ZIP code was then queried using the Google Maps altitude search function. All patients with procedures performed at an altitude of 4000 feet or higher were grouped into the “high-altitude” study cohort. This altitude was chosen on the basis of 1 prior study in the literature describing an increased risk of perioperative VTE in patients undergoing simple knee arthroscopy at altitudes above 4000 feet.<sup>25</sup> Patients with procedures performed at an altitude of 100 feet or lower were then grouped into a temporary “low-altitude” cohort for subsequent matching.

Patients in the low-altitude cohort were then matched to patients in the high-altitude cohort on the basis of 5-year age group (<65, 65-69, 70-74, 75-79, 80-84, >85 years), gender, and 5 comorbidities known to be associated with increased risk for postoperative VTE: obesity (body mass index >30 kg/m<sup>2</sup>), tobacco use, hypertension, diabetes mellitus, and hyperlipidemia.<sup>12</sup>

The overall total VTE rate (number of patients with either DVT or PE) as well as the individual lower extremity DVT, upper extremity DVT, and PE rates were assessed for both the high-altitude cohort and matched low-altitude cohort within 90 days postoperatively. The high-altitude cohort and matched low-altitude cohort were then compared on all assessed variables as well as chronic lung disease and the average Charlson Comorbidity Index (CCI) to ensure adequate matching. The rates of the 2 allowed concomitant procedures, subacromial decompression and biceps tenodesis, were also assessed and compared. Statistical comparisons of the cohort demographics and postoperative VTE rates were completed using Pearson  $\chi^2$  analysis. Odds ratios (ORs) were calculated with respective

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