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RESEARCH ARTICLE

# Hematoma Following Shoulder Arthroplasty: Incidence, Management, and Outcomes

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## Abstract

**Background:** A paucity of data regarding the implications of postoperative hematoma formation on outcomes after shoulder arthroplasty exists. Previous studies on major joint arthroplasty have associated postoperative hematoma formation with high rates of prosthetic joint infection (PJI) and reoperation.

**Methods:** A total of 6,421 shoulder arthroplasty cases were retrospectively reviewed from an institutional database (5,941 primary cases, 480 revision) between December 2008 and July 2017. Patients who developed a postoperative hematoma were identified through direct chart review. Cases with a history of shoulder infection treated with explant and antibiotic spacer placement were excluded. Demographics, surgical characteristics, treatment course, and outcomes were collected.

**Results:** Hematoma occurred in 105 (1.6%; 105/6421) cases within the first three postoperative weeks and was more common following revision (3.3%; 16/480) compared to primary cases (1.5 %; 89/5941; *P=0.002*). Overall, postoperative shoulder hematoma was successfully managed with nonoperative treatment in 87% of cases via observation (62%, 62/105) and aspiration (25%, 26/105). A total of 14 patients (0.22%, 14/6421) underwent reoperation for hematoma. Eight patients (7.6%, 8/105) that required reoperation for hematoma were diagnosed with PJI.

**Conclusion:** Postoperative hematoma is a complication of shoulder arthroplasty. While many postoperative hematomas can be managed without operative intervention, this analysis reiterates the association between hematoma formation and the development of PJI.

**Level of evidence:** IV

**Keywords:** Aspiration, Complications, Hematoma, Infection, Prosthetic Joint, Reverse total shoulder arthroplasty, Shoulder arthroplasty

## Introduction

Hematoma following shoulder arthroplasty is a well-recognized complication; however, limited data exist on the true incidence and clinical outcomes. Most studies have reported only postoperative shoulder hematomas that required reoperation with a reported incidence of 0.2-0.51%.[1-5] However, Werner et al found hematoma to be the most common complication (21%) following reverse shoulder arthroplasty (RSA). In addition, when they included both surgical and nonsurgical management of hematomas, aspiration was the definitive management of the hematoma in 42% of cases.[6]

Prosthetic joint infection (PJI) is a dreaded complication following shoulder arthroplasty (SA) with an overall prevalence reported at 1.2%.[1] The literature has shown hematoma formation following total elbow, knee, and hip arthroplasty to be a substantial risk factor for reoperation and PJI.[7-11] Cheng et al reported on 12 shoulder arthroplasties that underwent irrigation and debridement for hematoma formation and found 50%

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to have positive intraoperative cultures. [3] In a second report, they found three out of five patients that required reoperation for postoperative hematoma following shoulder arthroplasty to be infected. [5]

The rate of hematoma formation after shoulder arthroplasty and the impact on clinical results after shoulder arthroplasty remain uncertain. Theoretically, perioperative shoulder hematomas can create a ripe environment for infection due to persistent wound drainage, increased dead space, and media viable for rampant growth. Due to the acute soft-tissue distension, there is concern that hematomas can lead to early dislocation of reverse arthroplasty. As a collection of blood solidifies and reabsorbs, there is also a concern for the development of soft-tissue contracture and postoperative stiffness. The purpose of this study is to identify the incidence of postoperative shoulder hematoma after shoulder arthroscopy, identify risk factors for hematoma formation, and evaluate clinical outcomes associated with management.

## Materials and Methods

### *Patient Selection*

Following approval from the local institutional review board, an institutional database was utilized to identify all shoulder arthroplasty (primary or revision) cases from December 2008 to July 2017. The database was constructed using 23472, 23473, and 23474 common procedural codes (CPT) for total shoulder arthroplasty (TSA), revision of TSA, humeral or glenoid component, , and revision of TSA, humeral and glenoid component, respectively. A total of 5,941 (4,360 patients) primary shoulder arthroplasty cases and 480 (207 patients) revision shoulder arthroplasty cases were reviewed. There were 2,368 females (51.9%, 2368/4567) and the average age was 67.0 years old (age range: 18-95 years). Inclusion criteria for this analysis included patients undergoing primary or revision shoulder arthroplasty, anatomic total shoulder arthroplasty (aTSA), RSA, and hemiarthroplasty (HA), who developed postoperative shoulder hematoma within three weeks of surgery. The indications for RSA included cuff tear arthropathy (CTA) (35), post-traumatic arthritis (6), acute proximal humerus fracture (PHF) (5), primary osteoarthritis (OA) (2), and inflammatory arthritis (2). The indications for TSA included primary OA (26), post-traumatic arthritis (PTA) (4), and inflammatory arthritis (1). The indications for HA included primary OA (4), CTA (2), and inflammatory arthritis (1). The indications for revision arthroplasty were diverse and multifactorial. Patients who underwent component explantation and antibiotic spacer placement were excluded.

### *Definition of Postoperative Shoulder Hematoma*

Using an institutional search tool, we queried all postoperative clinic notes following 6,421 shoulder arthroplasty procedures for the word "hematoma". This query identified 686 clinical notes with the word "hematoma" documented following the index shoulder arthroplasty. From manual chart review, these notes were reviewed to identify if these were true postoperative shoulder hematomas within three weeks of shoulder arthroplasty for unique patients (excluding duplicates, and when "hematoma" was used to describe a risk associated with surgery or not related to shoulder arthroplasty [i.e., subungual hematoma]).

We defined postoperative shoulder hematoma if the attending surgeon using the word "hematoma" to describe the appearance of a surgical wound or shoulder on a physical exam in the postoperative clinic note within three weeks of the surgical procedure.

### *Data Collection*

Charts were reviewed for details from the index operation including demographics, history of a bleeding disorder, use of anticoagulant medication, indication for surgery, surgeon, use of drain, and length of clinic follow-up. Anticoagulation medication was defined as any preoperative anticoagulation or antiplatelet medication, including aspirin. Management of hematoma including observation, aspiration, cultures, unexpected return to the operating room, and resolution was retrospectively identified from chart review and collected.

### *Surgical Technique*

All arthroplasties were performed by one of eight shoulder fellowship-trained orthopedic surgeons. The deltopectoral approach in the beach chair position was utilized in all cases. Management of the cephalic vein was not recorded or standardized and mobilization medial or lateral was dictated by surgeon preference and patient anatomy. The use of drains was not standardized and was based on surgeon preference and the presence of persistent serosanguinous pooling prior to closure. All drains were placed deep into the deltopectoral interval. All drains were discontinued prior to discharge, typically on the first postoperative day. Routine venous thromboembolism prophylaxis consisted of early mobilization, in-hospital mechanical compression, and aspirin prophylaxis. Restarting preoperative anticoagulation was at the discretion of the attending. Tranexamic acid (TXA) was not used during the study period.

### *Hematoma Management and Outcomes*

Management of postoperative shoulder hematoma was determined and correlated with clinical outcomes. Clinical outcomes included an unexpected return to the operating room, development of PJI, and clinical range of motion (active forward elevation and active external rotation at 6-month postoperative visits). Over the study period, postoperative shoulder hematoma or associated deep infection was managed with observation, in-office aspiration, surgical irrigation, and debridement with or without polyethylene exchange, or resection arthroplasty and placement of an antibiotic spacer. Management was dictated by the treating surgeon and based upon wound appearance, signs of infection (persistent wound drainage and/or erythema), shoulder dislocation associated with hematoma, or imminent wound breakdown. In-office aspiration was performed with an 18-gauge needle

targeting subcutaneous hematomas with near-complete evacuation and decompression of the soft tissues. Aspirated fluid was discarded or sent for culture based on surgeon preference and index of suspicion for infection. All patients with a postoperative hematoma were followed for reoperation and complications over a minimum of 1 year.

### *Definition of Shoulder PJI*

In this study, we defined shoulder PJI based on the 2018 International Consensus Meeting on Musculoskeletal Infection (ICM) diagnostic criteria for the shoulder PJI. [12] With the nature of hematoma development in the acute postoperative period, no patients in this study had obtained erythrocyte sedimentation rate , C-reactive protein , synovial white blood cell sampling, or frozen sections in the infectious work-up.

### *Hematoma vs Non-Hematoma Matched Patient Comparisons*

For comparison of outcomes, patients who developed a hematoma postoperatively were matched one to one with patients who did not develop a hematoma by age (within five years), gender, body mass index (BMI) (within five kg/m$^2$), primary vs revision shoulder arthroscopy status, procedure (aTSA, RSA, HA), and indication for surgery. The match rate for surgical indication was 91% (96/105). These groups were then compared for clinical outcomes: return to the operating room, infection, and range of motion. Hematoma and control patients were followed over a minimum of 1 year for reoperation and complications. The average time of the last clinical follow-up for hematoma and control cohorts was 25.3 and 20.2 months, respectively.

### *Data Analysis*

To evaluate the hematoma cohort, descriptive statistics were used to determine the patient demographics and surgical characteristics. When comparing patients with a specific event (e.g., hematoma or PJI) to control patients, Chi-squared analyses were utilized for categorical variables. To compare continuous variables, the data were assessed for normality with skewness and kurtosis utilizing thresholds of 2 and 12, respectively. For parametric distributions, a paired Student's t-test was utilized. To evaluate non-parametric distributions, a Wilcoxon signed-rank test was utilized, and medians were reported for each group.

## Results

### *Incidence of Hematoma Following Shoulder Arthroplasty*

Postoperative shoulder hematoma occurred in 105 (1.6%; 105/6421) shoulder arthroplasties within the first three postoperative weeks [Table 1]. Hematoma formation was more common following revision shoulder arthroplasty (3.3%; 16/480) compared to primary shoulder arthroplasty (1.5%; 89/5941; *P=0.002*) and in males (2.1%) compared to females (1.2%; *P=0.003*).

### *Nonsurgical Management of Postoperative Shoulder Hematoma*

Observation was sufficient management, with complete resolution, for 65 patients (61.9%; 65/105; [Table 2]). Approximately one-third (34.3%; 36/105) of the patients with postoperative hematoma underwent aspiration in the clinic at an average of 15.1 days (range: 6-48 days) following surgery. Aspiration volume ranged from negligible to 500 milliliters. Five patients (13.9%, 5/36) underwent repeat aspiration for recurrent hematoma an average of 9.2 days following their initial aspiration. Ten patients (27.8%, 10/36) who underwent aspiration ultimately went to the operating room for definitive hematoma management. In total, aspiration was a successful definitive treatment in 26 (72.2%; 26/36) cases with complete resolution of the hematoma.

**Table 1. The 2018 International Consensus Meeting on Musculoskeletal Infection definition of shoulder PJI**

**DEFINITE PJI**

Meeting one of the following criteria is diagnostic of periprosthetic shoulder infection:
- A sinus tract communicating with the prosthesis is present.
- Gross intra-articular pus
- Two positive cultures with phenotypically-identical virulent organisms

**EVALUATION SCORING**

Weighted values for all positive tests performed as part of the diagnostic evaluation of a failed shoulder arthroplasty are summed below in Minor Criteria.
- 6 or greater with identified organism = probable PJI
- 6 or greater without identified organism = possible PJI
- 6 or less
- single positive culture virulent organism = possible PJI
- two positive cultures non-virulent organism = possible PJI
- negative cultures or only single positive culture for low virulent organism = PJI unlikely

| **Minor Criteria** | **Weight** |
|---|---|
| Unexpected wound drainage | 4 |
| Single positive tissue culture (virulent organism) | 3 |
| Single positive tissue culture (non-virulent organism) | 1 |
| Second positive tissue culture (identical non-virulent organism) | 3 |
| Humeral loosening | 3 |
| Positive frozen section (5 PMN in at least 5 high-power fields) | 3 |
| Positive pre-operative aspirate culture (low or high-virulent) | 3 |
| Elevated synovial neutrophil percentage (>80%)* | 2 |
| Elevated Synovial WBC (>3,000 cells / μL)* | 2 |
| Elevated ESR (>30 mm/hr)* | 2 |
| Elevated CRP (>10 mg/L)* | 2 |
| Elevated synovial alpha-defensin | 2 |
| Cloudy fluid | 2 |

*beyond six weeks from recent surgery
*PMN, polymorphonuclear neutrophils

**Table 2. Comparison of demographics and surgical type in patients with and without post-operative hematomas following shoulder arthroplasty**

| | Postoperative Hematoma | No Hematoma | *P-value* |
|---|---|---|---|
| Number (%) | 105 (1.6%) | 6,316 (98.4%) | N/A |
| Age (years)* | 68.8 ± 10.4 | 66.8 ± 10.9 | 0.66 |
| Gender (No, %) | | | |
| Male | 66 (2.1%) | 3037 (97.9%) | 0.003 |
| Female | 39 (1.2%) | 3279 (98.8%) | |
| Surgical Type (No, %) | | | |
| Primary | 89 (1.5%) | 5852 (98.5%) | 0.002 |
| Revision | 16 (3.3%) | 464 (96.7%) | |

*mean and standard deviation reported

### *Surgical Management of Postoperative Shoulder Hematoma*

A total of 14 patients (13.3%; 14/105) underwent reoperation at an average of 26.6 (range: 1-66) days due to hematoma. Patients who underwent reoperation for hematoma management had a higher BMI (32.2 vs 28.0 kg/m2; P=0.005; [Table 3]) and were more likely to have associated wound drainage (50% vs 6.6%; *P=0.0002*; [Table 3]).

Three patients (21.4%, 3/14), all with RSA, had concurrent glenohumeral prosthesis dislocation with a postoperative hematoma that required operative reduction. Two of these underwent open reduction while the third underwent a close reduction and had 300 mL of hematoma aspirated without sequelae. For the remainder of the cases, the hematoma was the sole indication for reoperation.

In total, twelve patients underwent irrigation and debridement with or without polyethylene exchange (I&D) at an average of 24.7 (range: 1-66) days. This was the definitive treatment in nine patients (75%; 9/12). Two patients (14.3%, 2/14) were definitively treated with repeat I&D at 16 and 27 days from the initial hematoma evacuation. Two patients, one having undergone prior I&D, (14.3%, 2/14) underwent resection arthroplasty and antibiotic spacer placement to treat an infected hematoma at 10 and 63 days from the index operation.

Two patients with perioperative hematomas returned to the operating room after hematoma resolution. One patient with an RSA had a traumatic fracture-dislocation that underwent open reduction and excision of displaced greater tuberosity fragment, and the other underwent revision of RSA humeral liner and glenospheres for a painful prosthesis.

### *Shoulder PJI Associated with Postoperative Hematoma*

During reoperation, eleven of the fourteen patients (78.6%, 11/14) had cultures taken at the time of reoperation, of which three also had preoperative office aspirations sent for culture. An additional 3 patients had office aspiration sent for culture and never required reoperation. In total, 14 patients with postoperative shoulder hematoma had cultures obtained in the postoperative period to evaluate for infection. Their culture results were no growth (5), coagulase-negative staphylococcus species (1), Enterococcus faecalis (2), Clostridium perfringens (1), methicillin-resistant Staphylococcus aureus (1), Cutibacterium acnes (2), Escherichia coli (1) and Serratia merascens (1).

Eight patients with postoperative shoulder hematoma met diagnostic criteria for PJI (7 definite PJI, 1 probable PJI) based on the ICM definition of shoulder PJI [Table 5]. Six of the eight patients were diagnosed with PJI at the time of hematoma management, the other two were diagnosed at 1.5 and 3.7 years after resolution of hematoma (these hematomas resolved with I&D in one case and closed reduction with aspiration in the other). Of these eight cases of PJI, initial surgical management consisted of six patients undergoing I&D, one resection arthroplasty, and one closed reduction with shoulder aspiration. Definitive management of PJI in these eight cases consisted of half resolving with I&D alone and the other half required resection arthroplasty with antibiotic spacer placement–only a single resected patient went on to

**Table 3. Postoperative shoulder hematoma definitive management segregated by primary or revision shoulder arthroplasty**

| | All (n=105) | Primary SA (n=89) | Revision SA (n=16) | *P-value* |
|---|---|---|---|---|
| **Observation** | 65 (61.9%) | 54 (60.7%) | 11 (68.8%) | |
| **Aspiration** | 26 (24.8%) | 23 (25.8%) | 3 (18.8%) | 0.80 |
| **Return to OR** | 14 (13.3%) | 12 (13.5%) | 2 (12.5%) | |
| **I&D w/wo poly exchange*** | 11 (10.5%) | 11 (12.4%) | 0 | |
| **Explant/spacer^** | 2 (3.8%) | 1 (1.1%) | 1 (6.3%) | N/A |
| **Aspiration / closed reduction** | 1 (0.95%) | 0 | 1 (6.3%) | |

OR=operating room
*Irrigation and debridement with or without polyethylene exchange
^Explantation and placement of antibiotic spacer

**Table 4. Comparison of patients with postoperative hematomas that required reoperation vs those managed with observation or aspiration alone**

| | Reoperation for Hematoma (n=14) | Nonsurgical Management of Hematoma (n=91) | *P-value* |
|---|---|---|---|
| **Age (years)*** | **64.9 ± 10.5** | **69.4 ± 10.5** | **0.13** |
| **Gender (%)** | | | |
| Male | 11 (78.6%) | 55 (61.9%) | 0.24 |
| Female | 3 (21.4%) | 36 (40.0%) | |
| **BMI (kg/m²)*** | **32.2 ± 5.4** | **28.0 ± 5.4** | **0.005** |
| **Surgical Type (%)** | | | |
| Primary | 12 (85.7%) | 77 (84.6%) | 1.0 |
| Revision | 2 (14.3%) | 14 (15.4%) | |
| Drain Use | 7 (50.0%) | 68 (74.7%) | 0.10 |
| Wound Drainage | 7 (50.0%) | 6 (6.6%) | 0.0002 |

*mean and standard deviation reported
BMI=body mass index; RA=rheumatoid arthritis

re-implantation. Patients who developed PJI in the setting of a hematoma had a higher BMI (32.5 versus 28.1 kg/m²; *P=0.03*; [Table 4]).

### *Hematoma Formation vs Matched Controls*

Compared to matched controls, patients who developed postoperative hematoma were more likely to have been on preoperative anticoagulation (39.1% versus 25.1%; *P=0.04*; [Table 6]. Drain use was not protective of hematoma formation (71.4% versus 81.0%; *P=0.10*) Hematoma formation was associated with a higher rate of subsequent PJI (7.6% versus 0.9%; *P=0.02*) and

**Table 5. Comparison of patients with aseptic hematoma and PJI-associated hematoma**

| | PJI diagnosis in patients with hematoma | Aseptic Hematoma | *P-value* |
|---|---|---|---|
| **Number (%)** | 8 (7.6%) | 97 (92.4%) | N/A |
| **Age (years)*** | 68.4 ± 10.9 | 69.1 ± 10.4 | 0.31 |
| **Gender (%)** | | | |
| Male | 6 (75.0%) | 60 (61.9%) | 0.71 |
| Female | 2 (25.0%) | 37 (38.1%) | |
| BMI (kg/m²)* | 32.5 ± 5.6 | 28.1 ± 5.4 | 0.03 |
| Surgical Type (%) | | | |
| Primary | 6 (6.7%) | 83 (93.3%) | 0.42 |
| Revision | 2 (12.5%) | 14 (87.5%) | |
| Surgical Indication (%) | | | |
| Rotator cuff arthropathy | 3 (8.1%) | 34 (91.9%) | 0.98 |
| Osteoarthritis | 2 (6.3%) | 30 (93.8%) | |
| Post-traumatic arthritis | 1 (10.0%) | 9 (90.0%) | |
| Instability | 2 (50.0%) | 2 (50.0%) | |
| Acute Fracture | 0 (0%) | 6 (100%) | |
| Miscellaneous | 0 (0%) | 12 (100%) | |
| RA | 0 (0%) | 4 (100%) | |
| Wound Drainage | 3 (37.5%) | 10 (10.3%) | 0.05 |

*mean and standard deviation reported
BMI=body mass index; RA=rheumatoid arthritis

**Table 6. Hematoma cases vs matched controls demographics, drain use, preoperative anticoagulation, and bleeding disorders**

| | Hematoma (n=105) | Matched Controls (n=105) | *P-value* |
|---|---|---|---|
| **Age (years)*** | 68.8 ± 10.4 | 68.5 ± 10.8 | 0.67 |
| **Gender** | | | |
| Male | 66 (62.9%) | 66 (62.9%) | 1.0 |
| Female | 39 (37.1%) | 39 (37.1%) | |
| BMI (kg/m$^2$)* | 28.6 ± 5.4 | 28.5 ± 5.5 | 0.81 |
| **Procedure (No, %)** | | | |
| Primary SA | 89 (84.8%) | 89 (84.8%) | |
| aTSA | 31 (34.8%) | 31 (34.8%) | |
| RSA | 50 (56.2%) | 50 (56.2%) | |
| HA | 8 (9.0%) | 8 (9.0%) | N/A |
| Revision SA^ | 16 (15.2%) | 16 (15.2%) | |
| aTSA | 3 (18.8%) | 3 (18.8%) | |
| RSA | 10 (62.5%) | 12 (75%) | |
| HA | 3 (18.8%) | 1 (6.3%) | |
| **Surgical Indication (No, %)** | | | |
| Primary SA | | | |
| Rotator cuff arthropathy | 37 (41.6%) | 36 (40.4%) | |
| Osteoarthritis | 32 (36.0%) | 31 (34.8%) | |
| Post-traumatic arthritis | 10 (11.2%) | 12 (13.5%) | |
| Acute Fracture | 6 (6.7%) | 6 (6.7%) | |
| Rheumatoid arthritis | 4 (4.5%) | 4 (4.5%) | |
| Revision SA | | | |
| Glenoid loosening | 5 (31.3%) | 3 (18.8%) | N/A |
| Instability | 4 (25%) | 0 (0%) | |
| Glenoid arthrosis | 3 (18.8%) | 10 (62.5%) | |
| Humeral loosening | 1 (6.3%) | 0 (0%) | |
| Periprosthetic fracture | 1 (6.3%) | 0 (0%) | |
| Stiffness | 1 (6.3%) | 0 (0%) | |
| Subscapularis failure | 1 (6.3%) | 0 (0%) | |
| Miscellaneous | 0 (0%) | 3 (18.8%) | |
| **Drain Use (No, %)** | 75 (71.4%) | 85 (81.0%) | 0.10 |
| **Preoperative Anticoagulation (No, %)** | 41 (39.1%) | 27 (25.7%) | 0.04 |
| **Bleeding Disorder (No, %)** | 1 (0.95%) | 0 (0%) | N/A |

SA=shoulder arthroplasty, aTSA=anatomic total shoulder arthroplasty; RSA=reverse shoulder arthroplasty; HA=hemiarthroplasty; BMI=body mass index
*mean and standard deviation reported
^Conversion arthroplasty to aTSA, RSA, HA

**Table 7. Hematoma cases vs matched controls rate of reoperation, PJI, and range-of-motion.**

| | Hematoma (n=105) | Matched Controls (n=105) | *P-value* |
|---|---|---|---|
| **Return to OR (No. Patients, %)** | 16 (15.2%) | 6 (5.7%) | 0.02 |
| **Hematoma related** | 14 (87.5%) | 0 | |
| **Hematoma and Dislocation** | 3 (18.8%) | 0 | |
| **Non-hematoma etiology** | 2 (12.5%) | 6 (100%) | |
| **Painful prosthesis** | 1 (6.3%) | 0 | |
| **GH dislocation** | 1 (6.3%) | 1 (16.7%) | N/A |
| **Rotator cuff tear** | 0 | 1 (16.7%) | |
| **Stiffness** | 0 | 1 (16.7%) | |
| **Subscapularis failure** | 0 | 1 (16.7%) | |
| **Glenoid arthrosis** | 0 | 1 (16.7%) | |
| **Infection** | 0 | 1 (16.7%) | |
| **PJI** | | | |
| Definite/Probable PJI | 8 (7.6%) | 1 (0.9%) | 0.02 |
| **Range-of-Motion at 6-month Follow-up** | | | |
| Active forward elevation | 133.5 ± 31.3 | 126.6 ± 36.3 | 0.23 |
| Active external rotation | 36.8 ± 14.1 | 32.1 ± 14.0 | 0.56 |

OR=operating room; GH=glenohumeral; PJI = periprosthetic joint infection

unexpected return to the operating room (15.2% versus 5.7%; *P=0.03*) compared to controls [Table 7]. Patients with postoperative hematomas had no deficit in active forward elevation (133.5 versus 126.6 degrees; *P=0.23*) or active external rotation (36.8 versus 32.1 degrees; *P=0.56*) compared to their matched controls at six-month follow-up.

## Discussion

A paucity of data regarding the implications of postoperative hematoma formation on outcomes after shoulder arthroplasty exists. Prior studies have associated hematoma formation with surgical site infection; however, they were limited to patients requiring a return to the operating room. [3,5] This study investigated the incidence of postoperative hematoma, risk factors for its development, and clinical outcomes associated with its management.

In our single-institution analysis of 6,421 shoulder arthroplasties, we report a 1.6% overall incidence of postoperative shoulder hematoma, where hematoma formation was more common after revision (3.3%) as compared to primary shoulder arthroplasty (1.5%). Bohsali et al retrospectively reviewed all studies evaluating complications following shoulder arthroplasty from 2006 to 2015 and reported hematoma incidence of 0.2% (30/19,262 shoulders), with greater occurrence in RSA (0.51%) - than aTSA (0.09%). [1] This is lower than our reported incidence and likely related to their definition of a complication as an event that resulted in adverse outcomes for the patient (i.e. reoperation). [1] Other studies have reported higher rates of hematoma formation after RSA (1-21%) and attributed this to the increased dead space created after RSA implantation compared to TSA. [2,4,6,12] The higher incidence of hematoma reported in the current study is likely a result of our definition of hematoma to include any hematoma noted on physical exam in the postoperative period regardless of treatment (observation, aspiration, reoperation).

Overall, postoperative shoulder hematoma was successfully managed with nonoperative management in 87% of cases via observation (62%, 62/105) and aspiration (25%, 26/105). Fourteen patients required reoperation for hematoma management, leading to a 0.22% (14/6421) rate of return to the operating room. Three patients had concurrent RSA prosthesis dislocations with hematoma formation that required reoperation. Hematoma formation may contribute to increased instability in the acute postoperative period. Cheung et al reported a very similar rate of shoulder arthroplasties that underwent reoperation for hematoma formation (0.29%).[3]

In our study, six (5.7%, 6/105) of the 105 patients with postoperative shoulder hematoma were diagnosed with PJI at the time of hematoma management, and an additional two patients (7.6%, 8/105) were diagnosed with PJI greater than one year from the time of hematoma resolution. Including the two late-diagnosed PJI, the rate of PJI in patients that required reoperation for

hematoma was 57.1%, and four eventually underwent resections arthroplasty, and antibiotic spacer placement. Hematoma formation after aseptic primary and revision shoulder arthroscopy was associated with a 7.6% rate of diagnosed and treated PJI, compared to 0.9% in matched controls. Cheung et al. reported on 12 patients with hematoma formation requiring operative treatment following shoulder arthroplasty (8 HA, 4 TSA), of which nine had intraoperative cultures obtained and six (50%, 6/12) were culture positive. [3] Two (17%) of their patients went on to resection arthroplasty for deep infection. [3] The strong association between postoperative hematoma requiring operative management and PJI has also been reported following total elbow, hip, and knee arthroplasty. [7-11] Previous studies have reported a 0.98-1.2% prevalence of PJI after shoulder arthroplasty, with RSA (2.9%) being more frequently affected than TSA (0.51%). [1,13] In our study, patients with postoperative shoulder hematoma and wound drainage were more likely to undergo reoperation (50%) compared to nonsurgical (6.6%) hematoma management. However, the association of wound drainage in hematomas that developed PJI (38%) versus non-infected hematomas (10%) did not reach significance (*P=0.053*) and our data may have been underpowered to detect a difference. Our results indicate that most postoperative hematomas do not develop infection but reiterates the strong association with infection in those that require reoperation. Therefore, we recommend intraoperative cultures should be obtained for all patients requiring reoperation for hematoma management. As with all cultures from revision shoulder arthroplasty, the decision to treat a particular organism should also consider the possibility of false contamination and overall clinical suspicion of infection. [15]

PJI following shoulder arthroplasty leads to substantial morbidity due to reoperations and lengthy periods of intravenous antibiotics. In addition, multiple papers have established the association between PJI and early demise. [14,15] Therefore, given the connection between hematoma and PJI, every effort should be made to prevent the development of a hematoma. Hematoma is more likely in revision shoulder arthroplasty, likely related to increased exposure and operative time, and the degree of bony debridement required to explant components and prepare for re-implantation. Possible strategies to decrease hematoma formation include the use of perioperative TXA, limiting potent pharmacologic anticoagulation, meticulous hemostasis, and limiting excessive soft-tissue dissection. Pauzenberger et al reported outcomes of a randomized, placebo-controlled study of 54 patients undergoing shoulder arthroplasty comparing TXA to placebo and found the TXA group to have statistically less occurrence of postoperative hematoma (25.9%) compared to placebo (59.3%). [16-19] Routine drain use persists in upper extremity arthroplasty, with little evidence regarding its efficacy, as compared to lower extremity arthroplasty, where it has been abandoned due to reports showing increased rates of blood transfusion without any meaningful benefit. 20 In this analysis, drain use did not prevent the development of a perioperative hematoma. Although hematoma formation was associated with an increased rate of reoperation and PJI, compared to matched controls, patients had equivalent active forward elevation and external rotation at a six-month follow-up visit.

The results of this study must be viewed in light of its limitations. This was a retrospective review with all the limitations inherent in that study design. If a surgeon identified and treated a postoperative shoulder hematoma but did not document "hematoma" in the patients' postoperative clinic note (i.e., fluid collection or swelling), then it would have been missed from this analysis. The shoulder arthroplasty database is based on CPT codes, which are unable to distinguish between TSA and RSA. This made it unfeasible to calculate the incidence of hematoma for TSA and RSA independently. Due to the retrospective nature of the study, we were unable to collect data on patient satisfaction and functional scores between patients with and without postoperative hematomas. Finally, the incidence of associated PJI was small and complicates in detecting predictors of this specific complication.

While many postoperative hematomas can be managed without operative intervention, this analysis reiterates the strong association between surgical treatment of hematomas and the development of PJI. In patients effectively treated, hematoma development does not appear to have a long-term impact on the range of motion. Strategies to prevent postoperative hematoma formation may have value in shoulder arthroplasty.

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