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Risk Factors for Stiffness Requiring Intervention After Ream-and-Run Arthroplasty

Corey J. Schiffman, MD, Kevin Jurgensmeier, MD, Jie J. Yao, MD, John C. Wu, MD, Anastasia J. Whitson, BSPH, Sarah E. Jackins, PT, Frederick A. Matsen III, MD, and Jason E. Hsu, MD

Investigation performed at the Department of Orthopaedics and Sports Medicine, University of Washington, Seattle, Washington

Background: Ream-and-run arthroplasty can improve pain and function in patients with glenohumeral arthritis while avoiding the complications and activity restrictions associated with a prosthetic glenoid component. However, stiffness is a known complication after ream-and-run arthroplasty and can lead to repeat procedures such as a manipulation under anesthesia (MUA) or open surgical revision. The objective of this study was to determine risk factors associated with repeat procedures indicated for postoperative stiffness after ream-and-run arthroplasty.

Methods: We conducted a retrospective review of our shoulder arthroplasty database to identify patients who underwent ream-and-run arthroplasty and determined which patients underwent subsequent repeat procedures (MUA and/or open revision) indicated for postoperative stiffness. The minimum follow-up was 2 years. We collected baseline demographic information and preoperative and 2-year patient-reported outcome scores and analyzed preoperative radiographs. Univariate and multivariate analyses determined the factors significantly associated with repeat procedures to treat postoperative stiffness.

Results: There were 340 patients who underwent ream-and-run arthroplasty. The mean Simple Shoulder Test (SST) scores for all patients improved from 5.0 ± 2.4 preoperatively to 10.2 ± 2.6 postoperatively ($p < 0.001$). Twenty-six patients (7.6%) underwent open revision for stiffness. An additional 35 patients (10.3%) underwent MUA. Univariate analysis found younger age ($p = 0.001$), female sex ($p = 0.034$), lower American Society of Anesthesiologists (ASA) class ($p = 0.045$), posterior decentering on preoperative radiographs ($p = 0.010$), and less passive forward elevation at the time of discharge after ream-and-run arthroplasty ($p < 0.001$) to be significant risk factors for repeat procedures. Multivariate analysis found younger age ($p = 0.040$), ASA class 1 compared with class 3 ($p = 0.020$), and less passive forward elevation at discharge ($p < 0.001$) to be independent risk factors for repeat procedures. Of the patients who underwent open revision for stiffness, 69.2% had multiple positive cultures for Cutibacterium.

Conclusions: Younger age, ASA class 1 compared with class 3, and less passive forward elevation in the immediate postoperative period were independent risk factors for repeat procedures to treat postoperative stiffness after ream-and-run arthroplasty.

Level of Evidence: Prognostic Level III. See Instructions for Authors for a complete description of levels of evidence.

Glenoid component wear and loosening are common causes of total shoulder arthroplasty failure[1-4]. Some patients considering shoulder arthroplasty wish to avoid the activity limitations and the risk of complications associated with a polyethylene glenoid component. Additionally, the absence of a polyethylene glenoid in shoulder arthroplasty eliminates the risk of revision related to glenoid wear, glenoid loosening, and humeral component loosening associated with polyethylene wear. These patients may consider a ream-and-run arthroplasty, which has been shown to improve pain and function in patients with glenohumeral arthritis without the limitations associated with a glenoid implant[5-7]. When compared with total shoulder arthroplasty, ream-and-run arthroplasty has been shown to have comparable outcomes and a high return-to-work rate for selected patients[6-12].

However, the avoidance of longer-term complications related to polyethylene wear and loosening must be balanced against the relatively higher rate of repeat operations after ream-and-run arthroplasty in the short term compared with total shoulder arthroplasty. Stiffness can develop following ream-and-run arthroplasty; repeat interventions such as a manipulation under anesthesia (MUA) or open surgical revision may be

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necessary. In a study performed by Somerson and Matsen[6], 19% of patients with a minimum 5-year follow-up underwent revision procedures, with the most common indication being stiffness. Getz et al.[5] found similar results, with a 25% revision rate at a mean of 2.7 years; all of these procedures were performed to treat persistent pain and stiffness.

It remains unclear which patients are at the greatest risk for developing stiffness following ream-and-run arthroplasty. Therefore, the objective of this study was to determine the predictors of postoperative stiffness requiring further intervention after ream-and-run arthroplasty.

Materials and Methods

This study was approved by the University of Washington institutional review board (STUDY00007300). It was a retrospective study of a longitudinally maintained institutional database of patients who underwent a primary shoulder arthroplasty between November 2010 and June 2018. We identified 392 patients who underwent ream-and-run arthroplasty and excluded 49 patients who did not have 2-year patient-reported outcomes. The minimum follow-up was 2 years (including follow-up appointments within 1 month before the 2-year mark). The 2-year outcome data were available for the remaining 343 patients (87.5%). An additional 3 patients who underwent open revision for reasons other than stiffness were excluded, leaving 340 patients in the final analysis. Baseline and demographic information included sex, age, body mass index (BMI), diagnosis, type of insurance, American Society of Anesthesiologists (ASA) class, tobacco use, alcohol use, opioid use, presence of diabetes, and history of ipsilateral shoulder surgical procedures. The visual analog scale (VAS) for pain scores, Simple Shoulder Test (SST) scores, and Single Assessment Numeric Evaluation (SANE) scores were collected preoperatively and at 2 years postoperatively.

Patient Selection and Rehabilitation Protocol

Patients were identified as candidates for ream-and-run arthroplasty if they wished to avoid having a polyethylene component implanted at the time of shoulder arthroplasty and were considered to be sufficiently motivated to remain compliant with a rigorous rehabilitation protocol focused on maintaining range of motion despite potential postoperative pain[13]. Patients were counseled that postoperative stiffness is more common with a ream-and-run arthroplasty compared with a total shoulder arthroplasty and that they would therefore be at higher risk for MUA or reoperation to treat postoperative stiffness. All other patients were treated with a total shoulder arthroplasty including a prosthetic glenoid component and were excluded from the study.

All patients underwent a ream-and-run arthroplasty using a previously reported technique, and a subscapularis peel was utilized in all cases[14]. Peripheral nerve blocks were not routinely used, as this is not the standard of care at our institution. The goals of glenoid reaming were to create a single, concave surface and to remove the least amount of bone without attempting to modify glenoid retroversion. A humeral head with anterior eccentricity was used if excessive posterior decentering was observed during intraoperative trialing[15]. Rotator interval plications were performed if persistent posterior decentering was a concern after the final components were implanted. All patients began a rehabilitation protocol consisting of daily range-of-motion exercises with a dedicated shoulder physical therapist on the day of the surgical procedure while in the hospital. The goal of the protocol was to achieve and maintain 150° of supine, active-assisted, forward elevation. The range of motion was measured by the physical therapist using a goniometer during each therapy session and on the day of discharge from the hospital. Patients were admitted to the hospital for 2 days for the first half of the study period but transitioned to an overnight stay in the second half of the study period.

Stiffness Requiring Intervention

Procedures to address stiffness were considered when forward elevation was <150° and did not improve despite an adequate 6-week trial of physical therapy. Occasionally, intervention was pursued earlier than 6 weeks if patients had substantial stiffness that was worsening or not improving with physical therapy. Open revision was typically performed in the setting of chronic stiffness (>3 months after the index arthroplasty). MUA was typically performed for stiffness in the acute and subacute stages (≤3 months after the index arthroplasty). However, some patients with symptoms lasting >3 months after the index arthroplasty elected to undergo MUA rather than open revision. All operative reports were reviewed to determine the indication for and details of repeat procedures. Only repeat procedures to treat stiffness were included; repeat procedures for other diagnoses such as rotator cuff tear or obvious infection were excluded from the final analysis.

Radiographic Analysis

Preoperative and postoperative radiographs, including an axillary view made with the arm in neutral rotation and elevated 90° in the plane of the scapula, were analyzed by a single observer[16]. On the preoperative radiographs, a Walch classification was assigned, and the glenoid version was measured by subtracting the angle formed by the glenoid articular surface and the plane of the scapula from 90°[17,18]. Posterior decentering of the humeral head on the reamed glenoid was measured using the technique published by Hsu et al.[15]. Postoperative version and posterior decentering were recorded using radiographs from the 2-year postoperative visit. For patients who did not have 2-year postoperative radiographs available, the latest radiographs were used and the time from the surgical procedure to the latest radiograph was recorded.

Culturing Methodology and Reporting

Cutibacterium periprosthetic joint infection is a recognized cause of delayed shoulder stiffness after shoulder arthroplasty[19,20]. Therefore, deep-tissue and implant samples were obtained from shoulders that underwent open revision for stiffness. Culturing and reporting were performed as previously reported[21-23].

Statistical Analysis

All study data were collected and managed using REDCap electronic capture tools hosted at the Institute of Translation

Health Sciences[24]. The primary outcome assessed was the need to treat stiffness with MUA or open revision. Continuous variables were presented as the mean and the standard deviation, and categorical variables were presented as frequencies and/or percentages. Assessment of differences in categorical variables between groups was performed using a chi-square test or a Fisher exact test. Significance was set at $p < 0.05$. Kruskal-Wallis or Mann-Whitney U tests were used for nonparametric variables. A multivariate analysis was performed using variables found to be significant in the univariate analysis. Kaplan-Meier survivorship analyses were performed using stiffness requiring intervention as the end point. Statistical analyses were performed with the use of SPSS (version 25.0; IBM).

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Results

In the final analysis, 340 patients (319 [93.8%] male) who underwent ream-and-run arthroplasty were included. The mean SST scores for all patients improved from 5.0 ± 2.4 preoperatively to 10.2 ± 2.6 postoperatively ($p < 0.001$), and the mean SANE scores improved from 40.6 ± 19.3 preoperatively to 80.3 ± 18.1 postoperatively ($p < 0.001$). The mean follow-up was 2.1 ± 0.2 years (range, 1.9 to 4.1 years).

Twenty-six patients (7.6%) underwent subsequent open procedures to treat stiffness. We excluded 3 patients who underwent a surgical procedure for reasons other than stiffness, including 2 patients who had rotator cuff tears and 1 patient who had an obvious infection, from the revision group. Four patients underwent a conversion to an anatomic total shoulder arthroplasty, and the remaining 22 patients had downsizing of the humeral head component. These procedures were performed at a mean of 20.6 months (range, 0.9 to 71.7 months) after the index arthroplasty. At the time of open revision, 69.2% (18 of 26) had ≥2 cultures positive for Cutibacterium. Once positive cultures were identified, patients were placed on either an oral antibiotic regimen of doxycycline or Augmentin (amoxicillin and clavulanic acid) or an intravenous regimen of ceftriaxone. None of these patients underwent single-stage or 2-stage revisions for infection.

Thirty-five patients (10.3%) elected to undergo an MUA. These procedures were performed at a mean of 8.7 months (range, 0.5 to 68.5 months) after the index arthroplasty, which was a significantly shorter time than the interval to open revision ($p < 0.001$). The mean SST scores of patients undergoing MUA (6.2 ± 3.4) were significantly lower ($p < 0.001$) than those of patients undergoing open revision (9.7 ± 2.5).

Patients who underwent a repeat procedure and the control group of patients who did not undergo a repeat procedure had similar preoperative mean SST scores (4.8 ± 2.2 compared with 5.0 ± 2.5; $p = 0.804$) and SANE scores (38.8 ± 19.5 compared with 41.0 ± 19.3; $p = 0.410$) (Table I). However, patients who underwent a repeat procedure had lower mean scores at 2 years for the SST (8.2 ± 3.4 compared with 10.6 ± 2.1; $p < 0.001$) and SANE (68.4 ± 21.0 compared with 82.7 ± 16.4; $p < 0.001$).

Patients who underwent repeat procedures were younger at the time of the arthroplasty (54.6 ± 9.3 compared with 58.9 ± 9.6 years; $p = 0.001$), more likely to be female (13% compared with 5%; $p = 0.034$), and healthier, as reflected by a lower ASA class ($p = 0.045$) (Table I). Radiographic analysis demonstrated that patients who underwent a repeat procedure had greater preoperative posterior decentering (10.7% ± 7.7% compared with 8.1% ± 8.4%; $p = 0.010$) but similar Walch classification ($p = 0.621$) and preoperative retroversion ($p = 0.671$). Patients who required a repeat procedure had less forward elevation (125.7° ± 29.6° compared with 143.3° ± 18.0°; $p < 0.001$) noted at the time of hospital discharge after the index surgical procedure. Preoperative diagnosis, BMI, insurance type, employment, opioid use, smoking status, prior procedures on the same shoulder, head thickness, use of an eccentric head, and rotator interval plication were not significantly different between those who required intervention and those who did not.

Multivariate analysis using variables that were found to be significant in the univariate analysis demonstrated that younger age (odds ratio [OR], 0.959 [95% confidence interval (CI), 0.921 to 0.998] per year; $p = 0.040$), ASA class 1 compared with class 3 (OR, 0.139 [95% CI, 0.026 to 0.734]; $p = 0.020$), and less forward elevation at discharge (OR, 0.962 [95% CI, 0.946 to 0.979] per degree; $p < 0.001$) were independent predictors associated with an intervention for stiffness (Table II).

Discussion

This study indicated that the ream-and-run procedure effectively restored shoulder comfort and function for the great majority of patients, without the risks and limitations associated with a prosthetic glenoid component. However, it also indicated that stiffness can be a problem after this procedure. To our knowledge, this is the first study of factors associated with the need for revision procedures to treat stiffness after a ream-and-run procedure. Achieving immediate range of motion and maintaining it throughout the rehabilitation period are an essential component of the rehabilitation after a ream-and-run arthroplasty. Despite their best efforts with rehabilitation, some patients develop stiffness after arthroplasty that requires intervention[5,6]. Our study identified younger age, ASA class 1 compared with class 3, and less active-assisted forward elevation at the time of discharge as independent predictors of the need for revision procedures. Over two-thirds of the patients having open revision for stiffness had multiple positive cultures for Cutibacterium.

Repeat procedures to treat stiffness consist of either an MUA during the acute or subacute period, in an attempt to release adhesions, or an open surgical revision in the chronic setting. Somerson and Matsen[6] found a revision rate of 19% at a minimum 5-year follow-up, and Getz et al.[5] found a 25% revision rate at a mean of 2.7 years, and all of those procedures were performed to treat persistent pain and stiffness. The

TABLE I Univariate Analysis Comparing Patients Who Did or Did Not Undergo MUA or Open Revision for Stiffness

Variables	No Repeat Procedure (N = 279)	MUA or Open Revision (N = 61)	P Value*
Age† *(yr)*	58.9 ± 9.6	54.6 ± 9.3	**0.001**
Sex‡			**0.034**
Female	13 (5%)	8 (13%)	
Male	266 (95%)	53 (87%)	
Diagnosis‡			0.099
Osteoarthritis	217 (78%)	44 (72%)	
Capsulorrhaphy arthropathy	2 (1%)	3 (5%)	
Chondrolysis	26 (9%)	6 (10%)	
Other	34 (12%)	8 (13%)	
Race‡			0.876
White	267 (96%)	58 (95%)	
Black	3 (1%)	1 (2%)	
Native American	2 (1%)	0 (0%)	
Other	7 (3%)	2 (3%)	
Marital status‡			0.522
Married	226 (81%)	46 (75%)	
Domestic partner	6 (2%)	1 (2%)	
Other	47 (17%)	14 (23%)	
BMI† *(kg/m²)*	29.1 ± 4.9	28.1 ± 3.9	0.292
Insurance‡			0.060
Medicare	67 (24%)	6 (10%)	
Medicaid	7 (3%)	3 (5%)	
Workers' Compensation	12 (4%)	6 (10%)	
Commercial	172 (62%)	42 (69%)	
Other	21 (8%)	4 (7%)	
Currently employed‡	193 (69%)	37 (61%)	0.351
Preoperative optimism†	9 ± 1	9 ± 1	0.647
Current opioid use‡	39 (14%)	12 (20%)	0.321
Smoking‡	13 (5%)	4 (7%)	0.538
Alcohol use‡	200 (72%)	42 (69%)	0.658
Other drug use‡	7 (3%)	2 (3%)	0.732
Diabetes‡	11 (4%)	3 (5%)	0.728
ASA class‡			**0.045**
1	45 (16%)	17 (28%)	
2	201 (72%)	41 (67%)	
3	33 (12%)	3 (5%)	
Antibiotic choice‡			0.592
Cefazolin	50 (18%)	9 (15%)	
Vancomycin and ceftriaxone	207 (74%)	45 (74%)	
Other	22 (8%)	7 (11%)	
Prior surgical procedure‡	104 (37%)	23 (38%)	0.955
Walch type‡§			0.621
A1	10 (4%)	1 (2%)	
A2	88 (32%)	15 (25%)	
B1	29 (10%)	8 (13%)	

continued

TABLE I (*continued*)

Variables	No Repeat Procedure (N = 279)	MUA or Open Revision (N = 61)	P Value*
B2	133 (49%)	36 (59%)	
C	2 (1%)	0 (0%)	
B3	10 (4%)	1 (2%)	
D	2 (1%)	0 (0%)	
Posterior decentering†§ *(%)*			
Preoperative	8.1 ± 8.4	10.7 ± 7.7	**0.010**
2 years	1.9 ± 4.9	2.4 ± 3.8	0.239
Retroversion†§ *(deg)*			
Preoperative	14.8 ± 9.8	13.9 ± 9.9	0.671
2 years	14.2 ± 9.1	13.1 ± 9.9	0.357
Humeral head size† *(mm)*	55.5 ± 1.6	55.4 ± 1.8	0.422
Humeral head thickness† *(mm)*	19.0 ± 4.1	19.0 ± 2.0	0.466
Rotator interval plication‡	65 (23%)	12 (20%)	0.615
Forward elevation at discharge† *(deg)*	143.3 ± 18.0	125.7 ± 29.6	**<0.001**
SST score†			
Preoperative	5.0 ± 2.5	4.8 ± 2.2	0.804
2 years	10.6 ± 2.1	8.2 ± 3.4	**<0.001**
SANE score†			
Preoperative	41.0 ± 19	38.8 ± 19.5	0.410
2 years	82.7 ± 16	68.4 ± 21.0	**<0.001**
VAS pain score†			
Preoperative	6.7 ± 1.9	6.8 ± 2.0	0.520
2 years	3.2 ± 6.4	3.4 ± 1.9	0.073

*Significant values are shown in bold. †The values are given as the mean and the standard deviation. ‡The values are given as the number of patients, with the percentage in parentheses. §Five patients in the no repeat procedure group did not have data for these categories.

overall rate of repeat procedures in the current study is similar to the previously reported 19% rate; however, the proportion of patients undergoing open revision (7.6%) is lower and that of patients undergoing MUA is higher (10.3%) in the current study. Of note, some patients elected to undergo MUA at times after a surgical procedure that were longer than 3 months (in 1 case, as long as 6 years), rather than having an open release. Further study will be needed to investigate the factors associated with a clinically important benefit from manipulation.

We found that younger age was an independent risk factor for repeat procedures to address stiffness in the current study. The reasons for this association are not clear. It is possible that younger patients have higher expectations and, therefore, a lower threshold for a second procedure to address stiffness. Getz et al.[5] also found that younger age was correlated with lower postoperative scores for the SANE, SST, and Penn Shoulder Score and that patients who underwent a revision surgical procedure were younger. Gilmer et al.[9] also found that younger patients had less favorable outcomes; male patients who were >60 years of age and did not have a history of surgical procedures had the best prognosis in terms of comfort and function after a ream-and-run arthroplasty.

We found that ASA class 1, when compared with class 3, was an independent risk factor for repeat procedures after ream-and-run arthroplasty. This contrasts with studies of anatomic total shoulder arthroplasty that found increasing comorbidities to be associated with revision. Leong et al.[25] found that a higher Charlson Comorbidity Index was associated with the need for revision of total shoulder arthroplasty. Similarly, Dillon et al.[26] found that higher BMI and diabetes were risk factors for repeat revision total shoulder arthroplasty. Patients who undergo ream-and-run arthroplasty are typically younger and often healthier than those undergoing total shoulder arthroplasty. Younger, healthier patients appear to be at greater risk for Cutibacterium periprosthetic joint infection[19].

Less forward elevation at the time of discharge from the hospital after a ream-and-run arthroplasty was another independent risk factor for a repeat procedure. This finding demonstrates that less range of motion in the immediate postoperative period can identify patients who may benefit from a more aggressive rehabilitation protocol. In contrast, Getz et al.[5] did not find a correlation between the postoperative range of

TABLE II Binomial Logistic Regression for Stiffness Requiring Open Revision or MUA

Variable	OR (95% CI)	P Value*
Age, per 1-year increase	0.959 (0.921 to 0.998)	**0.040**
Male sex	0.646 (0.197 to 2.121)	0.471
Preoperative decentering, per 1% increase	1.016 (0.975 to 1.058)	0.458
ASA class		
1	Reference	
2	0.510 (0.222 to 1.173)	0.113
3	0.139 (0.026 to 0.734)	**0.020**
Forward elevation at discharge, per 1° increase	0.962 (0.946 to 0.979)	**<0.001**

*Significant values are shown in bold.

motion and a revision surgical procedure. However, the range-of-motion measurements that were included in their analysis were at 6 weeks and 2 years postoperatively rather than immediately after the surgical procedure.

Univariate analysis indicted that the amount of preoperative posterior decentering was significantly greater in the group that required repeat intervention, but posterior decentering was not found to be independently predictive of stiffness on multivariate analysis. It is possible that another factor such as male sex was a confounding variable that led to a type-I error on univariate analysis. Alternatively, it is possible that preoperative posterior decentering is truly clinically relevant but was not independently predictive because of the method by which variables were included in our multivariate modeling. Posterior decentering is often addressed with increases in the thickness or diameter of the prosthetic head, changes in head eccentricity, and performance of rotator interval plication to center the head on the reamed glenoid. Although posterior decentering was not significant on multivariate analysis, these intraoperative modifications can increase the risk of postoperative shoulder stiffness and should be considered in patients who undergo a ream-and-run arthroplasty and are at risk for stiffness.

Finally, it is of note that over two-thirds (69.2%) of the open revisions for stiffness had multiple positive intraoperative cultures for Cutibacterium. It is recognized that stiffness can be a presenting symptom of a Cutibacterium infection, typically in the absence of the characteristic signs of periprosthetic joint infection, such as elevated serum markers, fever, chills, joint swelling, and a draining sinus. It is recognized that young, healthy patients are at greater risk for Cutibacterium periprosthetic joint infection[19]. This may partially explain the association of stiffness after ream-and-run arthroplasty, a procedure often selected by young, healthy patients. This finding suggests that surgeons should consider Cutibacterium infection as a potential cause of stiffness encountered after a ream-and-run arthroplasty.

This study had a few limitations. These procedures were performed at a high-volume tertiary care referral center; thus, our experience may not be generalizable. The indications for ream-and-run arthroplasty and its performance, including soft-tissue balancing, component sizing, and osseous procedures, may be handled differently by other surgeons. We aggressively adress postoperative stiffness in order to optimize patient function. Other surgeons may have different thresholds for intervening for stiffness. Also, we did not record preoperative or intraoperative range of motion and were thus limited to evaluating the postoperative range of motion. Lastly, the majority of our patients pursued postoperative rehabilitation at external facilities, which made it difficult to monitor their compliance with exercises.

In conclusion, although ream-and-run arthroplasty substantially improves shoulder comfort and function for patients wishing to avoid a prosthetic glenoid component, postoperative stiffness can present a problem. The clinical importance of this study is that it identified patients at increased risk for postoperative stiffness after a ream-and-run arthroplasty: those who are younger, those who are in ASA class 1 compared with class 3, and those who have less immediate postoperative forward elevation. These patients may benefit from greater soft-tissue releases, smaller humeral head components, more aggressive rehabilitation, and close monitoring of their range of motion after the surgical procedure. Furthermore, this study points out that surgeons should be alert to the possibility of Cutibacterium in shoulders developing stiffness: patients who underwent an open revision for stiffness had a substantial rate of intraoperative cultures positive for Cutibacterium. ■

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Corey J. Schiffman, MD[1]
Kevin Jurgensmeier, MD[2]
Jie J. Yao, MD[1]
John C. Wu, MD[1]
Anastasia J. Whitson, BSPH[1]
Sarah E. Jackins, PT[3]
Frederick A. Matsen III, MD[1]
Jason E. Hsu, MD[1]

[1]Department of Orthopaedics and Sports Medicine, University of Washington Medical Center, Seattle, Washington

[2]Department of Orthopedic Surgery, Mayo Clinic, Rochester, Minnesota

[3]Exercise Training Center, University of Washington, Seattle, Washington

Email for corresponding author: jehsu@uw.edu

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