Journal of Shoulder and Elbow Arthroplasty
Volume 2: 1–6
© The Author(s) 2018
DOI: 10.1177/2471549218778446
journals.sagepub.com/home/sea
SAGE

Lesser Tuberosity Osteotomy Outcomes After Anatomic Shoulder Arthroplasty in Patients With Atraumatic Avascular Necrosis

Stephen P Maier, BA[1], Cesar D Lopez, BS[1], Zachary J Bloom, MD[1], Brian B Shiu, MD[1], Djuro Petkovic, MD[1], William N Levine, MD[1] and Charles M Jobin, MD[1]

Abstract

Introduction: Lesser tuberosity osteotomy (LTO) is an attractive option for subscapularis management during anatomic shoulder arthroplasty due to the biomechanical strength and reliable bone-to-bone healing. Patients with humeral head avascular necrosis (AVN) may have compromised bone healing, and the outcomes of LTO during AVN are unknown.

Methods: A retrospective consecutive case series of 6 patients with Cruess grade 4 or 5 humeral head AVN who underwent anatomic shoulder arthroplasty with LTO from 2010 to 2016 was performed. Postoperative radiographic evaluation for LTO healing at 6 months was analyzed, and clinical outcomes at latest follow-up, including range of motion (ROM), strength, and pain were studied.>

Results: Average age was 50.3 years. AVN was secondary to sickle cell in 1 patient, steroid use for systemic lupus erythematosus in 4, and chronic alcoholism in 1. By 6 months after arthroplasty, 100% had radiographically united and healed LTO. Patients averaged $140 \pm 21^\circ$ of active forward elevation and $42 \pm 7^\circ$ of active external rotation. Patients reported an improvement in visual analogue scale pain from 8.3 preoperatively to 3.8 postoperatively. All patients had a normal abdominal compression test. No patients required revision surgery.

Conclusion: The use of LTO during anatomic shoulder arthroplasty for AVN has an excellent bony healing rate with improvements in pain, ROM, and strength. The diseases that cause humeral head AVN do not negatively influence LTO healing outcomes during anatomic shoulder replacement.

Level of Evidence: IV Case Series

Keywords

Lesser tuberosity osteotomy, avascular necrosis, osteonecrosis, shoulder arthroplasty, systemic lupus erythematosus, sickle cell

Date received: 18 February 2018; accepted: 19 April 2018

Introduction

Shoulder arthroplasty is an effective procedure for treating pain resulting from shoulder conditions structurally effecting the glenohumeral joint articular surfaces including advanced stage avascular necrosis (AVN).[1] Recovery after shoulder arthroplasty is often dependent on subscapularis function. It is controversial which subscapularis approach is best to expose the glenohumeral joint. The 3 most commonly employed techniques include subscapularis tenotomy, subscapularis peel, and lesser tuberosity osteotomy (LTO). Each technique has its own advantages and disadvantages, but clinical studies fail to demonstrate clinically significant superiority of one over

[1]Department of Orthopedic Surgery, Columbia University Medical Center, New York, New York

Corresponding Author:
Charles M Jobin MD, Associate Professor, Residency Program Director, Department of Orthopedic Surgery, Columbia University Medical Center, 622 West 168th Street, PH11-Center, New York, NY 10032, USA.
Email: jobin@columbia.edu

another.[2,3,4] It is unknown if atraumatic AVN, and its underlying diseases, negatively impact LTO healing potential. LTO offers an attractive technique for surgeons who are concerned about tendon to tendon healing in patients with AVN due to systemic disease, given the increased risk of subscapularis dysfunction and complete tendon tearing associated with subscapularis tenotomy compared to other management techniques.[3,4] Little is known about the use of LTO as a subscapularis management strategy in shoulder arthroplasty for atraumatic AVN. The purpose of this study is to describe the outcomes of shoulder arthroplasty with LTO in patients with atraumatic humeral head AVN and to demonstrate the radiographic healing outcomes of LTO compared to other subscapularis management techniques. We hypothesize that LTO can be used to approach the glenohumeral joint during total shoulder arthroplasty (TSA) in patients with AVN of the humeral head with evidence of good bony healing and improved clinical function.

Methods

Study Design

This study is a retrospective consecutive case series of 6 patients with Cruess grade 4 or 5 humeral head atraumatic AVN who underwent anatomic shoulder arthroplasty with LTO at one institution from 2010 to 2016. Patients were identified by current procedural terminology code as part of an institutional review board approved study. All patients had preoperative computed tomography or magnetic resonance imaging to evaluate the integrity of the lesser tuberosity bone and to assess the glenoid for secondary degenerative changes. Patients lost to follow-up or without a minimum of 3 months clinical and radiographic follow-up were excluded from the study. Patients were not excluded for concurrent steroid use or disease modifying antirheumatic drugs.

Surgical Technique

A deltopectoral approach was used in all cases. The subscapularis and lesser tuberosity were identified, and the tendon was tagged with sutures. An LTO was performed using an oscillating saw to create a thin 3 to 5 mm wafer of bone. The humeral inferior capsule was elevated off the humeral neck. The anterior humeral circumflex vessels were not coagulated. A humeral head cut was made at the level of the anatomic neck for anatomic shoulder arthroplasty. Preparation and trailing of the humeral replacement was performed, and if required, the glenoid was prepared for a component. Prior to placement of the humeral component, four #5 nonabsorbable transosseous sutures were placed through the bony bed of the humeral osteotomy site with 3 wrapping circumferentially around the humeral stem. During LTO repair, the 4 sutures were tied to compress the LTO repair and a tension band #2 stitch was placed to off-load the LTO repair. Of the 6 cases of anatomic shoulder arthroplasties, 2 were total shoulder replacement and 4 were hemiarthroplasty. Patients were maintained in a sling postoperatively for comfort for 2 weeks allowing active-assisted forward elevation and external rotation (ER) as tolerated by pain starting postoperative day 1, with restriction on lifting, carrying, or active internal rotation behind their back. At 2 weeks postoperatively, all patients were started on outpatient physical therapy 2 times per week for 10 weeks with goals to begin active range of motion (ROM) and gentile resistance at 6 weeks postoperatively. By 12 weeks postoperatively, if the LTO appeared healing on X-ray, the patients were allowed to begin strengthening without restriction.

Data Collection

Data collection included demographic information, radiographic evidence of LTO healing (union, nonunion, or displaced nonunion), as well as clinical outcomes, including ROM, subscapularis strength with abdominal compression testing and internal rotation strength in the abdominal compression position performed by the examining physician, and pain measured with the visual analogue scale (VAS). The primary outcome measure was radiographic evidence of bony healing. Each case was assessed with standardized posteroanterior, lateral, and axillary radiographs of the shoulder at routine postoperative visits. Preoperative radiographs were available for all 6 cases, and postoperative radiographs with a minimum follow-up of 4 months were also available in all cases. All films were analyzed by 2 fellowship-trained orthopedic surgeons who reviewed images for bony healing at the site of the LTO. There were no cases of disagreement.

Statistical Analysis

Statistical analysis was done using Microsoft Excel, and results were expressed using percentages, means, and standard deviations. Student's t tests were used for analysis, with the level of significance for each test set at 5% ($P < .05$).

Results

Patient Population

Anatomic shoulder arthroplasty with LTO was performed in 6 patients: 1 male and 5 females. The average age at the time of surgery was 50.3 years. AVN was

secondary to sickle cell in 1 patient (Figure 1), steroid use for systemic lupus erythematosus (SLE) in 4 patients, and chronic alcoholism in 1 patient. None of the patients were smokers, and none had preexisting diabetes mellitus. Patients had an average body mass index of 27.9 kg/m^2.

LTO Outcomes

Average radiographic follow-up was 6 months, with a range of 4 to 7 months, after arthroplasty, by which time 100% had radiographically united and healed LTO (Figure 2). Average postoperative clinical follow-up was 7 months, with a range of 3 to 13 months, at which time, patients averaged $143 \pm 21^\circ$ of active forward elevation (AFE) and $42 \pm 6^\circ$ of active external rotation (AER), compared to preoperative AFE of 109° and AER of 27° (Table 1, $P = .11$, $P = .39$, respectively). Patients reported an improvement of VAS pain after shoulder arthroplasty from 8.3 preoperatively to 3.8 postoperatively ($P < .05$, Table 1). All patients had a normal postoperative abdominal compression test at final clinical follow-up, and no patients required revision surgery.

Figure 1. Humeral Head AVN With Collapse. Radiographs of a 28-Year-Old Woman With Sickle Cell AVN With Head Collapse (Cruess stage 4) With Preserved Glenoid Cartilage on MRI.

Discussion

LTO had reliable 100% healing rate during anatomic shoulder arthroplasty for avascular necrosis due to SLE, sickle cell, and alcoholism. There are no prior

Table 1. Comparison of Presurgical and Postsurgical Range of Motion, Pain Scores, and Radiographic Evidence of Healing.

	Presurgical	Postsurgical
AFE	109°	143°
AER	27°	42°
Average VAS pain score	8.33	3.83
% Radiographic LTO healing	0%	100%

Abbreviations: AER, active external rotation; AFE, active forward elevation; LTO, lesser tuberosity osteotomy; VAS, visual analogue scale.

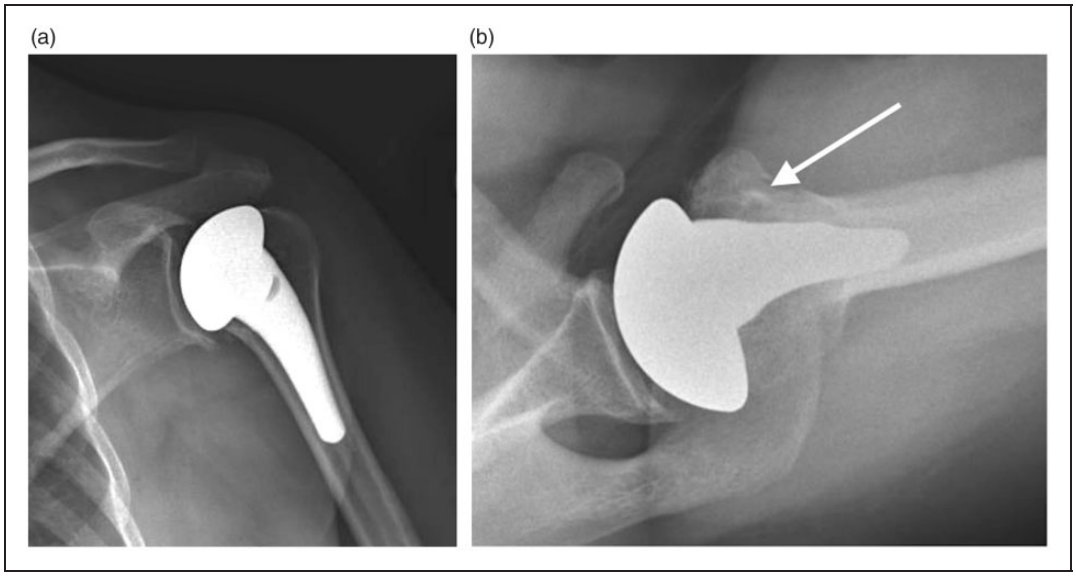

Figure 2. Shoulder Arthroplasty With LTO. The previously shown patient 6 months after shoulder arthroplasty with lesser tuberosity osteotomy (LTO) with LTO healing on (A) anteroposterior and (B) axillary X-ray views (arrow).

reports of LTO usage, nor LTO healing rates, during arthroplasty for AVN of the humeral head. Reports of shoulder arthroplasty for AVN are limited[5], and a systematic review of all available literature demonstrated no studies describing the use of LTO for subscapularis management.[5] The 3 largest studies of shoulder arthroplasty for atraumatic AVN were by the Mayo group with subscapularis tenotomy or peel performed in all cases.[6,7,8] In Schoch et al.'s article,[8] the operation-free survivorship for TSA in osteonecrotic shoulders was 88.5% at 5 years, 83.0% at 10 years, 78.8% at 15 years, and 78.8% at 20 years. Shoulder arthroplasty is effective for advanced stages of AVN of the humeral head but may have less optimal outcomes than TSA patients with osteoarthritis.[9,10] In primary osteoarthritis, LTO healing rates have been reported to be between 86% and 100%.[11,12,13,14] Our study is in line with expected LTO healing rates and included patients with various types of AVN including a majority of SLE and a minority of sickle cell and alcoholism patients with excellent LTO healing.

Risk factors for LTO healing have been identified in larger osteoarthritis case series to include tobacco use, male gender, and younger age.[14,15] No studies have reported, nor identified inflammatory arthritis, AVN, osteoporosis, or other systemic diseases as risk factors for LTO failure. Gerber et al. initially reported 100% LTO healing in 39 arthroplasty patients, of whom 10 had inflammatory arthritis.[11] It is unknown if the inflammatory arthritis caused an AVN type of arthritis or a more common erosive arthritis. Nevertheless, these inflammatory arthritis patients had impressive 100% bony healing results after LTO.[11] The only report of LTO in AVN is from Boileau et al. who studied post-traumatic AVN with tuberosity malunion that required osteotomy of the malunited lesser tuberosity.[1] Boileau et al. demonstrated that LTO in cases of fracture malunion with AVN can heal and provide acceptable functional results, but that greater tuberosity osteotomy and repair should be avoided due to high nonunion rates and complications.[1]

Biomechanical studies of LTO demonstrate robust strength and failure loads as well as decreased cyclic displacement.[16,17] Van den Berghe et al. concluded that LTO repair not only was better than a tendon-to-bone "peel" repair but also produced the best repair strength and restoration of subscapularis strength.[18] Another study confirmed superior biomechanical results with LTO compared to tenotomy.[19,20] But other studies have found no differences in maximum load to failure and strength between LTO, tenotomy repair, and peel.[20] Technical LTO failures have also been identified with LTO repair sutures pulling thru bone tunnels, so improved techniques utilize suture augments with cortical buttons or sutures around or through humeral stems have been developed.[18]

In clinical shoulder arthroplasty studies, subscapularis management options of LTO, subscapularis peel, and subscapularis tenotomy all appear to have similar outcomes in pain relief, function, and patient-reported outcome scores.[4] Lapner et al. compared peel and LTO in a randomized study and found no differences in subscapularis strength testing, Western Ontario Osteoarthritis of the Shoulder (WOOS), and American Shoulder and Elbow Surgeons scores.[10] Furthermore, Buckley et al. reported no differences in belly press strength, bear hug strength, and Disabilities of the Arm, Shoulder and Hand, WOOS, and Constant scores.[16] Other studies demonstrate excellent LTO results with improved healing and functional outcomes.[11,13,14,21,22,23] Furthermore, Scalise et al. demonstrated that LTO produced excellent clinical outcome scores, lower rates of postoperative subscapularis dysfunction, and universal healing of the LTO when compared to tenotomy.[13] When compared to subscapular peel, Shafritz et al. reported superior subscapularis testing with LTO.[24]

The limitations to our study include the small number and mixed AVN etiology of patients in this case series. Also, the retrospective design has no control group for comparison of outcomes. The small sample size and majority of sickle cell and lupus patients, rather than idiopathic steroid induced AVN, may account for a higher than expected postoperative VAS pain score when compared to pain scores reported by Schoch et al.[8]

Our study demonstrates that humeral head AVN does not negatively influence LTO healing outcomes and that LTO is likely a safe and effective surgical approach to subscapularis management during anatomic shoulder arthroplasty for AVN.

Conclusion

The use of LTO during anatomic shoulder arthroplasty for atraumatic AVN has an excellent bony healing rate with expected improvements in pain and ROM, with consistently good postoperative strength. Our results suggest that the diseases that cause humeral head AVN, specifically SLE, sickle cell disease, and alcoholism, may not be major risk factors for LTO healing. This study offers an initial case series supporting the use of LTO in patients suffering from atraumatic humeral head AVN who require shoulder arthroplasty.

Declaration of Conflicting Interests

The authors declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Charles M Jobin received consultant payments from Acumed, Depuy-Synthes-Mitek, Wright-Tornier, and Zimmer-Biomet, which is not directly related to the subject of this work. Jobin receives grant support from American Shoulder & Elbow Surgeons not related to the subject of this

work. Jobin is on the editorial board of Journal of American Academy of Orthopedic Surgeons. William N Levine is an unpaid consultant for Zimmer-Biomet and receives research grant financial support from Smith and Nephew not directly related to the subject of this work and is on the editorial/governing board of the Journal of American Academy of Orthopedic Surgeons.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: Charles M Jobin receives grant funding from Orthopaedic Scientific Research Foundation. The other authors, their immediate family, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

IRB Approval

Columbia University Institutional Review Board (IRB)—IRB-AAAL7810.

References

1. Boileau P, Trojani C, Walch G, Krishnan SG, Romeo A, Sinnerton R. Shoulder arthroplasty for the treatment of the sequelae of fractures of the proximal humerus. *J Shoulder Elbow Surg* 2001;10(4): 299–308. DOI: 10.1067/mse.2001.115985.
2. Gobezie R, Denard PJ, Shishani Y, Romeo AA, Lederman E. Healing and functional outcome of a subscapularis peel repair with a stem-based repair after total shoulder arthroplasty. *J Shoulder Elbow Surg* 2017. DOI: 10.1016/j.jse.2017.02.013.
3. Louie PK, Levy DM, Bach BR Jr., Nicholson GP, Romeo AA. Subscapularis Tenotomy Versus Lesser Tuberosity Osteotomy for Total Shoulder Arthroplasty: A Systematic Review. *Am J Orthop (Belle Mead NJ)* 2017;46(2): E131–E8. (ISSN: 1934-3418).
4. Shields E, Ho A, Wiater JM. Management of the subscapularis tendon during total shoulder arthroplasty. *J Shoulder Elbow Surg* 2017;26(4): 723–731. DOI: 10.1016/j.jse.2016.11.006.
5. Moineau G, McClelland WB Jr., Trojani C, Rumian A, Walch G, Boileau P. Prognostic factors and limitations of anatomic shoulder arthroplasty for the treatment of post-traumatic cephalic collapse or necrosis (type-1 proximal humeral fracture sequelae). *J Bone Joint Surg Am* 2012;94(23): 2186–2194. DOI: 10.2106/JBJS.J.00412.
6. Hattrup SJ, Cofield RH. Osteonecrosis of the humeral head: results of replacement. *J Shoulder Elbow Surg* 2000;9(3): 177–182. ISSN: 1058-2746.
7. Schoch BS, Barlow JD, Schleck C, Cofield RH, Sperling JW. Shoulder arthroplasty for atraumatic osteonecrosis of the humeral head. *J Shoulder Elbow Surg* 2016;25(2): 238–245. DOI: 10.1016/j.jse.2015.07.019.
8. Smith RG, Sperling JW, Cofield RH, Hattrup SJ, Schleck CD. Shoulder hemiarthroplasty for steroid-associated osteonecrosis. *J Shoulder Elbow Surg* 2008;17(5): 685-688. DOI: 10.1016/j.jse.2008.01.149.
9. Franceschi F, Franceschetti E, Paciotti M, Torre G, Samuelsson K, Papalia R, et al. Surgical management of osteonecrosis of the humeral head: a systematic review. *Knee Surg Sports Traumatol Arthrosc* 2016. DOI: 10.1007/s00167-016-4169-z.
10. Feeley BT, Fealy S, Dines DM, Warren RF, Craig EV. Hemiarthroplasty and total shoulder arthroplasty for avascular necrosis of the humeral head. *J Shoulder Elbow Surg* 2008;17(5): 689–694. DOI: 10.1016/j.jse.2008.03.009.
11. Gerber C, Yian EH, Pfirrmann CA, Zumstein MA, Werner CM. Subscapularis muscle function and structure after total shoulder replacement with lesser tuberosity osteotomy and repair. *J Bone Joint Surg Am* 2005;87(8): 1739–1745. DOI: 10.2106/JBJS.D.02788.
12. Lapner PL, Sabri E, Rakhra K, Bell K, Athwal GS. Comparison of lesser tuberosity osteotomy to subscapularis peel in shoulder arthroplasty: a randomized controlled trial. *J Bone Joint Surg Am* 2012;94(24): 2239–2246. DOI: 10.2106/JBJS.K.01365.
13. Scalise JJ, Ciccone J, Iannotti JP. Clinical, radiographic, and ultrasonographic comparison of subscapularis tenotomy and lesser tuberosity osteotomy for total shoulder arthroplasty. *J Bone Joint Surg Am* 2010;92(7): 1627–1634. DOI: 10.2106/JBJS.G.01461.
14. Small KM, Siegel EJ, Miller LR, Higgins LD. Imaging characteristics of lesser tuberosity osteotomy after total shoulder replacement: a study of 220 patients. *J Shoulder Elbow Surg* 2014;23(9): 1318–1326. DOI: 10.1016/j.jse.2013.12.010.
15. Shi LL, Jiang JJ, Ek ET, Higgins LD. Failure of the lesser tuberosity osteotomy after total shoulder arthroplasty. *J Shoulder Elbow Surg* 2015;24(2): 203–209. DOI: 10.1016/j.jse.2014.05.006.
16. Buckley T, Miller R, Nicandri G, Lewis R, Voloshin I. Analysis of subscapularis integrity and function after lesser tuberosity osteotomy versus subscapularis tenotomy in total shoulder arthroplasty using ultrasound and validated clinical outcome measures. *J Shoulder Elbow Surg* 2014;23(9): 1309–1317. DOI: 10.1016/j.jse.2013.12.009.
17. Ponce BA, Ahluwalia RS, Mazzocca AD, Gobezie RG, Warner JJ, Millett PJ. Biomechanical and clinical evaluation of a novel lesser tuberosity repair technique in total shoulder arthroplasty. *J Bone Joint Surg Am* 2005;87(Suppl 2): 1–8. DOI: 10.2106/JBJS.E.00441.
18. Van den Berghe GR, Nguyen B, Patil S, D'Lima DD, Mahar A, Pedowitz R, et al. A biomechanical evaluation of three surgical techniques for subscapularis repair. *J Shoulder Elbow Surg* 2008;17(1): 156–161. DOI: 10.1016/j.jse.2007.04.016.
19. Schrock JB, Kraeutler MJ, Houck DA, Provenzano GG, McCarty EC, Bravman JT. Lesser tuberosity osteotomy and subscapularis tenotomy repair techniques during total shoulder arthroplasty: A meta-analysis of cadaveric studies. *Clin Biomech (Bristol, Avon)* 2016;40:33–36. DOI: 10.1016/j.clinbiomech.2016.10.013.
20. Giuseffi SA, Wongtriratanachai P, Omae H, Cil A, Zobitz ME, An KN, et al. Biomechanical comparison of lesser tuberosity osteotomy versus subscapularis tenotomy in total shoulder arthroplasty. *J Shoulder Elbow Surg* 2012;21(8): 1087–1095. DOI: 10.1016/j.jse.2011.07.008.

21. De Wilde LF, De Coninck T, De Neve F, Berghs BM. Subscapularis release in shoulder replacement determines structural muscular changes. *Clin Orthop Relat Res* 2012;470(8): 2193–2201. DOI: 10.1007/s11999-012-2291-x.
22. Jandhyala S, Unnithan A, Hughes S, Hong T. Subscapularis tenotomy versus lesser tuberosity osteotomy during total shoulder replacement: a comparison of patient outcomes. *J Shoulder Elbow Surg* 2011;20(7): 1102–1107. DOI: 10.1016/j.jse.2011.03.019.
23. Krishnan SG, Stewart DG, Reineck JR, Lin KC, Buzzell JE, Burkhead WZ. Subscapularis repair after shoulder arthroplasty: biomechanical and clinical validation of a novel technique. *J Shoulder Elbow Surg* 2009;18(2): 184–192; discussion 97–98. DOI: 10.1016/j.jse.2008.09.009.
24. Shafritz AB, Fitzgerald MG, Beynnon BD, DeSarno MJ. Lift-off Test Results After Lesser Tuberosity Osteotomy Versus Subscapularis Peel in Primary Total Shoulder Arthroplasty. *J Am Acad Orthop Surg* 2017;25(4): 304–313. DOI: 10.5435/JAAOS-D-16-00138.