J Shoulder Elbow Surg (2016) 25, 22-30

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

Rotator cuff tear shape characterization: a comparison of two-dimensional imaging and three-dimensional magnetic resonance reconstructions

Soterios Gyftopoulos, MD[a,*], Luis S. Beltran, MD[a], Kevin Gibbs, MD[a], Laith Jazrawi, MD[b], Phillip Berman[a], James Babb, PhD[a], Robert Meislin, MD[b]

[a]*Department of Radiology, NYU Langone Medical Center, New York, NY, USA*
[b]*Department of Orthopaedic Surgery, NYU Langone Medical Center, New York, NY, USA*

Background: The purpose of this study was to see if 3-dimensional (3D) magnetic resonance imaging (MRI) could improve our understanding of rotator cuff tendon tear shapes. We believed that 3D MRI would be more accurate than two-dimensional (2D) MRI for classifying tear shapes.
Methods: We performed a retrospective review of MRI studies of patients with arthroscopically proven full-thickness rotator cuff tears. Two orthopedic surgeons reviewed the information for each case, including scope images, and characterized the shape of the cuff tear into crescent, longitudinal, U- or L-shaped longitudinal, and massive type. Two musculoskeletal radiologists reviewed the corresponding MRI studies independently and blind to the arthroscopic findings and characterized the shape on the basis of the tear's retraction and size using 2D MRI. The 3D reconstructions of each cuff tear were reviewed by each radiologist to characterize the shape. Statistical analysis included 95% confidence intervals and intraclass correlation coefficients.
Results: The study reviewed 34 patients. The accuracy for differentiating between crescent-shaped, longitudinal, and massive tears using measurements on 2D MRI was 70.6% for reader 1 and 67.6% for reader 2. The accuracy for tear shape characterization into crescent and longitudinal U- or L-shaped using 3D MRI was 97.1% for reader 1 and 82.4% for reader 2. When further characterizing the longitudinal tears as massive or not using 3D MRI, both readers had an accuracy of 76.9% (10 of 13). The overall accuracy of 3D MRI was 82.4% (56 of 68), significantly different ($P = .021$) from 2D MRI accuracy (64.7%).
Conclusion: Our study has demonstrated that 3D MR reconstructions of the rotator cuff improve the accuracy of characterizing rotator cuff tear shapes compared with current 2D MRI–based techniques.
Level of evidence: Level III, Diagnostic Study.

Keywords: 3D MRI; rotator cuff tear shape; rotator cuff tear

This study was approved by the NYU School of Medicine Institutional Review Board: No. i14-00476. Informed consent was waived for this retrospective Health Insurance Portability and Accountability Act–compliant study.

*Reprint requests: Soterios Gyftopoulos, MD, Department of Radiology, NYU Langone Medical Center, 660 First Avenue, New York, NY 10016, USA.
E-mail address: soterios20@gmail.com (S. Gyftopoulos).

1058-2746/$ - see front matter © 2016 Journal of Shoulder and Elbow Surgery Board of Trustees.
http://dx.doi.org/10.1016/j.jse.2015.03.028

A complete description of a rotator cuff tendon tear that is seen on magnetic resonance imaging (MRI) should include a number of important characteristics, such as its location, degree of tendon involvement (partial vs. full thickness), size, and degree of retraction. A characteristic that is not typically included in the imaging report but plays an important role in the management of the patient's rotator cuff tear is the shape of the tear. Compared with a radiologist's interpretation of knee MRI, in which the shape of a meniscal tear is regularly included in the description, the shape of a rotator cuff tendon tear remains a relatively difficult and misunderstood concept that has not taken a prominent place in the lexicon of the musculoskeletal radiologist.[5]

The shape of a rotator cuff tear can play an important role in the surgeon's approach (e.g., portal placement) and selection to repair as well as in the likelihood of clinical success after the repair.[2,4,9] Having this information before surgery is useful to the surgeon as it will permit more complete surgical planning and allow the surgeon to provide prognostic information to the patient based on the surgical success of certain shaped tears.[2,4] The accurate determination of the shape of the tear could also help in deciding whether the tear is reparable as well as if it would be worthwhile to proceed with surgery. In addition, a correctly defined tear shape could help determine if there is enough tendon tissue remaining to allow marginal convergence during the repair. Prior studies have demonstrated that the characterization of rotator cuff tears and their shape can be difficult during arthroscopy and using MRI.[7,13] A classification system for rotator cuff tear shapes using MRI has been presented in the literature and is based on the 2-dimensional (2D) measurements of the length and width of the tears.[4,14] In our experience, this system has not been accurate when our results are compared with what is seen during arthroscopy.

The use of 3-dimensional (3D) imaging has greatly improved our understanding and visualization of bone injuries in the shoulder. The use of 3D imaging in soft tissue injuries, such as in the evaluation of tendon tears, has not been as well explored up until this point. The purpose of this feasibility study was to see if 3D imaging could improve our understanding of rotator cuff tendon tear shapes on MRI. Our hypothesis is that 3D reconstructions of rotator cuff tears would improve our understanding of the tear shape and thus lead to improved accuracy of the tear shape characterization compared with the current 2D MRI–based classification system using the findings at arthroscopy as the "gold standard."

Materials and methods

Patients

We performed a retrospective review of MR examinations conducted during an 18-month period with the following inclusion criteria: preoperative MRI (1.5T or 3T) performed at our institution that demonstrated a full-thickness tear of the supraspinatus or infraspinatus tendon and arthroscopic surgery at our institution by 1 of 2 fellowship-trained sports medicine orthopedic surgeons within 6 months of the MRI examination. Exclusion criteria included prior shoulder surgery, preoperative MRI performed at another institution, and no full-thickness tendon tear seen in arthroscopy. This resulted in a total of 34 patients who could be included in our study.

MRI technique

There were 17 1.5T and 17 3T noncontrast MR examinations included in the study. There was no significant difference in the quality of the imaging performed in comparing the studies performed on our 1.5T scanners with those performed on our 3T scanners. The sequences and parameters for the MR examinations were as follows: coronal oblique turbo spin-echo proton density weighted (slice thickness, 3 mm; repetition time [TR] range/echo time [TE] range, 2100-2500/25-35) and fat suppressed T2 weighted (slice thickness, 3 mm; TR range/TE range, 3500-4000/55-60), sagittal oblique T1 weighted (slice thickness, 3 mm; TR range/TE range, 450-600/12-15) and fat suppressed T2 weighted (slice thickness, 3 mm; TR range/TE range, 3500-4000/55-65), and axial fat suppressed proton density weighted (slice thickness, 3 mm; TR range/TE range, 2100-2500/25-37). The matrix was 256 $\times$ 256, whereas the field of view was 140 for all the studies. Imaging was done with the arm at the patient's side and placed in the neutral position with the thumb up. The appropriate positioning was confirmed for each examination during imaging, with repositioning performed when necessary.

The coronal oblique T2-weighted imaging underwent manual segmentation, generating 3D reconstructions of each rotator cuff tear (Vitrea 4.1; Vital Images, Minnetonka, MN, USA). The margins of the rotator cuff were outlined manually along different points (anterior to posterior) from the insertional tendon fibers to the myotendinous junction, typically 4 or 5. The outlines were then connected through automatic interpolation, producing a 3D reconstruction of the cuff (Figs. 1-4). An additional line was placed on the 3D reconstruction to mark the location of the glenohumeral joint relative to the cuff insertion. The post-processing time for each reconstruction was between 2 and 3 minutes.

Arthroscopic evaluation

Two fellowship-trained, sports medicine–trained orthopedic surgeons (14 years and 22 years, respectively) reviewed the operative reports, arthroscopic photographs, and postoperative records for each patient. Each of the included patients had the rotator cuff surgery performed by one of these surgeons. The shape of each rotator cuff tear was reviewed and agreed on in consensus without the use of measurements. The tears were initially classified as either crescent shaped or longitudinal (Fig. 1). A tear was described as crescent shaped if its width (anteroposterior [AP] dimension) was greater than its length (medial to lateral; i.e., retraction). A longitudinal tear was used when the length was greater than its width. The longitudinal tears were further classified into U and L shaped. A U-shaped tear was described when