Three-Dimensional Magnetic Resonance Imaging Quantification of Glenoid Bone Loss Is Equivalent to 3-Dimensional Computed Tomography Quantification: Cadaveric Study

Adam B. Yanke, M.D., Jason J. Shin, M.D., Ian Pearson, B.S., Bernard R. Bach Jr., M.D., Anthony A. Romeo, M.D., Brian J. Cole, M.D., M.B.A., and Nikhil N. Verma, M.D.

Purpose: To assess the ability of 3-dimensional (3D) magnetic resonance imaging (MRI, 1.5 and 3 tesla [T]) to quantify glenoid bone loss in a cadaveric model compared with the current gold standard, 3D computed tomography (CT). **Methods:** Six cadaveric shoulders were used to create a bone loss model, leaving the surrounding soft tissues intact. The anteroposterior (AP) dimension of the glenoid was measured at the glenoid equator and after soft tissue layer closure the specimen underwent scanning (CT, 1.5-T MRI, and 3-T MRI) with the following methods (0%, 10%, and 25% defect by area). Raw axial data from the scans were segmented using manual mask manipulation for bone and reconstructed using Mimics software to obtain a 3D en face glenoid view. Using calibrated Digital Imaging and Communications in Medicine images, the diameter of the glenoid at the equator and the area of the glenoid defect was measured on all imaging modalities. **Results:** In specimens with 10% or 25% defects, no difference was detected between imaging modalities when comparing the measured defect size (10% defect $P = .27$, 25% defect $P = .73$). All 3 modalities demonstrated a strong correlation with the actual defect size (CT, $\rho = .97$; 1.5-T MRI, $\rho = .93$; 3-T MRI, $\rho = .92$, $P < .0001$). When looking at the absolute difference between the actual and measured defect area, no significance was noted between imaging modalities (10% defect $P = .34$, 25% defect $P = .47$). The error of 3-T 3D MRI increased with increasing defect size ($P = .02$). **Conclusions:** Both 1.5- and 3-T–based 3D MRI reconstructions of glenoid bone loss correlate with measurements from 3D CT scan data and actual defect size in a cadaveric model. Regardless of imaging modality, the error in bone loss measurement tends to increase with increased defect size. Use of 3D MRI in the setting of shoulder instability could obviate the need for CT scans. **Clinical Relevance:** The goal of our work was to develop a reproducible method of determining glenoid bone loss from 3D MRI data and hence eliminate the need for CT scans in this setting. This will lead to decreased cost of care as well as decreased radiation exposure to patients. The long-term goal is a fully automated system that is as approachable for clinicians as current 3D CT technology.

From the Sports Medicine Division, Department of Orthopaedics, Rush University (A.B.Y., B.R.B., A.A.R., B.J.C., N.N.V.), Chicago, Illinois, U.S.A.; Department of Orthopaedics, Royal University Hospital, University of Saskatchewan (J.J.S.), Saskatoon, Canada; and Rush University Medical School (I.P.), Chicago, Illinois, U.S.A.

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Address correspondence to Adam B. Yanke, M.D., Rush University Medical Center, 1611 W Harrison St., Suite 300, Chicago, IL 60614, U.S.A. E-mail: Adam.Yanke@RushOrtho.com

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In young athletes who participate in high-risk sports, recurrent anterior shoulder instability is common following an initial traumatic dislocation.[1] Glenoid bone loss has been reported in up to 73% of recurrent dislocators.[2] Critical-sized glenoid defects are associated with a recurrence rate of 67% to 89% after soft tissue stabilization alone.[3-5] Yamamoto et al.[6] showed in a cadaveric study that osseous defects ≥19% of the glenoid width are unstable even after Bankart repair. Therefore, during presurgical planning for shoulder stabilization, recognizing and accurately quantifying the amount of glenoid bone loss is critical.

Clinical determination of glenoid bone loss can be performed via plain radiographs, computed tomography (CT), or magnetic resonance imaging (MRI). Although radiographs are useful in screening for glenoid bone loss, based on cadaveric studies, the prediction error and standard deviation of plain radiographs are double those of CT or MRI.[7] Radiographs and even 2-dimensional (2D) advanced imaging modalities, such as MRI or CT, are less accurate because of sensitivity to patient positioning and scanning technique. Although 2D MRI is similar to 2D CT in determining bone loss,[8] cadaveric and clinical studies have shown that both are clearly inferior to 3-dimensional (3D) CT.[7,9]

Three-dimensional CT allows for simplified patient positioning and, with reformatting, the humeral head can be subtracted to provide an unobstructed view of the glenoid. Therefore, 3D CT has been found to be accurate and reliable in representing the complex glenoid anatomy, and thus emerged as the gold standard.[7,9-11] CT scans also carry the added risk of exposing the patient to 2.06 mSv of irradiation.[12] This is roughly equivalent to the amount of background radiation (ubiquitous ionizing radiation, including natural and artificial sources, that individuals on Earth are exposed to) one is exposed to over 8 months, which can be significant for young adults.[13]

Currently, MRI is the reference standard when assessing soft tissue and is typically ordered by clinicians prior to obtaining a CT scan to evaluate the surrounding non-osseous structures after shoulder dislocation.[14-16] The ability to use a single study to evaluate both soft tissue injury and bone loss would establish MRI as the preferred imaging modality for evaluating instability pathology. Previous reports have demonstrated conflicting outcomes when comparing CT to MRI for quantification of glenoid bone loss and most have used suboptimal cadaveric models with bone only after soft tissue dissection.[7,8,17,18]

The purpose of this study was to assess the ability of 3D MRI (1.5- and 3-tesla [T]) to quantify glenoid bone loss in a cadaveric model compared with the current gold standard, 3D CT. Our hypothesis was that both 1.5- and 3-T 3D MRI would have similar measurement error as 3D CT.

Methods

We received investigational review board exempt status for this cadaveric study. Six whole fresh-frozen shoulders (6 males, 3 right, 3 left, age range: 63-72 years old) were used for the study. None of the specimens had a history of shoulder trauma or previous shoulder surgery. All specimens were inspected to confirm intact labrum, bone, and articular surfaces. The specimens were frozen at −20°C and thawed overnight at room temperature on the day of testing for a single freeze-thaw cycle.

Before imaging, the shoulders underwent an extended deltopectoral approach to expose the glenohumeral joint. This exposure included soft tissue takedown of the subscapularis to allow for later repair. After dissection, the labrum was elevated and mobilized using an arthroscopic elevator. The anteroposterior (AP) dimension of the glenoid was measured by the operating surgeon through the bare area with a handheld digital caliper (0.1 mm resolution) in a manner similar to that used clinically with an arthroscopic probe. A gross photograph (Canon PowerShot S100) was recorded using a paper ruler for calibration. The shoulder was then subsequently closed in layers using nonabsorbable braided suture. Specifically, the subscapularis was closed with no. 2 Ethibond suture, repairing the tendon to the remaining tendon that remained on the lesser tuberosity. Care was taken to keep the labrum intact, although a formal repair was not performed with regard to the labrum. The specimen then underwent scanning (CT, 1.5-T MRI, and 3-T MRI) without defect creation.

Both 1.5- and 3-T MRI scans used T1 coronal, sagittal oblique, and axial views. T1 weighting was selected because it most accurately represents osseous detail.[19] The 1.5-T MRI (Magnetom Essenza; Siemens Healthcare) protocol included the following: slice thickness 3.5 mm, gap 1.0 mm, response time 479 milliseconds, echo time 16 milliseconds, and field of view 160 mm. The 3-T MRI (Magnetom Verio; Siemens Healthcare) protocol included the following: slice thickness 2.0 mm, gap 0.5 mm, response time 400 milliseconds, echo time 22 milliseconds, and field of view 130 mm. The CT scans, which were obtained in coronal, sagittal oblique, and axial planes by use of 0.625 mm contiguous slices (120 kV, 260 mA) (Fig 1), were then processed into 3D en face glenoid (sagittal oblique) views with humeral subtraction (Volume Viewer 8.9.21; GE Healthcare).

Dissection was carried out again to create glenoid defects correlating to 10% glenoid bone loss. Using