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ORIGINAL ARTICLE

Do magnetic resonance imaging and computed tomography provide equivalent measures of rotator cuff muscle size in glenohumeral osteoarthritis?

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Background: Rotator cuff muscle volume is associated with outcomes after cuff repair and total shoulder arthroplasty. Muscle area on select magnetic resonance imaging (MRI) slices has been shown to be a surrogate for muscle volume. The purpose of this study was to determine whether computed tomography (CT) provides an equivalent measurement of cuff muscle area to a previously validated MRI measurement.
Methods: We included 30 patients before they were undergoing total shoulder arthroplasty with both preoperative CT and MRI scans performed within 30 days of one another at 1 institution using a consistent protocol. We reoriented CT sagittal and MRI sagittal T1 series orthogonal to the scapular plane. On both CT and MRI scans, we measured the area of the supraspinatus, infraspinatus–teres minor, and subscapularis on 2 standardized slices as previously described. We calculated intraclass correlation coefficients and mean differences.
Results: For the 30 subjects included, when MRI and CT were compared, the mean intraclass correlation coefficients were 0.989 (95% confidence interval [CI], 0.976-0.995) for the supraspinatus, 0.978 (95% CI, 0.954-0.989) for the infraspinatus–teres minor, and 0.977 (95% CI, 0.952-0.989) for the subscapularis. The mean differences were 0.2 cm^2 (95% CI, 0.0-0.4 cm^2) for the supraspinatus ($P = .052$), 0.8 cm^2 (95% CI, 0.1-1.4 cm^2) for the infraspinatus–teres minor ($P = .029$), and –0.3 cm^2 (95% CI, –1.2 to 0.5 cm^2) for the subscapularis ($P = .407$).
Conclusion: CT provides nearly equivalent measures of cuff muscle area to an MRI technique with previously validated reliability and accuracy. While CT underestimates the infraspinatus area as compared with MRI, the difference is less than 1 cm^2 and thus likely clinically insignificant.
Level of evidence: Level III; Diagnostic Study

Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained. This study was performed under University of Utah Institutional Review Board–approved protocol No. 71740.

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Rotator cuff muscle volume is associated with outcomes after rotator cuff repair and shoulder arthroplasty.[4,5,8-10,15,20,27] Rotator cuff muscle atrophy is common in patients with glenohumeral osteoarthritis and rotator cuff pathology.[15,20,21,28] Therefore, accurate and reliable measurement and classification of rotator cuff volume is clinically important for diagnostic and treatment purposes.

Current measurement and classification systems for rotator cuff muscle degeneration are limited. The most commonly used classification is the Goutallier system for both fatty infiltration and atrophy.[10] However, the Goutallier system has limited reliability, although reliability is influenced by the individual assigning grades.[14,19,22,25,30] A wide variety of systems have been proposed to improve on the Goutallier system by more specifically quantifying rotator cuff muscle atrophy.[13,16-18,23,24,26,28,29,32] The ideal system would measure rotator cuff muscle volume by measuring the area on each slice through the entirety of the muscle from the origin to the insertion, and such systems are sufficiently accurate and reliable to be used in computational modeling.[2,11,12,31] However, measurement of muscle volume in this manner involves substantial time (up to 2 hours per scan).[24] Thus a system that allows volume extrapolation from area on select slices would be preferable. In addition, many prior systems have only been validated for evaluation of the supraspinatus, and thus their reliability and accuracy in the other rotator cuff muscles are unknown.[18,23,26,28]

Tingart and colleagues[17,29] described a method for analysis of the rotator cuff muscle area on 2 magnetic resonance imaging (MRI) slices that allows evaluation of all 4 rotator cuff muscles, and they have established the reliability and accuracy of this method by comparison with volume via the water-displacement method. However, this technique has not been validated on computed tomography (CT). CT scans are more widely available, are less expensive, and provide a better assessment of osseous morphology. Prior to shoulder arthroplasty, CT scans are commonly ordered preoperatively to assess glenoid morphology in patients with glenohumeral osteoarthritis. As rotator cuff muscle volume correlates with outcome after shoulder arthroplasty, accurate and reliable assessment of rotator cuff muscle volume preoperatively, before shoulder arthroplasty, is relevant clinically.[15,20] Because CT scans are more commonly acquired preoperatively, before shoulder arthroplasty, if CT can be validated for the measurement of rotator cuff muscle volumes, it may reduce the number of scans obtained in the future, thus saving cost.

The purpose of this study was to determine whether CT provides an equivalent measurement of rotator cuff muscle area to a previously validated MRI-based measurement in the setting of glenohumeral osteoarthritis. We hypothesized that there would be no statistical differences between CT and MRI rotator cuff area measurements.

Materials and methods

This was a retrospective comparative radiographic study. We evaluated a list of patients from the University of Utah to identify those who underwent both MRI and CT scans prior to primary total shoulder arthroplasty performed for glenohumeral osteoarthritis. The exclusion criteria were studies that did not include a sagittal CT series with extension to the medial border of the scapula and a sagittal T1 MRI series with extension to the medial border, hardware artifacts, poor-quality images, images obtained outside of our institution, pathologies other than glenohumeral osteoarthritis, and concomitant full-thickness rotator cuff tears.

Sample size determination

In a previous study, the intraclass correlation coefficient (ICC) for MRI muscle area measurement was 0.93-0.96.[17] We determined that an ICC of 0.75 was the minimum acceptable agreement for clinical and research use based on previously published norms.[6] Given these expected and minimum ICCs and 2 observations per subject, we determined 30 subjects would be necessary to achieve 80% power using .05 as the threshold for significance. We screened subjects retrospectively in list-wise fashion starting from the most recent shoulder arthroplasty on May 3, 2017, until we reached this threshold.

Data collection and radiographic measurement protocol

Once the cohort was isolated, all scans were reviewed by an orthopedic surgeon (P.N.C.) with fellowship training in shoulder and elbow surgery with 1.5 years in practice to ensure that we included all of the relevant series and images, that there was no full-thickness rotator cuff tear, and that there was concomitant glenohumeral osteoarthritis. We exported the included scans to DICOM (Digital Imaging and Communications in Medicine) format and uploaded them to a third-party DICOM viewer for analysis (Osirix; Pixmeo, Geneva, Switzerland). We anonymized and randomized the scans. The reviewer described earlier analyzed the MRI scans first and the CT scans 1 week later. For both MRI and CT, we first reoriented each sagittal series into the plane of the scapula as previously described.[3]

We measured rotator cuff muscle area as previously described.[17,29] In brief, we identified the most lateral sagittal image in which the scapular spine was connected to the scapular body as sagittal slice 1. We counted the number of slices between this image and the glenoid. We selected another more medial sagittal slice, the same distance medially from slice 1 as slice 1 was from the glenoid. We identified this second medial slice as slice 2. This method thus has 3 equidistant slices—a medial slice, the most lateral slice to contain the scapular spine–body connection, and the glenoid slice (Fig. 1). On slices 1 and 2, we outlined the muscle bellies of the supraspinatus, subscapularis, and infraspinatus–teres minor using the "closed