Magnetic resonance imaging is comparable to computed tomography for determination of glenoid version but does not accurately distinguish between Walch B2 and C classifications

Article *in* Journal of shoulder and elbow surgery / American Shoulder and Elbow Surgeons ... [et al.] · October 2016
DOI: 10.1016/j.jse.2016.09.024

J Shoulder Elbow Surg (2016) ■■, ■■–■■

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

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ORIGINAL ARTICLE

Magnetic resonance imaging is comparable to computed tomography for determination of glenoid version but does not accurately distinguish between Walch B2 and C classifications

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Background: Computed tomography (CT) scan is the standard for the preoperative assessment of glenoid version and morphology before total shoulder arthroplasty. However, the capacity of magnetic resonance imaging (MRI) to visualize bone morphology has improved with advancing technology. The purpose of this study was to compare the accuracy of MRI to CT for assessment of glenoid version and Walch classification.
Methods: Three fellowship-trained shoulder surgeons assessed glenoid version and Walch classification of 30 patients with primary shoulder osteoarthritis who received both CT and MRI scans before total shoulder arthroplasty. Version measurements, Walch classification, and observer agreement were compared.
Results: Mean glenoid version was −15.5° and −18.6° by CT and MRI, respectively ($P = .17$). Interobserver reliability coefficients were good for both imaging modalities (CT, 0.73; MRI, 0.62). Intraobserver coefficients were good to excellent for CT (range, 0.76-0.87) and good for MRI (range, 0.75-0.79). For Walch classification, interobserver reliability for both modalities was merely fair, whereas intraobserver reliability was moderate to good. Although identification of type A1, A2, and B1 was nearly identical between CT and MRI, there was observer disagreement on type B2 ($P = .001$) and C glenoids ($P = .03$). Specifically, MRI underidentified type B2 and overidentified type C compared with CT.
Conclusions: MRI is largely comparable to CT scan for evaluation of the glenoid, with similar measurements of version and identification of less extreme Walch glenoids. However, MRI is less accurate at distinguishing between type B2 and C glenoids.

This study was approved by the Institutional Review Board of New England Baptist Hospital: Project No. 679572.

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http://dx.doi.org/10.1016/j.jse.2016.09.024

Level of evidence: Level III; Diagnostic Study

Keywords: Osteoarthritis; glenoid version; Walch classification; computed tomography; magnetic resonance imaging; arthroplasty

Measurement of glenoid version in patients with primary glenohumeral osteoarthritis is crucial for planning the preparation and positioning of the glenoid component before shoulder arthroplasty. Osteoarthritis is generally accompanied by varying levels of retroversion,[12,26] and the prosthetic glenoid component should ideally mimic normal biomechanics by restoring near-neutral version. Failure to rectify version is implicated in premature glenoid component loosening and posterior subluxation of the humeral head.[11,19,23] Whereas conventional axillary radiography (AXR) is cost-effective and convenient for initial diagnosis of osteoarthritis, computed tomography (CT) provides comprehensive 3-dimensional (3D) visualization and is superior for accurate preoperative measurement of version and glenoid wear pattern with the relative position of the humeral head (ie, Walch classification).[17,18]

Magnetic resonance imaging (MRI) provides excellent visualization of soft tissue but generally does not match CT scan for characterizing glenohumeral bone architecture.[22] An MRI scan may be obtained before shoulder arthroplasty to evaluate the rotator cuff. A rotator cuff tear or concern for rotator cuff integrity is an indication for reverse total shoulder arthroplasty (RSA), which demonstrates favorable outcomes in cases of rotator cuff deficiency.[7,8] Glenoid morphology may also be appreciated using MRI, but it is unclear whether it could serve as a viable alternative to CT for version measurement and identification of Walch classification. Raymond et al recently demonstrated that MRI is a satisfactory method of measuring preoperative glenoid version with greater accuracy than conventional AXR. They indicated that further research comparing MRI with CT would be particularly beneficial to fully understand the utility of preoperative MRI.[20]

To our knowledge, there is no existing study comparing the accuracy of MRI and CT imaging in the measurement of glenoid version before shoulder arthroplasty. Given that MRI offers an additional element—rotator cuff assessment—over CT, we hypothesized that it may be credible to rely on a single MRI scan to accurately visualize glenoid version, Walch classification, and the rotator cuff.

Methods

We identified 30 consecutive patients who received both CT and MRI scans for evaluation of glenohumeral osteoarthritis from 2011 through 2012 from 2 surgeons' practices (A.J. and S.M.). At the time of clinical evaluation, all patients were considering elective shoulder arthroplasty for treatment of primary osteoarthritis. Both surgeons routinely order preoperative CT and MRI scans to evaluate glenoid morphology and rotator cuff integrity, respectively. Patients with rheumatoid, post-traumatic, or postcapsulorrhaphy arthritis were excluded to minimize confounding factors that might influence interpretation of the results by the observers.

All 30 helical CT scans and 30 MRI scans were obtained at a single institution using the same machines and standard scan settings. CT scans were obtained using the General Electric LightSpeed VCT system (Fairfield, CT, USA). Settings were maintained at 1.25-mm slice thickness with 2.5-mm multiplanar 3D reconstructions. MRI was performed using a General Electric high-field 1.5T scanner with an 8-channel shoulder coil. Scan settings were maintained at 3-mm slice thickness and 0.5-mm gap width with a field of view of 14 or 15 cm. There were 6 diagnostic sequences with axial, coronal, and sagittal T2 weighting as well as coronal T2 with frequency-selective fat suppression and coronal and axial intermediate echo time proton density images.

Three fellowship-trained surgeons (X.L., S.M., and J.P.D.) graded glenoid version and Walch classification at 2 separate sessions administered at a minimum of 6 weeks apart. Thus, for each imaging modality, there were a total of 180 observations for version measurement and 180 observations for Walch classification among the sample of 30 shoulders after both sessions. The observers were blinded to the identity and demographics of the patients. All imaging was presented to observers by study staff on the same radiologic viewing software, IMPAX 6 picture archiving and communication system client by Agfa-Gevaert (Mortsel, Belgium).

Glenoid version was measured on axial CT and MRI slices immediately inferior to the coracoid process according to the widely accepted method originally described by Freidman et al.[12] Walch glenoid classification was evaluated according to the guidelines proposed by Walch et al.[26] Specifically, types A1 and A2 are identified by minor and major central glenoid erosion, respectively. Types B1 and B2 both display posterior subluxation of the humeral head. Type B1 lacks erosion, whereas B2 exhibits posterior erosion resulting in a biconcave appearance. Last, type C is characterized by retroversion in excess of 25° due to glenoid dysplasia.

To determine whether MRI serves as a valid modality for version measurement and determination of Walch glenoid classification, we proceeded with our analysis under the assumption that CT yields the most accurate values. Thus, measurements obtained by MRI were tested for accuracy using the benchmark established by CT.

Statistical methods

Mean glenoid version and Walch classification incidence rate were each calculated from the total of 180 observations after both sessions. To evaluate the categorical variables, χ^2 and Fisher exact tests were performed. Student *t*-test was used for continuous variables.

A fully crossed, 2-way observer model was used for the grading and analysis of interobserver agreement. Intraobserver agreement and interobserver agreement were quantified using weighted κ index values for glenoid version and Fleiss κ for Walch classification. We interpret the qualitative agreement level of the resulting coefficients as follows: ≤0.2, poor; 0.21 to 0.4, fair; 0.41 to 0.6, moderate; 0.61 to 0.8, good; and ≥0.81, excellent.

Statistical analysis was performed by an experienced biostatistician using SAS 9.4 (SAS Institute, Cary, NC, USA). The 2-tailed threshold of significance was set at $P < .05$.

Results

The mean glenoid version measured by the observers was −15.5° and −18.6° by CT and MRI, respectively ($P = .17$). Interobserver reliability coefficients for version measurements were good at 0.73 and 0.62 for CT and MRI, respectively. However, interobserver reliability for Walch glenoid classification was only fair for both CT and MRI (Table I).

Intraobserver reliability coefficients for version measurement by MRI were good, with values of 0.75, 0.79, and 0.78 for observers 1, 2, and 3, respectively. Intraobserver reliability for CT version measurements ranged from good to excellent at 0.76, 0.87, and 0.81 for observers 1, 2, and 3, respectively. For Walch glenoid classifications, intraobserver reliability coefficients using Fleiss κ indicated moderate agreement for CT, whereas those for MRI indicated good agreement (Table I).

Whereas identification of A1, A2, and B1 Walch glenoids was nearly identical between CT and MRI, there was disagreement with regard to B2 ($P = .001$) and C type glenoids ($P = .03$). Specifically, MRI underidentified B2 and overidentified C glenoids compared with CT (Table II).

Discussion

For the purposes of approximating glenoid version, MRI is a reliable method that is comparable to CT scan while simultaneously allowing assessment of rotator cuff integrity. We found the degree of glenoid retroversion as measured by both MRI and CT to be consistent with existing research that establishes average version of an arthritic glenoid as ranging from −8.6° to −16° when it is measured by CT.[12,14,17,21,26] This is compared with the healthy glenoid, which assumes near-neutral version.[12,17,21] Given that CT is widely understood to be the optimal modality for accurate measurement of glenoid version, our findings support the conclusion that MRI is similarly accurate. Both modalities can be assumed to provide more reliable and accurate approximations compared with conventional AXR.[18,20]

Evaluation of rotator cuff integrity is crucial in preoperative decision-making; a rotator cuff tear or concern for rotator cuff integrity is an indication for RSA. MRI is the optimal tool for diagnosing rotator cuff disease, and our results indicate that MRI is also adequate for the measurement of version. This is important knowledge for surgeons and may allow an important shift in routine preoperative practices. Where appropriate, economic cost and the patient's time commitment could be reduced by transitioning to use of a single 3D imaging modality—MRI—rather than the standard of 2. As payment models transition toward an emphasis on value, this may be especially relevant. Moreover, MRI does not subject patients to ionizing radiation that occurs during CT imaging. This is notable as the widespread use of CT has been questioned in recent years.[6] Additional research investigating any potential consequences of relying exclusively on MRI and AXR to evaluate glenoid version and morphology before shoulder arthroplasty would certainly be beneficial. We acknowledge that it is always prudent for the surgeon to maintain a low threshold for requesting both CT and MRI preoperatively. A surgeon's familiarity with MRI as a means to assess the glenoid might also dictate whether he or she elects to obtain a CT scan for planning surgery.

Although interobserver and intraobserver reliability of version measurement was good to excellent across all observers for both imaging modalities, CT scan uniformly demonstrated better reliability coefficients than MRI. Ultimately, CT is superior to MRI for evaluation of degenerative changes to glenohumeral morphology. CT images provide a cleaner visualization of bone architecture, allowing more straightforward interpretation of the glenoid and humeral head positioning. Moreover, the common method of version measurement employed in this study was originally described and validated by Friedman et al using CT scans.[12] Whereas we

Table I Fleiss κ for observer agreement on Walch classification

		Imaging modality	
		CT	MRI
Intraclass	Observer 1	0.60	0.63
	Observer 2	0.57	0.73
	Observer 3	0.47	0.61
Interclass	First session	0.34	0.26
	Second session	0.26	0.23

CT, computed tomography; *MRI*, magnetic resonance imaging.

Table II Walch classification by imaging modality

	Walch classification				
	A1	A2	B1	B2	C
CT, n (incidence)	77 (43%)	17 (9%)	37 (21%)	26 (14%)	23 (13%)
MRI, n (incidence)	76 (42%)	19 (11%)	38 (21%)	8 (4%)	39 (22%)
P value	.9	.7	.9	.001	.03

CT, computed tomography; *MRI*, magnetic resonance imaging.

have shown the MRI can yield statistically comparable measurements by the same method, CT remains the ″gold standard″ for both version measurement and glenohumeral evaluation as a whole. Recent advances in 3D reconstructions solidify the utility of CT scans for preoperative planning.[4,14,15,21]

We identified a difference in the Walch glenoid classification as evaluated by CT and MRI. Assuming that CT affords more accurate appraisal of glenoid morphology, the observers significantly overidentified C and underidentified B2 glenoids using MRI (Table II). Walch et al describe the type C glenoid as dysplastic with retroversion exceeding 25° and a reported incidence of 9%. On the other hand, the type B2 glenoid is predominantly characterized by a biconcave glenoid wear pattern with posterior subluxation of the humeral head and an incidence of 15%.[26] The observers in this study identified type C and B2 glenoid incidence of 13% and 14% by CT, respectively (Table II), which is consistent with Walch et al. Thus, we can conclude that MRI lacks the sensitivity of CT to accurately distinguish between type B2 and type C. We postulate that CT allows better visualization of glenoid biconcavity, specifically the subtle bone prominence between the neoglenoid and the remnant native glenoid fossa (Fig. 1). As a result, on MRI scans, the observers identify an exaggerated incidence of type C glenoids, many of which would be considered type B2 on a CT scan.

Although we found that MRI overestimated the incidence of Walch type C glenoids (22%), Raymond et al reported a contradictory trend with a lower type C incidence of 8.3% when measured by MRI.[20] This could implicate a systematic error of differing subjective interpretations of Walch classification by the observers in the 2 studies. Further research would be useful for clarifying the efficacy of MRI for identifying type B2 and type C glenoids. Until there is better consensus, it would be prudent for surgeons to obtain a preoperative CT scan for patients with substantial retroversion that could be misconstrued on an MRI study. The distinction between type B2 with acquired retroversion and dysplastic type C glenoids is important. Acquired retroversion may be corrected with many well-described techniques, such as eccentric reaming before implantation of the glenoid component[9]; however, the optimal preparation of a dysplastic glenoid with severe retroversion and insufficient bone is unclear.[1,2,9,10,24] In these cases, a CT scan is necessary to comprehensively evaluate the glenoid, and RSA may be considered. Whereas Mizuno et al have reported excellent clinical outcomes using RSA with patients with a biconcave (B2) glenoid,[16] we are not aware of any studies with documented outcomes regarding type C glenoids.

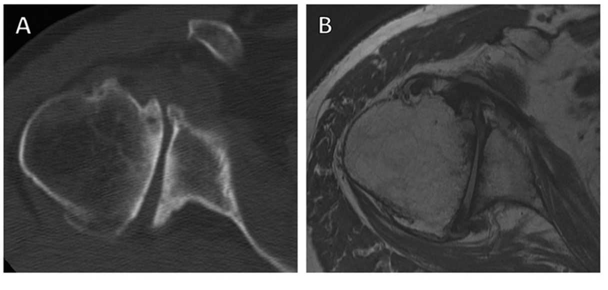

Figure 1 Comparison between (**A**) computed tomography (CT) and (**B**) magnetic resonance imaging (MRI) axial slice views of the same glenohumeral joint at approximately equivalent axial position. In this example, glenoid biconcavity is more evident on the CT scan, thereby enabling observers to properly identify the glenoid as a Walch type B2. On MRI, however, the glenoid could be subjectively interpreted as a Walch type C because of severe retroversion and much subtler presentation of biconcavity.

We do not aim to suggest that MRI and CT are interchangeable for visualization of glenoid morphology. Preoperative CT scans are undoubtedly a valuable tool for surgeons in shoulder arthroplasty. Recent advancements in 3D CT reconstructions allow novel methods of measuring glenoid version and precisely calculating reaming for ideal placement of the glenoid component. For example, patient-specific instruments are promising new tools that rely specifically on 3D CT modeling to optimize preparation of the glenoid and placement of the glenoid component.[13] We did not use these 3D methods in this study. We also acknowledge that the variability of version measurements on CT arising from inconsistent orientation of the scapula has been well described.[5,25] Nevertheless, our aim was to compare basic version measurement by CT and MRI scan as would occur in a routine clinical setting and according to the most established method described by Friedman et al.[12]

We report relatively poor interobserver agreement on Walch classification for both imaging modalities. This reflects the subjective and occasionally ambiguous nature of the original classification scheme. In particular, the features of a type C glenoid are subject to a variety of interpretations. In their original publication, Walch et al defined the type C glenoid as exceeding 25° of retroversion and having dysplastic origin.[26] However, it is unclear whether extreme retroversion (>25°) due to acquired erosion rather than congenital dysplasia should be considered type B2 or type C, especially when lacking the biconcavity associated with type B2. A similar ambiguity arises in considering a dysplastic glenoid with moderate retroversion that does not exceed 25°. Recently, Bercik et al (including Walch as senior author) have acknowledged the unclear wording of the original paper and refined the definition of type C to be exclusively dysplastic with retroversion >25° not caused by erosion. They proceeded to recommend an additional classification of B3, which demonstrates acquired retroversion exceeding 15° and a monoconcave wear pattern.[3] However, this modified Walch classification was not available when our study was carried out, and any attempt to normalize the observers' definitions of each glenoid type by addressing these ambiguities before the study would have introduced significant bias. We reason that the Walch classification system in its premodified form is widespread and accepted by researchers, and we have elected to report these findings regardless.

Conclusions

In the evaluation of primary glenohumeral osteoarthritis, MRI is comparable to CT for the accurate measurement of glenoid version and identification of type A1, A2, and B1 glenoids. However, MRI is inferior to CT for the identification of Walch type B2 and C glenoids. We suggest that a CT scan may be unnecessary for preoperative planning of shoulder arthroplasty when the surgeon decides that conventional radiographs and MRI have provided sufficient visualization. The incentives for omitting a CT scan arise from the obligation to reduce costs and to avoid unnecessary exposure of patients to ionizing radiation. Otherwise, CT remains the standard for comprehensive evaluation of glenohumeral morphology, especially in cases of severe glenoid retroversion with posterior subluxation or dysplastic glenoid disease.

Disclaimer

Andrew Jawa has been a paid speaker for DJO Global and a consultant for Wright Medical.

Suzanne Miller has been a consultant for Stryker.

Xinning Li is a paid consultant for Mitek and Tornier.

All the other authors, their immediate families, 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.

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