Article published online: 2020-04-27

Double-Blinded Randomized Study of the Correlation between Simple Radiography and Magnetic Resonance Imaging in the Evaluation of the Critical Shoulder Angle: Reproducibility and Learning Curve*

Estudo duplo-cego randomizado da correlação entre radiografia simples e ressonância magnética na avaliação do ângulo crítico do ombro: Reprodutibilidade e curva de aprendizado

José Carlos Garcia Junior[1] Leandro Sossai Altoe[1] Rachel Felix Muffareg do Amaral[2] Andre Yui Aihara[2,3] Hilton Vargas Lutfi[1] Marcelo Boulos Dumans Mello[1]

[1] Instituto NAEON, São Paulo, SP, Brazil
[2] Diagnósticos da América S/A (Dasa), São Paulo, SP, Brazil
[3] Department of Radiology, Universidade de São Paulo, São Paulo, SP, Brazil

Address for correspondence José Carlos Garcia Jr., PhD, Instituto Naeon, Avenida Ibirapuera 2144, cj 82 - São Paulo, SP, 04028-001, Brazil (e-mail: josecarlos@naeon.org.br).

Rev Bras Ortop 2021;56(1):78–82.

Abstract

Objective To evaluate the feasibility of magnetic resonance imaging (MRI) to obtain the critical shoulder angle (CSA) comparing the results obtained through radiography and MRI, and assess the learning curves.

Methods In total, 15 patients were evaluated in a blinded and randomized way. The CSA was measured and compared among groups and subgroups.

Results The mean angles measured through the radiographic images were of 34.61 ± 0.67 and the mean angles obtained through the MRI scans were of 33.85 ± 0.53 ($p = 0.29$). No significant differences have been found among the groups. The linear regression presented a progressive learning curve among the subgroups, from fellow in shoulder surgery to shoulder specialist and radiologist.

Conclusion There was no statistically significant difference in the X-rays and MRI assessments. The MRI seems to have its efficacy associated with more experienced evaluators. Data dispersion was smaller for the MRI data regardless of the experience of the evaluator.

Keywords

- rotator cuff
- shoulder joint
- radiography
- magnetic resonance imaging
- reproducibility of results

Resumo

Objetivo Avaliar a confiabilidade da obtenção do ângulo crítico do ombro (ACO) na ressonância magnética (RM) comparada com esse mesmo ângulo obtido por meio de radiografias, e avaliar a curva de aprendizado do método.

* *Work developed at Núcleo Avançado de Estudos em Ortopedia e Neurocirurgia (Naeon) and Diagnósticos da América S/A (Dasa), São Paulo, SP, Brazil.*

received
March 10, 2019
accepted
October 30, 2019
published online
April 27, 2020

DOI https://doi.org/10.1055/s-0040-1701288.
ISSN 0102-3616.

Thieme Revinter Publicações Ltda., Rua do Matoso 170, Rio de Janeiro, RJ, CEP 20270-135, Brazil

Palavras-chave

- manguito rotador
- articulação do ombro
- radiografia
- ressonância nuclear magnética
- reprodutibilidde dos testes

Métodos As imagens de radiografias e RMs de 15 pacientes foram avaliadas prospectivamente de forma cega e randômica. O ACO foi medido e comparado entre os grupos e subgrupos.

Resultados A média dos ACOs nas imagens de radiografia foi de 34,61° ± 0,67, e na RM, 33,85° ± 0,53 ($p = 0{,}29$). Não houve diferença estatisticamente significativa. Houve curva de aprendizado progressiva na regressão linear entre os subgrupos, de especializando em ombro a especialista e radiologista.

Conclusão Não houve diferença estatisticamente significativa entre o ACO por imagens de radiografia e RM. O método da RM parece ter sua eficiência associada a avaliadores mais experientes. Independente da experiência do avaliador, a variabilidade dos dados foi menor nas avaliações por RM.

Introduction

The etiology of rotator cuff tendinopathy is not yet fully known, but mechanical overload is one of the most suggested causes for tendon degeneration, and it may be influenced by the constitutional factors of the affected individuals.[1–3] The critical shoulder angle (CSA), which is obtained through radiographic evaluations, has been considered an important predictive factor for mechanical overload.[4,5] A biomechanical assay analysis has also corroborated the establishment of this correlation.[6]

The CSA is criticized by some authors, who did not find this same correlation; however, inadequate positioning on the radiographs may have been a limiting factor in these studies.[7] Based on the possible source of patient positioning bias, tests showing images with better quality would be the logical way to improve the reproducibility in the evaluation of the CSA.

Some authors suggested the use of computed tomography, and found a high degree of agreement with the radiographic study.[8] However, tomography exposes the patient to higher doses of radiation than radiography, and its indication should be more carefully evaluated.[9] The use of nuclear magnetic resonance (NMR) does not use ionizing radiation, being widely requested for the evaluation of various orthopedic conditions, and it also has less dependence on positional factors that may skew the traditionally used radiographic image.

In a recent CSA study using magnetic resonance imaging (MRI), it was suggested that there was higher data variability of the MRI when compared to radiography, which was more evident in patients with osteoarthritis, and that the method would not be adequate.[10]

The present study aims to evaluate the viability of the MRI to obtain the CSA, and the correlation between the results obtained in radiographic and MR images by a new MR evaluation methodology.

Materials and Methods

The present prospective, randomized, double-blinded comparative study for radiographic and MRI evaluation of the CSA was approved by the institutional ethics committee under number 2.706.960, CAAE: 87182318.2.0000.8054.

The examinations of 15 patients were randomly evaluated and blinded to the evaluator. Only examinations of patients who were to undergo both radiography and MRI on the same day, and with positioning standardization, were used.

Inclusion Criteria

Patients over 18 years of age of both sexes who agreed to participate in the study and had any of the following symptoms: shoulder strength loss, instability, range of motion limitation, and pain.

Exclusion Criteria

Patients with shoulder deformities, with shoulder fracture sequelae, previous shoulder surgeries, radiographic positioning error, and indigenous individuals, those mentally handicapped, or those from other populations who have any ethical conflict.

An Espree 1.5 tesla (Siemens, Munich, Germany) MRI machine was used, as well as an MS–18S® (General Electric, Boston MA, US) digital radiography equipment.

The pattern of analysis for the position of the radiograph was true anteroposterior, with the patient in the orthostatic position, and rays penetrating at 90° in the glenoid joint. The MRI was performed with the patient in supine position.

The coronal MRI was established and standardized during the study, and we evaluated the best visualization of the target structures, and compared it with the radiographic results.

The CSA was calculated with the help of the Carestream (Carestream Health, Onex Corporation, Toronto, Ontario, Canada) software. After standardization, the values obtained were analyzed using the STATA (StataCorp, College Station, TX, US) software, version 15.0.

The MRI measurements used T1-weighted images for better bone visualization in the axial and coronal planes (►**Figure 1**).

In the axial plane, the section with the largest lateral projection of the acromion was identified and marked as the lateral point.

The central point of the glenoid cavity was also found in the axial plane, and marked in the software to use this point to establish the most central section in the coronal plane.

The lateral point was superimposed on all coronal plane images; the most central section of this plane was used to

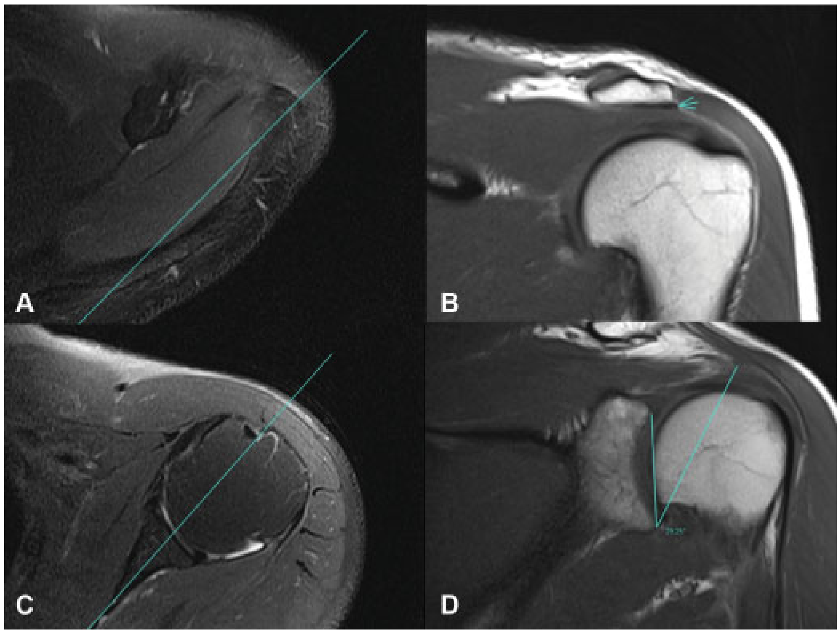

Fig. 1 (A) Marking of the most lateral point of the acromion;T2 image, axial plane. (B) Marking of the most lateral point of the acromion; T1 image, coronal plane. (C) Marking of the center of the glenoid; T2 image, axial plane. (D) Critical shoulder angle (CSA) measurement; coronal image at the central section of the glenoid. Line between the glenoid border and the projection for this section of the most lateral point of the acromion, obtained in sections A and B.

mark the line of the superoinferior axis of the glenoid cavity, and the line between the lowest point of the glenoid and the lateral point was artificially inserted into the image by the software. The angle between these two straight lines was considered the CSA measured by MRI.

The measurement of the angle on the radiographs followed the patterns described by Moor et al[4] (►**Figure 2**).

The data were blindly and randomly evaluated by three evaluators, one fellow in shoulder surgery, a shoulder specialist with three years of experience, and a musculoskeletal radiology specialist with three years of experience, to establish a learning curve.

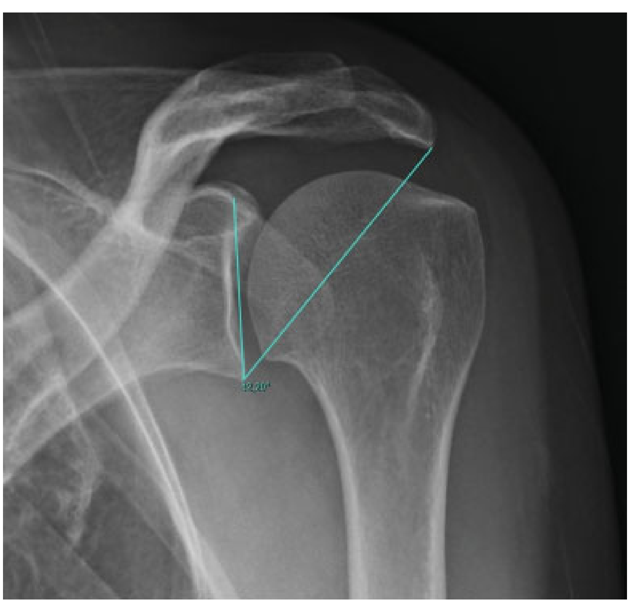

Fig. 2 Measurement of the CSA by radiography.

The statistical evaluation was performed respecting the nature of the data. The results were presented in the format of mean ± standard error (standard deviation, SD). Data were considered significant with $p < 0.05$ in a two-tailed curve. The patient examinations were blindly and randomly evaluated. In the parametric data, comparisons were made using paired *t* tests, analysis of variance (ANOVA) and the Tukey test.

A comparison was also made between the means obtained by the evaluators and the linear regression in order to establish the differences in the learning curves of the evaluation of the radiographs and the MRI between the fellow in shoulder surgery and the specialist with 3 years of experience in shoulder surgery.

Results

The mean of the angles measured by the radiographs was of 34.61 ± 0.67(SD: 4.54) and the mean of the MRI exams was of 33.85 ± 0.53 (SD: 3.54); $p = 0.29$. The mean difference between the radiographic and MRI angles was of $0.76° \pm 0.72$(SD: 4.81).

Separate data and comparisons in the subgroups fellow in shoulder surgery, shoulder specialist, and radiologist are summarized in ►**Table 1**. The comparisons between groups by the Tukey method are summarized in the ►**Table 2**.

In the linear regression, the difference in degrees of the evaluation between radiographs and the MRI showed a constant of 3.07° with coefficient of -1.15°, which is multiplied by 1 for the fellow group, by 2 for the specialist group, and by 3 for the radiologist group.

Table 1 Means with standard errors of the angles by subgroup

	X-Ray	Magnetic resonance imaging (MRI)	Mean difference (X-Ray versus MRI)	*p*-value (X-Ray versus MRI)
Fellow in shoulder surgery	35.21° ± 1.32	33.19° ± 0.87	2.02°	0.15
Shoulderspecialist	34.43° ± 1.09	33.86° ± 0.92	0.57°	0.57
Radiologist	34.19° ± 1.15	34.49° ± 0.98	0.30°	0.84
Analysis of variance among groups	0.82	0.62	0.42	

Table 2 Tukey assessment among groups and significance of the differences

Tukey	*p*-value of the X-Ray among groups	*p*-value of the magnetic resonance imaging (MRI) among groups	Difference in *p*-value (X-Ray versus MRI) among groups
Radiologist versus fellow in shoulder surgery	0.82	0.59	0.40
Fellow in shoulder surgery versus specialist	0.89	0.87	0.69
Radiologist versus specialist	0.99	0.88	0.87

Discussion

The CSA has been used to evaluate patients with various degenerative and inflammatory processes of the shoulder. Its data provide an expectation that relates this angle to some types of injuries.[4]

This angular evaluation, however, does not take into account the forces of other muscles such as the pectoralis major, the latissimus dorsi and the biceps, which may also contribute to a more accurate predictability of mechanical shoulder overloads,[4–6,11,12] since muscle recruitment simplifications are used even in its theorizing.[11–13] Passive structures are also not taken into account this evaluation, as in the current models only at the extremes of movement they would have some influence on the forces acting on the shoulder.[14]

The assessment of the critical shoulder angle is made by radiographic examination; however, in patients already undergoing MRI, the use of this ionizing radiation may be unnecessary. The present study shows a tendency adverse to that of the literature to compare CSA evaluations by radiography and MRI.[10] This divergence may have its origin in the following methodological errors of the literature: the most lateral point of the clavicle did not have a properly standardized marking, the sample was insufficient, it was not validated in internal validation tests, and the MRI and radiography tests were not performed at the same time.

The radiographic examination may present greater difficulty in standardization, being more dependent on human variables to be performed. This fact becomes clear when we evaluate the differences between dispersion data in all groups: data dispersion was greater in the radiographic evaluation groups than in the MRI groups, regardless of the type of evaluator.

There was greater agreement and proximity of data among more experienced examiners, with the musculoskeletal radiology specialist presenting the closest data, demonstrating that there is a clear learning curve, which is more important in the MRI assessment. In the ANOVA, there is greater agreement in the radiographic evaluation among the groups and, considering the results demonstrated by the Tukey technique, data dispersion and linear regression, there is a clear learning curve, possibly linked to the greater familiarity with imaging tests, especially the MRI.

The learning curve of the MRI assessment seems to be more dependent on specific training than the radiographic assessment curve. However, this fact may also be related to the higher exposure of the fellow in shoulder surgery to the radiographic exam during his training in general orthopedics, so this professional was more familiarized with radiographic evaluations than MRI images.

These mechanical effects do not seem to influence image extraction.

Conclusion

There were no statistically significant differences in MRI data and CSA radiographs, with a mean divergence between the methods of only 0.76°.

The MRI seems to have its efficiency associated with more experienced evaluators.

Regardless of the evaluator's experience, data variability was lower in the MRI assessments.

Conflict of interests
The authors have no conflict of interests to declare.

References

1 Fukuda H, Hamada K, Yamanaka K. Pathology and pathogenesis of bursal-side rotator cuff tears viewed from en bloc histologic sections. Clin Orthop Relat Res 1990;(254):75–80
2 Bedi A, Maak T, Walsh C, et al. Cytokines in rotator cuff degeneration and repair. J Shoulder Elbow Surg 2012;21(02):218–227
3 Hashimoto T, Nobuhara K, Hamada T. Pathologic evidence of degeneration as a primary cause of rotator cuff tear. Clin Orthop Relat Res 2003;(415):111–120

4 Moor BK, Bouaicha S, Rothenfluh DA, Sukthankar A, Gerber C. Is there an association between the individual anatomy of the scapula and the development of rotator cuff tears or osteoarthritis of the glenohumeral joint?: A radiological study of the critical shoulder angle Bone Joint J 2013;95-B(07):935–941
5 Gomide LC, Carmo TC, Bergo GHM, Oliveira GA, Macedo IS. Associação entre o ângulo crítico do ombro e lesão do manguito rotador: um estudo epidemiológico retrospectivo. Rev Bras Ortop 2017;52(04):423–427
6 Gerber C, Snedeker JG, Baumgartner D, Viehöfer AF. Supraspinatus tendon load during abduction is dependent on the size of the critical shoulder angle: A biomechanical analysis. J Orthop Res 2014;32(07):952–957
7 Chalmers PN, Salazar D, Steger-May K, Chamberlain AM, Yamaguchi K, Keener JD. Does the critical shoulder angle correlate with rotator cuff tear progression? Clin Orthop Relat Res 2017;475 (06):1608–1617
8 Bouaicha S, Ehrmann C, Slankamenac K, Regan WD, Moor BK. Comparison of the critical shoulder angle in radiographs and computed tomography. Skeletal Radiol 2014;43(08):1053–1056
9 Smith-Bindman R, Lipson J, Marcus R, et al. Radiation dose associated with common computed tomography examinations and the associated lifetime attributable risk of cancer. Arch Intern Med 2009;169(22):2078–2086
10 Spiegl UJ, Horan MP, Smith SW, Ho CP, Millett PJ. The critical shoulder angle is associated with rotator cuff tears and shoulder osteoarthritis and is better assessed with radiographs over MRI. Knee Surg Sports Traumatol Arthrosc 2016;24(07):2244–2251
11 Nikooyan AA, Veeger HE, Westerhoff P, Graichen F, Bergmann G, van der Helm FC. Validation of the Delft Shoulder and Elbow Model using in-vivo glenohumeral joint contact forces. J Biomech 2010;43(15):3007–3014
12 Favre P, Snedeker JG, Gerber C. Numerical modelling of the shoulder for clinical applications. Philos Transact A Math Phys. Eng Sci 2009;367(1895):2095–2118
13 Oizumi N, Tadano S, Narita Y, Suenaga N, Iwasaki N, Minami A. Numerical analysis of cooperative abduction muscle forces in a human shoulder joint. J Shoulder Elbow Surg 2006;15(03):331–338
14 Lippitt S, Matsen F. Mechanisms of glenohumeral joint stability. Clin Orthop Relat Res 1993;(291):20–28

