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

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Keywords
► rotator cuff
► shoulder joint
► radiography
► magnetic resonance imaging
► reproducibility of results

Abstract

Objectiveto 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.

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

ResultsThe 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.

ConclusionThere 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.

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.

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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. The critical shoulder angle (CSA), which is obtained through radiographic evaluations, has been considered an important predictive factor for mechanical overload. A biomechanical assay analysis has also corroborated the establishment of this correlation.

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. 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. However, tomography exposes the patient to higher doses of radiation than radiography, and its indication should be more carefully evaluated. The use of nuclear magnetic resonance (NMR) does not use ionizing radiation, being widely recommended 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.

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.

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.
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. (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.

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 $0.76° ± 0.72$ (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 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.
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 overload,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 the MRI groups, regardless of the type of evaluator.

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 evaluators, 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.

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### 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° ± 1.13  | 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                                                 |
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