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ORIGINAL ARTICLE

Ultrasonography and magnetic resonance imaging of elbow ligaments: a comparative study

Ultrassonografia na avaliação de ligamentos de cotovelo: estudo comparativo com imagem de ressonância magnética

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ABSTRACT

Objective: To determine the value of ultrasonography in elbow ligament assessment compared to magnetic resonance imaging. **Methods:** A prospective single-center study involving 30 volunteers with no elbow joint changes. Two experienced ultrasound specialists evaluated both elbows of each volunteer, resulting in 60 evaluations per physician and totaling up 120 evaluations. Magnetic resonance images were obtained using a 3-Tesla machine and evaluated by two experienced radiologists, totaling up 120 exams. Each examiner assigned subjective, zero-to-5 scores to ligaments imaged, where zero corresponded to non-identified ligament and 5 to visualization of the entire ligament. The level of significance was set at 5%. Bland-Altman dispersions and plots were prepared for each pair of measurements obtained. **Results:** All ligaments were amenable to sonographic identification; scores of 4 or 5 were assigned by examiners based on ligament visibility. Ligaments could also be identified using magnetic resonance imaging and were assigned scores of 5 by examiners. All ligaments were described as intact and healthy by all four examiners. Comparative analysis of elbow ligament sonographic and magnetic resonance imaging findings did not differ significantly. **Conclusion:** Ultrasonography and magnetic resonance imaging can be considered equivalent modalities for elbow ligament assessment in the hands of experienced examiners.

Keywords: Ligaments/diagnostic imaging; Elbow; Ultrasonography; Magnetic resonance imaging

RESUMO

Objetivo: Avaliar o desempenho da ultrassonografia na avaliação dos ligamentos do cotovelo, comparando os achados com ressonância magnética. **Métodos:** Estudo prospectivo unicêntrico envolvendo 30 pacientes, sem alterações articulares nos cotovelos. Dois ultrassonografistas experientes avaliaram ambos os cotovelos de cada um dos pacientes, com 60 avaliações cada médico e 120 avaliações no total. As imagens de ressonância magnética foram obtidas em aparelhos 3 Tesla. Dois radiologistas experientes avaliaram as imagens, com total de 120 exames. Cada examinador deu uma nota subjetiva, de zero a 5, para os ligamentos avaliados; zero correspondeu a ligamento não identificado, e 5 a ligamento visualizado integralmente. Foi considerado nível de significância de 5%. Para cada par de medidas obtidas, construíram-se

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dispersões e parcelas de Bland-Altman. **Resultados:** Todos os ligamentos foram identificados pelos examinadores de ultrassonografia, recebendo pontuação 4 ou 5, em relação à sua visibilidade, e foram identificados pelos examinadores de ressonância magnética, com pontuação 5. Foram considerados intactos e saudáveis pelos quatro examinadores. As comparações entre ultrassonografia e ressonância magnética na avaliação dos ligamentos do cotovelo não demostraram diferenças significativas. **Conclusão:** Quando realizada por examinadores experientes, a ultrassonografia pode ser considerada semelhante à ressonância magnética na avaliação de ligamentos do cotovelo.

Descritores: Ligamentos/diagnóstico por imagem; Cotovelo; Ultrassonografia; Imagem por ressonância magnética

INTRODUCTION

Magnetic resonance imaging (MRI) is currently the most popular imaging modality for elbow ligament assessment. Excellent spatial resolution and high reproducibility allowing for accurate differentiation between the annular, radial collateral and anterior and posterior bands of the medial and lateral ulnar collateral ligaments make MRI the imaging modality of choice for elbow ligament assessment.[1-6]

Ultrasonography (US) imaging of elbow ligaments is seldom requested and related studies are scarce. Ligaments appear as linear structures with regular contour and similar morphology, echogenicity and echotexture to tendons on US.[7-12]

High spatial resolution, high sensitivity and specificity, easy patient positioning, dynamic maneuvers during examination, high repeatability indices once proper understanding of the anatomy and technique is achieved and ease of access are thought to be contributing factors to sonographic identification of elbow ligaments.[13-17]

At the time of writing, qualitative and quantitative studies comparing the efficacy and reliability of US and MRI in elbow ligament assessment were lacking.

OBJECTIVE

To determine the ability of ultrasonography to image elbow ligaments identified using magnetic resonance imaging in asymptomatic volunteers, to investigate the levels of agreement between both imaging modalities in identification of different elbow ligaments, and to compare sonographic and magnetic resonance imaging measurements of ligament width.

METHODS

This study involved 30 volunteers with no history of ligament changes or elbow joint-related clinical complaints and submitted to US and MRI examination. Most volunteers were recruited among Radiology Service personnel at our institution. Participants were duly informed of study particularities and objectives by examiners and signed an Informed Consent form. This study was approved by the Research Ethics Committee of *Hospital Israelita Albert Einstein*, opinion no. 691.072, CAAE: 23800913.9.0000.0071.

Ultrasound examinations were performed using a specific protocol and dedicated equipment; a specific algorithm was used to reduce image discontinuity-related spicules and disorganizations and for improved contrast resolution and distinction of border and margin interfaces.

High frequency linear transducers ideal for imaging of superficial structures and ultrasound frequencies ranging from 5 to 12MHz were used.

Ultrasound image analysis was carried out by two experienced radiology specialists (Examiner A and Examiner B; 17 and 20 years in practice, respectively) with specific training in musculoskeletal sonography.

The right and left elbows of each participant were imaged by individual examiners (120 US examinations; 60 per examiner).

Therefore, the sample comprised 60 elbows (120 examinations per imaging modality); 5 ligaments were imaged per elbow, totaling up 1,200 ligament assessments.

Magnetic resonance imaging was performed using a 3-Tesla system (Tim Trio, Siemens®, Erlanger, Germany) and dedicated elbow coil; 3.0mm-thick axial, coronal and sagittal images were obtained in proton density weighed sequences (time repetition – TR, 2,300ms; time echo – TE, 30ms) with 640×640 matrix size and 1.817×902 field of view (FOV), fat saturation and no intravenous contrast agents. Images were obtained using dedicated elbow coil with the joint in central position.

Magnetic resonance imaging were analyzed by two experienced radiology specialists (Examiner C and Examiner D; 20 and 7 years in practice respectively) with specific training in musculoskeletal imaging.

Magnetic resonance imaging of the right and left elbows of each of the 30 volunteers were analyzed by individual examiners (120 MRI examinations; 60 per examiner).

Prior to measurements, examiners were instructed about criteria to be employed in this study. Individual ligaments were imaged independently from a temporal and spatial perspective. Ligament integrity was defined as follows: identification of individual ligaments and respective attachment sites, constant width and homogeneous longitudinal fibers.

Central segment width measurements of the anterior band of the medial ulnar collateral ligament were taken from US and MRI images. Ligaments were measured at 1/4, 2/4 and 3/4 segments. When analyzing target ligaments, examiners were instructed to fill out a spreadsheet based on a zero to 5 ligament scoring system, as follows: zero, ligament not identified; 1, ligament visualization <50%; 2, ligament visualization =50%; 3, ligament visualization >50%; 4, visualization of the entire ligament without identification of attachment sites and 5, visualization of the entire ligament and attachment sites.

Ligaments identified in US images were evaluated according to the following criteria: visualization of ligament fibers and attachment sites, assigned scores (zero to 5), width measurements and echogenicity assessment.

Ligaments identified in MRI images were evaluated as follows: visualization of ligament fibers and attachment sites, assigned scores (zero to 5), width measurements and signal assessment.

Score 5 ligaments with constant width and homogeneous signal were defined as intact ligaments.

The hypothesis of equivalence between pooled US (Examiners A and B) and MRI (Examiners C and D) measurements taken from right and left elbows was tested using a mixed model with the equivalence margin set at 0.5. Agreement between width measurements taken by different examiners using different devices per side and per site was investigated using the intraclass correlation coefficient, with 95% confidence intervals. Bland-Altman dispersion plots were prepared for each pair of measures obtained by two examiners. Based on autocorrelation and dependent variable principles, individuals were defined as sampling units in this study, which comprised more than 20 volunteers – a large enough sample for the experimental designed adopted. Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) software and the level of significance set at 5%.

RESULTS

Examiners were able to identify all ligaments using US. A total of 600 ligaments were imaged (120 US examinations; 300 ligaments imaged in 60 examinations performed by Examiner A and 300 ligaments imaged in 60 examinations performed by Examiner B). Of these, 590 (98.3%) were assigned scores of 5 and only 10 (1.6%) scored 4. All ligaments were described as intact by both US examiners.

Examiners were able to identify all ligaments using MRI. Scores of 5 were assigned to all ligaments examined (Table 1) based on visibility criteria. All ligaments were described as intact by both MRI examiners.

Sonography and MRI were equivalent imaging modalities for elbow ligament assessment in the hands of experienced examiners and specialists. Reproducibility of qualitative and quantitative findings of sonographic elbow ligament imaging performed by two experienced examiners amounted to 97.8%, as shown in figures 1 to 3. The correlation between both imaging modalities is clearly observed in figure 4.

Reproducibility of qualitative and quantitative findings of MRI of elbow ligaments performed by two experienced examiners amounted to 99.0%.

Table 1. Scoring system employed for ligament classification based on visible ligament portions. Imaging modality-specific (ultrasonography or magnetic resonance imaging) scores assigned by different examiners were correlated

Score	Description
1	Ligament not identified
2	Ligament visualization <50%
3	Ligament visualization =50%
4	Ligament visualization >50%
5	Entire ligament visualization, except attachments

DISCUSSION

The US and MRI findings of elbow ligaments did not differ significantly in this study. Images obtained using either imaging modality were equally accurate from a qualitative and a quantitative standpoint.

Sonographic identification of elbow ligaments was unexpectedly easy from the start, despite progressive improvement with increased expertise (*i.e.*, higher number of examinations performed). Ligament integrity could be safely attested in all US examinations performed. Likewise, all ligaments could be accurately identified and measured. Scores assigned by Examiners

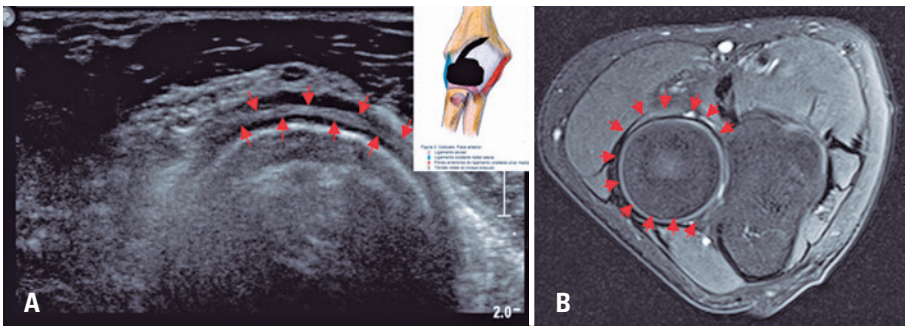

Figure 1. Annular ligament (red arrows) of the left elbow. (A) Ultrasound image. Note probe position (upper right-hand corner); (B) Axial magnetic resonance image: annular ligament and respective attachment sites on the medial and lateral aspect of the olecranon

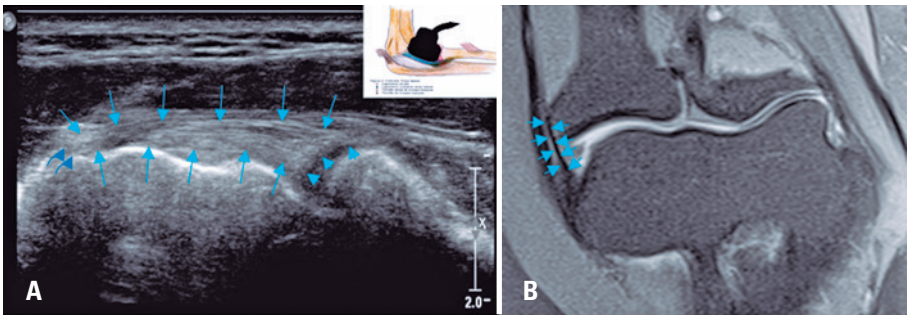

Figure 2. Lateral radial collateral ligament (light blue arrows). (A) Ultrasound image. Note probe position (upper right-hand corner) and attachments on the lateral epicondyle (blue arrowheads) and lateral aspect of the annular ligament (dark blue curved arrows); (B) Axial magnetic resonance image. Mid-third and distal attachment sites (on the annular ligament) of the lateral radial collateral ligament (blue arrows)

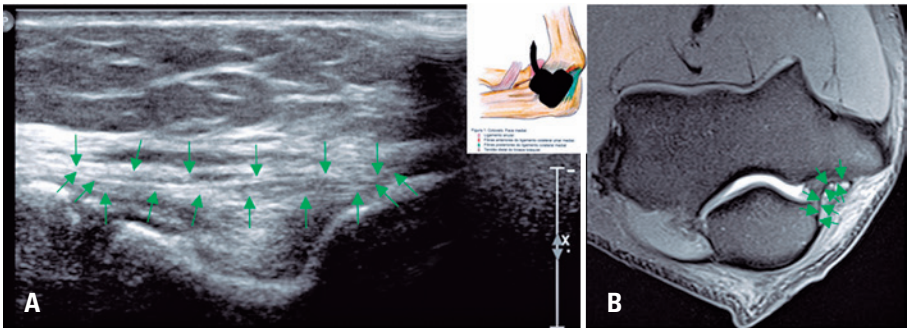

Figure 3. Posterior fibers of the medial ulnar collateral ligament (green arrows) and respective attachments on the posteromedial region of the medial aspect of the olecranon and medial epicondyle. (A) Ultrasound image. Note probe position (upper right-hand corner); (B) Axial magnetic resonance image

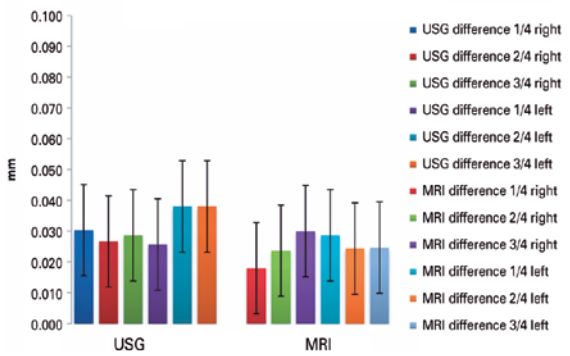

Figure 4. Mean differences between measurements taken by Examiners A and B (ultrasonography — USG) and C and D (magnetic resonance imaging — MRI). Bar indicates maximum and minimum differences

A and B differed minimally and non-significantly. Inter-examiner differences were thought to reflect natural variability between professionals.

Sonographic analysis in this study is amenable to criticism due to difficulties associated with US image interpretation, which may reflect mild imperfections in recorded material (*e.g.*, anisotropic diffusion and blurring due to loss of sharpness at the time of image freezing) or eventual unrecorded ligament portions (attachment sites in particular). Doubts (on the part of independent examiners) concerning appropriate depth

for image acquisition and resulting confusion in fiber delineation in some cases (whether superficial or deep) should also be accounted for. Finally, occasional reversal of craniocaudal probe orientation during US examination may be interpreted as erroneous ligament denomination by independent examiners.

Therefore, sonographic imaging of elbow ligaments should be performed by experienced radiology specialists exposed to proper continuous training in musculoskeletal sonography, if inaccurate results inconsistent with MRI findings are to be avoided.

Ligament integrity parameters are another important point regarding the application of statistical analysis. Ligament width is a major criterion in ligament integrity determination and statistical calculations are thought to be useful and valid. As far as echogenicity is concerned, intact ligaments normally present with homogeneous echogenicity and signal. In spite of direct correspondence between methods, these features have not been stratified. Echogenicity and signal may be classified as homogeneous or heterogeneous. Given all ligaments imaged were described as homogeneous, statistical analysis of this variable was not required.

Similar quantitative findings in US and MRI examinations bring both imaging modalities to the same level. Hence, besides MRI - a well-established tool for elbow ligament assessment – we now have US, offering physicians two reliable diagnostic imaging alternatives.

This study emphasizes the value of US as a practical and effective radiologic imaging modality for elbow ligament assessment and an alternative to MRI. Ultrasonography is a fast, user-friendly and widely available tool and may therefore be beneficial to patients.[18,19]

Proximity to the skin surface and lack of interposing bone structures make elbow ligaments easy to access and facilitate acquiring images of most dynamic manoeuvres involved in orthopedic assessment of this joint.

Wide availability, multiplanar and dynamic imaging are additional advantages of US over MRI. The applicability of US in settings where MRI is not available or in patients who do not have access to MRI cannot be overemphasized.[19,20]

Findings of this study are also relevant from a teaching standpoint. Ultrasonography may contribute to the understanding of elbow ligament anatomy and is yet another real-time teaching tool for radiologic dissection of elbow tendons.

Hence, proper training of radiologists on the use of this imaging modality could benefit a larger population of patients.

CONCLUSION

Qualitative and quantitative analysis of sonographic and magnetic resonance imaging findings by experienced examiners yielded similar outcomes. Both methods proved highly accurate for elbow ligament imaging, despite the current consensus about the absolute diagnostic superiority of magnetic resonance imaging over other imaging modalities, including ultrasonography. Findings of this study represent a paradigm shift and introduce a wider array of alternatives for elbow ligament imaging. Ultrasonography provides similar levels of accuracy to magnetic resonance imaging in the hands of experienced examiners.

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