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Original Article

New quantitative method to measure the Hill-Sachs lesion: validation of Hardy's radiographic method for MRI/AMRI☆

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ABSTRACT

Objective: To validate Hardy's radiographic method for magnetic resonance imaging/magnetic resonance arthrography (MRI/MRA) in the assessment of Hill-Sachs lesion (HSL) involvement in patients with a history of anterior shoulder instability.

Methods: This study retrospectively evaluated 53 shoulder radiographs and MRI/MRA to compare the measurements of HSL through Hardy's radiographic method. Imaging exams used in the study were conducted between the March 2013 AND September 2015. The data obtained from these exams were carried out during 2015. Inclusion criteria were previous history of anterior instability of the shoulder, presence of LHS, and radiographs at 70° medial rotation.

Results: MRI/MRA had a sensitivity of 100% and specificity of 100% when using the Hardy's radiographic method 20% cutoff point to measure the HSL.

Conclusion: MRI/MRA can be used to assess the degree of HSL involvement with the same reliability as Hardy's radiographic method.

Novo método quantitativo para medida da lesão de Hill-Sachs: validação do método radiográfico de Hardy para ressonância magnética/artro-RNM

Palavras-chave:
Índices de instabilidade
Luxação do ombro
Imagem por ressonância magnética

RESUMO

Objetivo: Validar o índice radiográfico de Hardy para ressonância magnética/artrorressonância magnética (RM/ARM) na avaliação do grau de acometimento da lesão de Hill-Sachs (LHS) em pacientes com histórico de instabilidade anterior do ombro.

Métodos: Foram avaliados retrospectivamente 53 exames radiográficos e de RM/ARM do

☆ Study conducted at Hospital Ortopédico de Belo Horizonte, Belo Horizonte, MG, Brazil.

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ombro para comparação das medidas da LHS por meio do índice radiográfico de Hardy. Os exames de imagem usados no estudo foram feitos entre março de 2013 e setembro de 2015. A coleta dos dados desses exames foi feita durante 2015. Os critérios de inclusão foram: história de instabilidade anterior do ombro, presença de LHS e radiografias em rotação medial com 70°.

Resultados: A RM/ARM apresentou sensibilidade de 100% e especificidade de 100% quando usado o ponto de corte de 20% do índice de Hardy para mensuração da LHS.

Conclusão: A RM/ARM pode ser usada para avaliação do grau de acometimento da LHS com a mesma confiabilidade da avaliação radiográfica pelo índice de Hardy.

Introduction

The Hill-Sachs lesion (HSL), described in 1940, was defined as an impaction fracture of the lateral posterosuperior portion of the humeral head against the glenoid cavity; it can be identified on medial rotation radiography.[1] This lesion occurs in association with anterior instability of the shoulder joint; according to the reports in the literature, it is present in 40–100% of cases.[2,3]

Burkhart et al.[4] introduced the concept of the engaging HSL. According to those authors, these lesions would be oriented parallel to the edge of the glenoid cavity when the shoulder is in the most vulnerable position for anterior dislocation (*i.e.*, maximum abduction and lateral rotation). These lesions predispose to dislocation recurrence or instability symptoms following Bankart's arthroscopic repair, as well as its failure. Some authors have indicated the location of engaging HSL as the most important factor for instability relapse.[5,6]

Numerous imaging methods can be used to quantify and classify a bone defect of the humeral head. Thus, according to the size and extent of the defect, the remplissage procedure can be used; this technique consists of tenodesis of the infraspinatus tendon at the HSL defect site. The purpose of this technique is to transform intra-articular HSL into extra-articular, in order to prevent engagement in lateral abduction and rotation movements. In 2012, Hardy et al.[8] measured the depth of the HSL in relation to the radius of the humeral head, on 45° medial-rotation radiographs. Gyftopoulos et al.[9] assessed HSL by MRI on axial and sagittal sections; they quantified depth, craniocaudal and anteroposterior extent, and volume. For an accurate and detailed assessment of soft tissue and bone lesions in cases of glenohumeral instability, radiographic (X-ray), magnetic resonance angiography (MRA) or MRI, and computed tomography (CT) images are required. These exams are time-consuming, which delays the treatment, increases the costs to the system, and creates a bureaucracy in the evaluation by the attending physician.

This study is aimed at validating the Hardy radiographic index for MRI/MRA in patients with a history of anterior shoulder instability, thus improving the clinical assessment of these images. The authors hypothesized that the Hardy radiographic index could be used in MRI/MRA with the same reliability.

Materials

This is a prospective analytical study of 53 shoulders, in which radiographic and MRI/MRA exams were performed from March 2013 to September 2015. All exams were performed exclusively in a single radiology clinic (Axial Medicina Diagnóstica). The data was collected and reviewed from the database of the surgical shoulder group of the Hospital Ortopédico de Belo Horizonte, Minas Gerais, Brazil. Subsequently, the exams were evaluated at Axial Medicina Diagnóstica and reviewed by only one radiologist, who had over 10 years of experience in the musculoskeletal area.

The variables gender, age, and dominant side were not considered. The inclusion criteria were history of anterior shoulder instability, presence of HSL, radiographs with 70° of internal rotation, in addition to the presence of MRI and/or MRA. Patients with a diagnosis of adhesive capsulitis, previous proximal humeral fracture, reverse HSL, and glenohumeral arthrosis were excluded from the study, as well as those with poor quality images and those with reports from other radiologists.

During MRI/MRA assessment, if the patient had not undergone X-ray or if that exam had been inadequately performed, the patient was asked to return to the clinic and a new X-ray was done under the supervision of a training physician specializing in shoulder surgery.

After applying the inclusion and exclusion criteria, 53 shoulders were assessed.

Methods

Radiographs were taken in a true anteroposterior orthostatic incidence (with the radiographic beam at 30° of the scapular plane) with the elbow flexed at 90° and the arm at 70° of internal rotation, measured with a goniometer. Poor-quality X-rays were repeated under the supervision of a training physician specializing in shoulder surgery. From this incidence, the Hardy index (Fig. 1A and B) was calculated, described as the ratio of HSL depth to the radius of the humeral head ($p/r \times 100\%$), which were measured using PACS software (Kodak Carestream PACS).

To calculate this measurement, it was necessary to outline the best fit for the humeral head. Subsequently, two

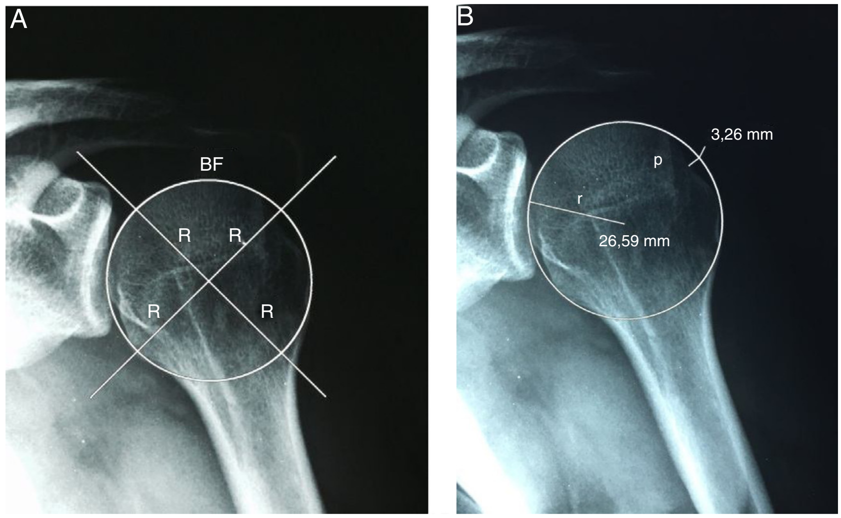

Fig. 1 – Demonstration of the evaluation of the Hardy index on X-ray. (A) The line around the humeral head represents the best fit (BF). The two perpendicular lines must have radii (*R*) with the closest possible values between them, thus determining the center of the head. (B) Determination of the humeral head radius (*r*) and the greatest depth of the HSL defect (*p*). After the perpendicular lines are removed, the Hardy index is calculated as the ratio of the depth (*p*) to the radius (*r*): *p*/*r*.

perpendicular lines (diameters = 2 *R*) were drawn in the probable center of the humeral head. Thus, these lines were required to have the same diameter, so that the center of the humeral head could be correctly located.

All patients underwent MRI or MRA (Magnetom Essenza 1.5 T, Siemens Healthcare) in the supine position with the shoulder in neutral rotation; T2-weighted sequences were used with or without fat suppression (TR/TE 2280/42, FOV 160 × 100 mm, matrix 384 × 70, 3 mm thickness) on an axial plane, which was post-processed (Kodak Carestream PACS) for bone defect calculation.

The HSL was calculated from the selection of two images. The first image where the greatest depth of the defect was observed, and the second, the largest transverse diameter of the humeral head. In both images, a virtual circle was drawn (best fit) coinciding with the articular surface. In the first image, the distance between the deepest point of the lesion and the arch (*p*) was calculated; in the second, the radius of the humeral head was calculated from the circle (*r*). The same index was obtained by the relation between the measurements (Fig. 2A–C). It is important to note that, in order to reach the correct depth of the HSL, it is necessary to identify the cortical defect, disregarding the bone edema. The images of the 53 patients were evaluated with the help of PACS software (Kodak Carestream PACS).

Regarding the 20% cut-off point evaluated by X-ray for remplissage indication or not,[7] the Receiver Operating Characteristic (ROC) curve was used to achieve the highest sensitivity and specificity in MRI/MRA.

The statistical analysis was performed using MedCalc software.

This study was approved by the research ethics committee of the institution.

Results

Fifty-three radiographic exams from 23 MRIs and 30 MRAs were analyzed. The mean degree of HSL involvement, calculated on X-ray using the Hardy index, was 18.37%. The mean values found for MRI and MRA were 17.91% and 17.93%, respectively.

The statistical analysis of the present study indicated a sensitivity rate of 100% and a specificity rate of 100% to evaluate HSL through MRI/MRA compared with X-ray, with a statistically significant similarity ($p < 0.0001$).

With the calculation of the area of the ROC curve, a cut-off point of 20% can be determined for the indication of the remplissage procedure (Table 1).

Discussion

The authors believe that the characteristics of the HSL have demonstrated an increasing applicability in the prognosis of the instabilities of the shoulder. Engaging lesions have shown worse results regarding arthroscopic stabilization.[4,10] Often, additional arthroscopic or even open procedures are necessary to avoid the risk of postoperative recurrence.[11,12] Many studies have been conducted to measure the size of the HSL, its position in relation to the edge of the glenoid cavity (engaging or non-engaging lesions), and to quantify the percentage of humeral head volume involved, considering the cut-offs of 20% to 40% for surgical intervention.[13,14] In a recent study by Cho et al.,[6] 3-D CT was used to determine HSL size, location, and its orientation when engaging. These authors concluded that lesions predisposed to engagement are typically larger and more horizontal.

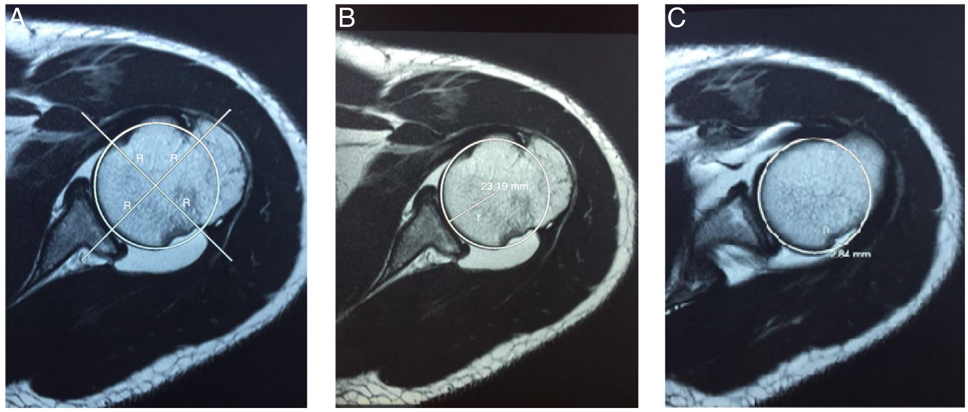

Fig. 2 – Demonstration of Hardy index assessment on MRI/MRA. (A) The line that circumscribes the humeral head determines the best fit. The two perpendicular lines must have radii (R) with the closest possible values between them, thus determining the center of the head; (B) humeral head radius (*r*); (C) depth of the HSL defect (*p*). The Hardy index is calculated as the ratio of the depth (*p*) over the radius (*r*): *p*/*r*. It is important to note that (*p*) and (*r*) are measured at different levels of the humeral head (the HSL is posterosuperior and the largest radius (*r*) is more inferior to it).

Table 1 – MRI/MRA sensitivity and specificity according to the Hardy index.

Hardy index (%)	Sensitivity	Confidence interval (95%)	Specificity	Confidence interval (95%)
≥5	100	79.4–100.0	0	0.0–9.5
>5	100	79.4–100.0	2.7	0.07–14.2
>8	100	79.4–100.0	5.41	0.7–18.2
>9	100	79.4–100.0	10.81	3.0–25.4
>10	100	79.4–100.0	16.22	6.2–32.0
>11	100	79.4–100.0	21.62	9.8–38.2
>12	100	79.4–100.0	27.03	13.8–44.1
>13	100	79.4–100.0	40.54	24.8–57.9
>14	100	79.4–100.0	51.35	34.4–68.1
>15	100	79.4–100.0	64.86	47.5–79.8
>16	100	79.4–100.0	72.97	55.9–86.2
>17	100	79.4–100.0	83.78	68.0–93.8
>18	100	79.4–100.0	86.49	71.2–95.5
>19	100	79.4–100.0	91.89	78.1–98.3
>20	100	79.4–100.0	100	90.5–100.0
>21	81.25	54.4–96.0	100	90.5–100.0
>22	62.5	35.4–84.8	100	90.5–100.0
>23	50	24.7–75.3	100	90.5–100.0
>27	37.5	15.2–64.6	100	90.5–100.0
>28	31.25	11.0–58.7	100	90.5–100.0
>29	25	7.3–52.4	100	90.5–100.0
>33	18.75	4.0–45.6	100	90.5–100.0
>34	12.5	1.6–38.3	100	90.5–100.0
>35	6.25	0.2–30.2	100	90.5–100.0
>36	0	0.0–20.6	100	90.5–100.0

In 2007, Yamamoto et al.[5] introduced the concept of glenoid track as a region of the humeral head that slides into the glenoid cavity during abduction and lateral rotation. These authors also described that, when the HSL is extended more medially along the glenoid track, the risk of dislocation increases considerably. Furthermore, they suggested that the location, not the size or depth of the defect, is more important in determining engagement.

The identification and quantification of bone defects observed in anterior shoulder instability, such as HSL and lesions to the anterior border of the glenoid cavity, have gained increasing importance when drafting a treatment plan; however, it has not been given the same importance in radiological literature as that given to soft tissue injuries.[9,15] An accurate appraisal of bone lesions is crucial to determine the technique and success of surgery in these patients, especially in those with recurrent instability after previous capsuloligamentous repair.[16,17]

In 2006, in a prospective study, Boileau et al.[18] established factors that predispose to glenohumeral instability recurrence: age under 20 years; the practice of competitive, contact, or weight sports; ligament hyperlaxity; and visible bone defects in the humeral head and in the glenoid cavity. In 2012, Hardy et al.[8] evaluated 71 patients with traumatic shoulder instability with radiographs and arthrotomography. They found a sensitivity of 84% in the detection of HSL on X-rays in an anteroposterior view with 45° of internal rotation; those authors used the depth of the lesion and the radius of the humeral head (*p/r*). The same authors also observed that the HSL volume was significantly higher in patients with recurrent instability.

During the literature search for the present study, it was observed that the positioning used by Hardy et al.[8] placed the affected upper limb in 45° of internal rotation; however, in a presentation by the same author in 2007, the position of the arm was described as 70° of internal rotation. Faced with an impasse regarding which would be the best position, the author of the method was sent an E-mail with this question; he clarified that the correct position would be at least 70° of internal rotation.

It is noteworthy that the method recommended by Hardy et al.[8] established that HSL with values greater than 15% presented a recurrence rate of up to 56% when only the Bankart arthroscopic repair was performed. For values lower than 15%, the failure rate decreased to 16%. However, it is difficult for the technician to properly position the patient for the X-ray at a medial rotation of 70°, estimate the best fit, locate the center of the humeral head and determine the correct depth of the lesion. Radiography is a swift and less expensive method; it has been preferred over other methods, such as 3D-CT and MRI/MRA. This service routinely uses X-rays to evaluate shoulder instability in the anteroposterior, anteroposterior with 70° of internal rotation, and Bernageau glenoid profile views.

MRI/MRA has demonstrated a high sensitivity and specificity for the detection of bone defects in the humeral head. In a study with 87 patients with glenohumeral instability who underwent to MRI and arthroscopy, Hayes et al.[19] detected a sensitivity up to 96.3% and a high specificity of 90.6% for MRI.

Thus, MRI has been recommended for detection of bone defects of the glenoid cavity or humeral head, besides labral, chondral, and ligament lesions.[16,20] To date, no MRI/MRA study has established a cut-off value for indicating the remplissage procedure. This indication is still done as described by Hardy et al.[8]

In the present study, the maximum sensitivity and specificity in the evaluation of HSL was achieved by MRI/MRA; in the indication of the remplissage procedure, the authors considered the cut-off value 20%, which is the same as in the original study by Hardy et al.[8] Despite the validation of the method, the confidence interval should be considered, which could be lower if the sample had been more representative.

Gyftopoulos et al.[9] compared the findings of the physical examination with location and size (craniocaudal, anteroposterior, depth, and volume) of the HSL on MRI. They found greater lesions in the engaging-type patients, but this difference was not statistically significant.

The present study was aimed at validating the Hardy radiographic method with MRI/MRA. Some important points should be noted. Variables such as gender, age, and dominant side were not taken into account, as the present study did not focus on functional assessment, but rather on imaging methods. Another extremely relevant factor that has not been found in the literature is the observation made by the radiologist of the group that, in the MRI/MRA, the radius of the humeral head cannot be measured in the same slice used to measure the greater depth of the HSL, otherwise the index value will be overestimated. The radius of the humeral head should be measured at its largest diameter and the HSL, at the slice where it presents its greatest depth, which generally does not coincide since the HSL is located more superiorly and has a larger, lower radius.

In turn, Gracitelli et al.[21] evaluated the percentage of HSL involvement (in MRI or CT-arthrogram), considering as parameters the radius of the humeral head and the depth of the lesion in the same axial section. In the present authors' view, this measurement will only be overestimated if the largest radius of the humeral head is at the same height as the greatest depth of the HSL.

The main difficulties observed in the present study were the positioning of the patient at the moment of radiography, defining the best fit, and the real determination of the depth on X-rays, especially for those with very small HSL, due to the possible overlapping of images. The use of MRI/MRA as a single method for measuring bone lesions, with the goal of finding a practical and objective method that minimizes possible evaluation or positioning errors and also provides information on the involved soft tissue (labrum, ligaments, and cartilage), would bring more comfort and safety to the patient and reliability to the physician. This reliability translates into accuracy for the measurement of the HSL radius and depth with the aid of a software, as well as of the best fit, mainly because it does not require a precise positioning of the patient by the X-ray technician. Thus, the present study should contribute to a more precise quantitative analysis of posterosuperior lateral humeral head lesions by MRI/MRA of any dimension.

Conclusion

MRI/MRA has shown to have high sensitivity and specificity when a cutoff point of 20% is established as a criterion for indicating the remplissage technique. Thus, MRI/MRA reduces the time and facilitates a medical evaluation in the consulting room, because the surgeon gains other information, such as location and volume of the HSL and presence of labral, chondral, and ligament lesions, whenever these complementary exams are requisitioned. The present results confirm the proposed hypothesis.

Conflicts of interest

The authors declare no conflicts of interest.

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