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MRI classification of rotator cuff arthropathy

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There are several classifications of rotator cuff arthropathy, which are predominantly based on the X-ray examination of patients. The aim of the study was to develop an MRI classification of rotator cuff arthropathy of the shoulder joint. Methods. We included to the study MRI examinations of 91 patients with rotator cuff arthropathy. Presence of acromion acetabularization, deterioration of the shoulder joint articular cartilage, fatty degeneration of the rotator cuff muscles (except teres minor muscle) according to the Goutallier classification, global fatty degeneration index (GFDI) were determined on MRI. Results. After analyzing the above-mentioned criteria, we divided all patients into 4 groups depending on the stage of the disease. We compared the distribution of patients into groups according to the Hamada X-ray classification and according to the proposed MRI classification and made sure of the reproducibility of the data. Conclusion: After comparing Hamada's classification and our classification, we found that the first stage according to Hamada's classification corresponds to the first stage of our MRI classification, the second stage corresponds to the second and third stages of MRI classification, the third, fourth and fifth stages according to Hamada's classification correspond to the fourth stage of our MRI classification. The MRI classification of rotator arthropathy of the shoulder joint presented by us has advantages over the Hamada classification and other radiological classifications, since it takes into account not only the migration of the humeral head and the presence of omarthrosis, but also answers the question of the condition of the rotator cuff muscles, which allows us to determine the rational tactics of surgical treatment in this group of patients.

На сьогодні існує кілька класифікацій ротаторної артропатії, які переважним чином ґрунтуються на рентгенологічному обстеженні хворих. Мета. Розробити класифікацію, засновану на даних магнітно-резонансної томографії (МРТ) ротаторної артропатії плечового суглоба. Методи. До дослідження включено МРТ-обстеження 91 хворого. Визначали наявність ацетабуляризації акроміона, зменшення величини суглобового хряща плечового суглоба, жирову дегенерацію м'язів ротаторної манжети плеча (окрім малого круглого м'яза) за класифікацією Goutallier на сагітальних зрізах у Y-проєкції, глобальний індекс жирової дегенерації (GFDI), ушкодження інших м'якотканинних структур ПС (суглобова губа, зв'язки, які утримують сухожилок довгої головки біцепса тощо). Результати. Ураховуючи зазначені критерії ми розділили всіх хворих на 4 групи залежно від стадії захворювання. Порівнюючи розподіл хворих за групами згідно з класифікацією Hamada та запропонованою нами, ще раз переконалися у відтворюваності даних. Висновки. Під час порівняння ступеней за класифікацією Hamada та МРТ, з'ясували, що 1 відповідає 1; 2 — 2 та 3; 3, 4 та 5 — 4 ступеню МРТ класифікації. Наведена нами МРТ класифікація ротаторної артропатії плечового суглоба має переваги над Hamada й іншими рентгенологічними класифікаціями, оскільки вона враховує не лише міграцію головки плечової кістки та наявність омартрозу, а й відповідає на питання про стан м'язів ротаторної манжети плеча, що дозволяє визначитися з раціональною тактикою хірургічного лікування цієї групи хворих.

Ключові слова. Ротаторна манжета плеча, ротаторна артропатія, сухожилок надостьового м'яза, плечовий суглоб.

Key words. Shoulder rotator cuff, rotator cuff arthropathy, massive rotator cuff tear, shoulder joint

Introduction

Rotator cuff arthropathy (RCA) is a pathological condition of the shoulder joint (SJ) that develops as a result of massive (two or more) rotator cuff tendon ruptures, degenerative changes in the SJ, and cranial or ventrocranial displacement of the humeral head [1–4].

There are several classifications of rotator cuff arthropathy, which are primarily based on radiological examinations of patients [1, 4–6]. One of the main classifications is the radiological classification by Hamada [1, 6, 7], where the primary criterion for evaluation is the measurement of the acromio-humeral distance. Other criteria include the reduction of the distance between the scapula and humeral head due to cartilage damage in the SJ and the deformation (collapse) of the humeral head. Other well-known classifications are by Seebauer [6] and Favard [1, 7], which are also based on radiological research. The main criteria in these are the reduction of the acromio-humeral and scapulo-humeral distances and the deformation of the humeral head [7, 8]. However, all of these classifications fail to account for the condition of the rotator cuff muscles, the presence of concurrent disorders of the shoulder joint (SJ), and as a result, they do not assist clinicians in determining the appropriate surgical approach. Furthermore, when a rotator cuff tendon rupture is suspected, most patients are only referred for MRI examinations. X-ray imaging of the SJ is generally not performed regularly, nor is it done in the specific projections or angles recommended by the authors of these classifications. A review of the global literature revealed that no MRI-based classification of rotator cuff arthropathy has been developed that integrates established radiological classifications, takes into account the state of the rotator cuff muscles, and provides physicians with a comprehensive framework for guiding treatment decisions.

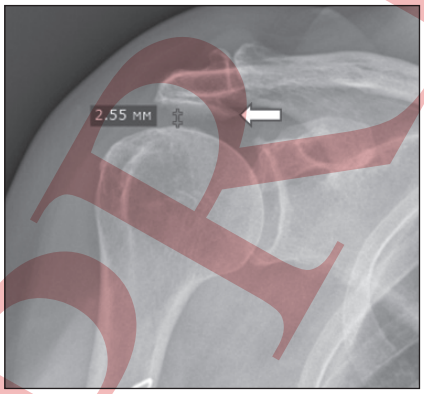

Fig. 1. X-ray of the right shoulder joint in the anteroposterior projection, showing grade 3 rotator cuff arthropathy (2.55 — the size of the subacromial space; the arrow indicates acromion acetabularization)

Purpose: To develop a classification based on MRI data of rotator cuff arthropathy of the shoulder joint.

Materials and methods

The study included MRI examinations of 91 patients who were hospitalized between 2014 and 2024 at the Clinic of Reconstructive and Restorative Surgery of the Upper Limb at the State Institution "National Institute of Traumatology and Orthopedics of the National Academy of Medical Sciences of Ukraine" (Kyiv) and had rotator cuff arthropathy of varying degrees at the time of examination. The age of the patients ranged from 35 to 80 years (mean 48.2 ± 19.8). The work was approved by the local bioethics committee (protocol No. 6 dated 14.07.2025) of the respective institution in accordance with the ICH GCP guidelines, the Helsinki Declaration on Human Rights and Biomedicine, as well as the current legislation of Ukraine. All participating patients were informed about the plan and conditions of the study and gave their written and verbal consent.

All patients underwent clinical and radiological examinations before the start of treatment. X-ray images of the SJ were performed in a standing or sitting position, with the X-ray beam perpendicular to the axis of the scapula at a craniocaudal angle of 20° (Figure 1) to determine the degree of rotator cuff arthropathy according to Hamada. The normal acromio-humeral interval was considered to be between 8–12 mm [1, 7–13].

Additionally, all patients underwent MRI examinations of the anatomical structures of the SJ, including the rotator cuff tendons and muscles, using T1, T2, Pd, and Pdfatsat imaging sequences. MRI was used to assess the following:

1. Presence of acromion acetabularization (Figure 2a);
2. Reduction in the joint cartilage thickness of the SJ (Figure 2b);
3. Fatty degeneration of rotator cuff muscles (excluding the teres minor muscle) according to the Goutallier classification on sagittal sections in the Y projection [9, 10–13] (Figure 2c);
4. Global Fatty Degeneration Index (GFDI) [7, 10];
5. Damage to other soft tissue structures of the SJ (labrum, ligaments holding the long head of the biceps tendon, etc.).

The Global Fatty Degeneration Index (GFDI) is an indicator used in orthopedics to quantitatively assess the severity of fatty degeneration, or fatty infiltration,

in the rotator cuff muscles. It is calculated as the average score based on the Goutallier scale (from 0 to 4) assigned to the supraspinatus, infraspinatus, and subscapularis muscles, which are identified via MRI. A high GFDI indicates more severe fatty infiltration and is associated with a worse prognosis, including an increased risk of re-rupture and decreased functional outcomes after rotator cuff surgery [1, 7, 10].

The study's inclusion criteria comprised the following: verified massive rotator cuff tendon rupture and rotator cuff arthropathy of the shoulder joint (SJ) irrespective of severity; availability of MRI scans conducted with a magnetic field strength of 1.5 Tesla; participant age between 35 and 80 years; and the absence of concomitant shoulder joint conditions, including arthritis, calcific tendinitis, or any bony pathology affecting the proximal epimetaphysis of the humeral bone.

Statistical data processing was carried out using the STATISTICA 12.0 software package. The Student's t-test was used for comparisons between two groups, assuming normal distribution of the data. The Mann-Whitney U test was applied for comparisons between two or more groups when the data distribution deviated from normal. The χ^2 test was used to assess the differences in distribution between two samples.

Results

Table 1 displays the SJ classification of rotator cuff arthropathy, which was developed by our team and is based on MRI results. This classification allows for dividing patients into four groups according to the severity of the disease (Table 1), which is determined by the degree of fatty degeneration in the RCMs and changes in the bony structure of the SJ, both of which can be clearly evaluated during MRI examination (Fig. 1, 2).

In no case did we observe acromion acetabularization without fatty degeneration of the RCM or a global fatty degeneration index (GFDI) > 3 in the absence of fatty degeneration of the supraspinatus muscle. Thus, all patients with rotator cuff arthropathy of the SJ were classified by severity (Table 2).

Table 1

MRI classification of rotator cuff arthropathy of the shoulder joint

Degree of rotator cuff arthropathy	MRI feature
1	Fatty degeneration of the supraspinatus muscle: < Grade 3 on the Goutallier scale GFDI < 1; No acromion acetabularization and/or arthritic changes in the shoulder joint
2	Fatty degeneration of the supraspinatus muscle: ≥ Grade 3 on the Goutallier scale GFDI = 1–1.9 No acromion acetabularization and/or arthritic changes in the shoulder joint
3	Fatty degeneration of the supraspinatus muscle: ≥ Grade 3 on the Goutallier scale GFDI > 2–2.5 No acromion acetabularization and/or arthritic changes in the shoulder joint
4	Fatty degeneration of the supraspinatus muscle: ≥ Grade 3 on the Goutallier scale GFDI > 2.5 Presence of acromion acetabularization and/or arthritic changes in the shoulder joint

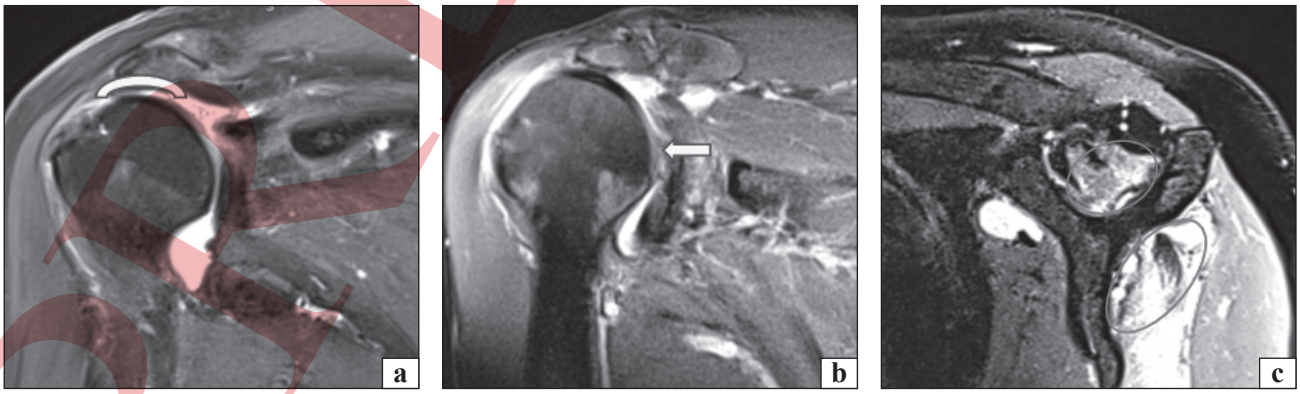

Fig. 2. MRI scan of the SJ: a) Frontal section in T2 Pdfatsat mode (yellow line indicates acromion acetabularization). b) Frontal section in T2 Pdfatsat mode (yellow arrow shows damage to the articular cartilage of the SJ). c) Sagittal section in T2 Pdfatsat mode (ellipses indicate remnants of the supraspinatus and infraspinatus muscles). Grade 3 fatty degeneration of the supraspinatus and grade 4 fatty degeneration of the infraspinatus muscles according to Goutallier

The majority of patients — 35 (38.5 %)—had grade 2 rotator cuff arthropathy according to the MRI findings (p = 0.031). The number of patients with grade 1 and grade 3 was comparatively low, accounting for 21 (23.1 %) and 20 (21.9 %) individuals, respectively. The smallest cohort comprised grade 4 patients, totaling 15 (16.5 %). In no case were signs of disease progression observed simultaneously in two groups.

Table 3 shows the distribution of patients according to the Hamada classification. It should be noted that the majority of patients had grades 1 and 2 rotator cuff arthropathy, i.e., they exhibited only soft tissue changes in the RCM, which were indirectly indicated on X-ray by a reduction in the subacromial space. Only patients with grades 3–5 rotator cuff arthropathy displayed radiological changes such as omarthrosis and acromion acetabularization.

By comparing Tables 2 and 3, we found that patients with grade 1 rotator cuff arthropathy according to the Hamada classification significantly corresponded to grade 1 in our MRI-based classification (p = 0.03); patients with grade 2 were categorized as grades 2 and 3 in the MRI classification (p = 0.67), while those with grades 3, 4, and 5 in the Hamada classification corresponded to grade 4 in the MRI classification (p = 0.041).

Table 2

Distribution of patients by grades of rotator cuff arthropathy according to MRI findings

Grade	Number of patients, (%)
1	21 (23.1)
2	35 (38.5)
3	20 (21.9)
4	15 (16.5)

Table 3

Distribution of patients by degree of rotator cuff arthropathy according to radiographic examination

Grade	Number of patients, (%)
1	21 (23.1)
2	55 (60.4)
3	8 (8.8)
4	4 (4.4)
5	3 (3.3)

Table 4 presents the treatment options for each grade of rotator cuff arthropathy of the SJ.

Thus, reverse shoulder arthroplasty is indicated for patients over 60 years of age with grade 3 rotator cuff arthropathy or grade 4 according to the MRI classification. In certain instances, reconstructive procedures involving the SJ are considered the optimal approach.

Discussion

The MRI classification of rotator cuff arthropathy of the SJ, as developed by our team, offers clinicians a dependable framework for selecting optimal treatment strategies for patients across all stages of rotator cuff arthropathy. This classification has been invaluable in our clinical practice for the past 10 years, allowing us to compare treatment outcomes using different methods.

In fact, our classification is a combination of the Hamada and Goutallier scales [1, 7, 10], which considers only the gross changes in the SJ, significantly reducing the likelihood of errors. For instance, when evaluating the acromio-humeral index (AHI) — the distance between the inferior surface of the acromion and the humeral head — 5 mm is considered grade 2 rotator cuff arthropathy according to Hamada, while 6 mm is considered grade 1. An error of 1 mm is highly probable and depends on the physician's experience, the quality, and the accuracy of the X-ray. Failure to properly position the X-ray beam at a 20° angle relative to the horizontal axis (top-to-bottom) and perpendicular to the axis of the scapula will prevent correct diagnosis (Figure 1). In our classification, the AHI is disregarded; the key factor is the presence of acromion acetabularization, which assigns the patient to grade 4 RCA with corresponding surgical treatment options. The dual evaluation of fatty degeneration according to Goutal-

Table 4

Treatment of rotator cuff arthropathy of the shoulder joint based on MRI findings

Grade	Surgical treatment
1	Rotator cuff tendon repair (open or arthroscopic)
2	Restoration of the superior capsule of the shoulder joint (open or arthroscopic).
3	In patients under 60 years of age — tendon transfer of the latissimus dorsi to the position of the external rotators, or the upper portion of the pectoralis major to the position of the internal rotators. In patients over 60 years of age — reverse shoulder arthroplasty
4	Reverse shoulder arthroplasty

lier, first for the supraspinatus and then for other muscles, along with the determination of the GFDI, also significantly reduces the risk of error.

Upon reviewing the English-language literature, we found no publications that combine the Hamada and Goutallier classifications. The vast majority of studies aimed to compare radiographic and MRI findings, particularly focusing on AHI and how factors like upper limb positioning, tendon tear size, and the time since injury affect the AHI [12–17, 20]. R. Mirzayan et al. noted that for early-stage rotator cuff arthropathy (grades 1–2), AHI values measured on radiographs did not correlate with MRI findings. Therefore, in the early stages of the disease, it is not possible to diagnose rotator cuff arthropathy using MRI. However, in the later stages (grades 3–5), there is no significant difference in AHI values [18]. C. M. Werner et al. also highlighted that AHI values for patients with rotator cuff arthropathy obtained from MRI and CT scans differed significantly from those obtained by X-ray. In their study, the authors found that AHI values during MRI correlated well with fatty degeneration of the RCM and proposed a formula to convert these MRI-based values into those obtained from radiographs [19].

Interesting findings by P. N. Chalmers et al. demonstrated that the AHI value was not dependent on the size of the rotator cuff tendon tear, and its progression over time did not influence the AHI value [5].

We believe that our proposed MRI-based classification has significant advantages over the Hamada scale and other classifications that rely solely on radiological changes in the SJ. This is because our classification takes into account not only the caudal displacement of the humeral head and the presence of articular cartilage damage in the SJ but also provides insight into the condition of the rotator cuff muscles and concomitant shoulder joint abnormalities.

Conclusions

By comparing the Hamada classification with our MRI-based classification, we found that: Grade 1 on the Hamada scale corresponds to grade 1 in our MRI classification. Grade 2 on the Hamada scale corresponds to grades 2 and 3 in our MRI classification. Grades 3, 4, and 5 on the Hamada scale correspond to grade 4 in our MRI classification.

The proposed MRI classification of rotator cuff arthropathy of the shoulder joint has advantages over the Hamada classification and other radiological classifications, as it not only considers the migration of the humeral head and the presence of omarthrosis but also addresses the condition of the rotator cuff muscles. This allows for a more rational approach to determining the appropriate surgical treatment strategy for this group of patients.

Conflict of interest. The authors declare that there is no conflict of interest.

Future research prospects. A promising direction for our upcoming research is the study of other significant pathological changes in the shoulder joint to further enhance our classification. However, adding more factors may make it more cumbersome and harder to understand for practicing orthopedic surgeons.

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Authors' contribution. Strafun S. S. — concept and design of the study; Bogdan S. V. — collection and processing of materials, writing the text; Strafun O. S. — Systematic analysis of the data; Serhienko R. O. — Systematic analysis of the data.

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