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PŮVODNÍ PRÁCE

Reliability of Ellman Classification System in Partial Thickness Rotator Cuff Tears on Magnetic Resonance Views

Spolehlivost Ellmanovy klasifikace u parciální ruptury rotátorové manžety na MR zobrazení

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ABSTRACT

PURPOSE OF THE STUDY

The current study aimed to investigate the intra- and inter-observer reliability of the Ellman classification system in partial-thickness rotator cuff tears through magnetic resonance imaging (MRI) scans instead of arthroscopic views.

MATERIAL AND METHODS

Pre-operative MRI scans of 45 patients, with confirmed partial-thickness rotator cuff rupture in previous arthroscopic surgeries (performed by the senior author), were obtained from Picture Archiving and Communication Systems records. The observers (n=8) were asked to categorize MRI scans according to Ellman's classification of location and grade. There were four orthopedic surgeons less experienced in rotator cuff operations in the first group and four more experienced orthopedic surgeons in the second group. They were asked to re-evaluate the MRI scans six weeks later, without access to their previous answers. Reliability evaluation was performed within and among the groups. It was also evaluated if the surgeon's experience increased the reliability of the classification. Fleiss kappa coefficient was used for the inter-observer reliability and Cohen kappa coefficient for the intra-observer reliability, and post hoc analysis was performed.

RESULTS

When all observers were examined in the inter-observer evaluation, it was seen that there was moderate agreement in the first location evaluation (κ=0.414); however, there was fair agreement in all other evaluations in both groups (κ=0.339–0.383–0.337, respectively). When all observers were examined in the mean intra-observer evaluation, it was seen that there was substantial agreement in both evaluations (κ=0.795–0.721, respectively).

DISCUSSION

A classification system must be valid, reliable, and reproducible. It should establish a standard terminology for both surgeons and researchers. The correct identification of the tear configuration is crucial for selecting the correct repair technique. In our study, in which we evaluated the Ellman classification, which is frequently used in arthroscopic diagnosis, we investigated its intra-observer and inter-observer reliability on MRI scans. Although the mean intra-observer evaluation results were substantial agreement (κ=0.795–0.721, respectively), inter-observer evaluation results were fair agreement (κ=0.339–0.383–0.337, respectively) except for the first location evaluation (κ=0.414).

CONCLUSIONS

Although intra-observer reliability was satisfactory, the Ellman system used in the classification of partial-thickness rotator cuff tears was not found to be useful by using only MRI views because of fair inter-observer reliability except for the first location evaluation, which was moderate agreement.

Key words: partial, rotator cuff, tear, Ellman classification, reliability, validity.

INTRODUCTION

Determining whether the rotator cuff tear is total or partial thickness is important in the treatment. In addition, the localization and depth of the tear may also change the treatment method in partial rotator cuff injuries (8, 11). For this reason, the sensitivity and specificity of magnetic resonance imaging (MRI), which is frequently used in making an operation decision, gains importance. Smith et al. In a meta-analysis study they conducted, the sensitivity and specificity values of MRI in partial thickness rotator cuff tears were determined as 0.80 and 0.95, respectively. They stated that the sensitivity and specificity for full-thickness tears were 0.91 and 0.97, respectively (13).

Many classification systems deal with rotator cuff pathologies by assessing the condition of tendons such as Neer (9), Snyder (14), Habermeyer (6) and Ellman (3), or the level of fatty degeneration in muscles such as Goutallier (5). Neer defines rotator cuff disease into three stages by looking at histological samples of the rotator cuff tissue, considering the age factor. However, this system has important clinical and intraoperative limitations, and it does not include the evaluation of

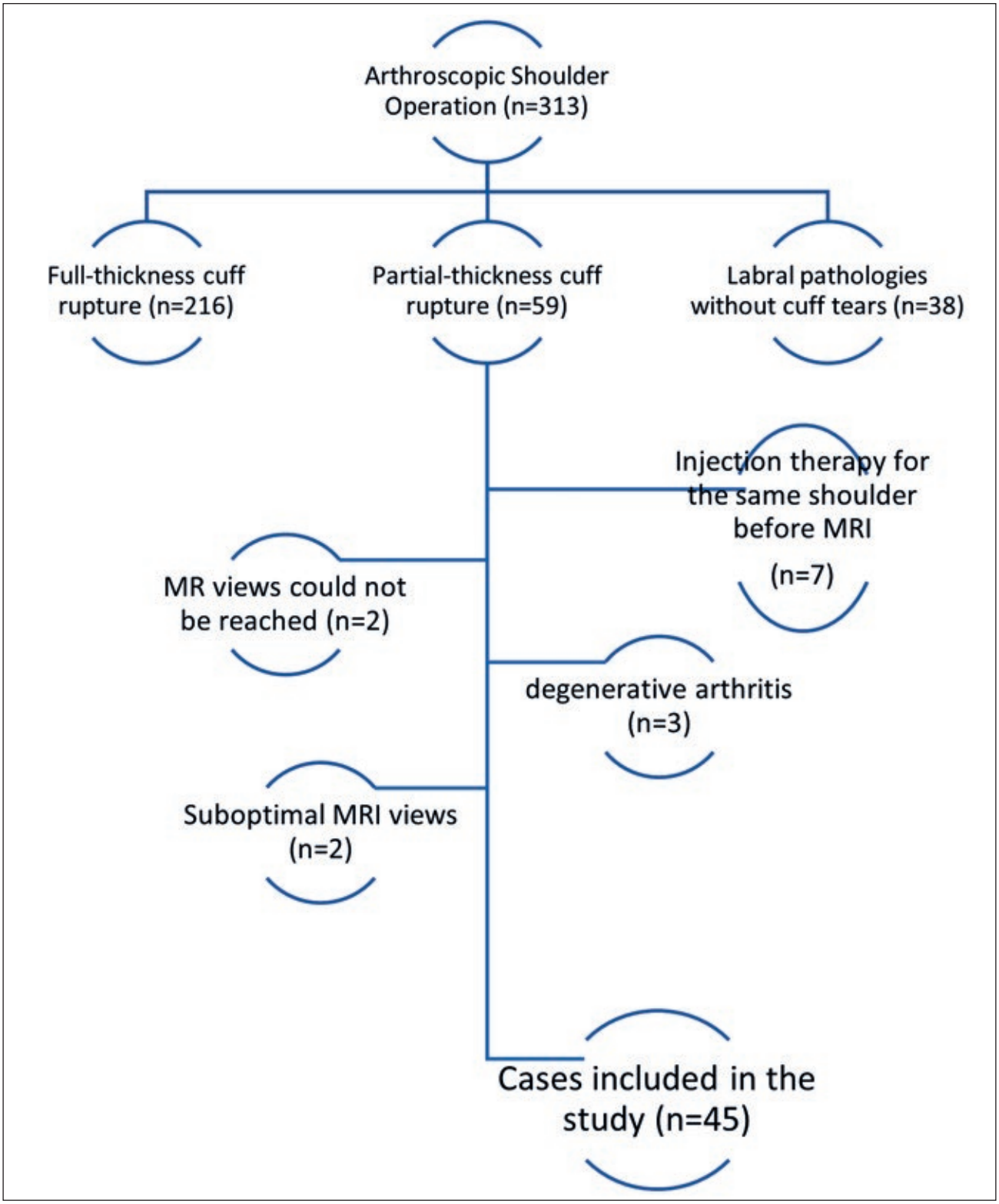

Fig. 1. Flow chart of cases.

partial-thickness tears. In Snyder's classification, evaluation is made according to the localization and severity of the tear. Habermeyer evaluation is a classification consisting of arthroscopic data for articular-sided supraspinatus footprint lesions. The Ellman classification is used for interpreting the grade and location of the partial-thickness tears, which was first described in the arthroscopic findings of partial-thickness rotator cuff tears.

Inter-observer evaluation of the Elmann Classification was performed on arthroscopy videos by Kuhn et al. (7), but no previous reliability studies of the Ellman

Fig. 2. Example of an intra-tendinous tear (grade IIIC) from a T2-weighted oblique coronal section.

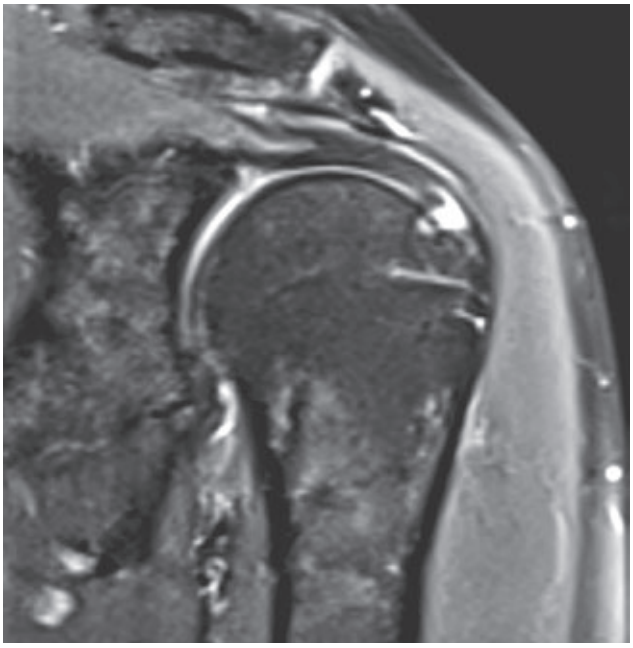

Fig. 3. Example of an articular surface tear (grade IIIA) from a T2-weighted oblique coronal section.

classification have been performed on MRI scans. Properly recognizing the features of the rotator cuff tear would indicate the appropriate treatment. Accurate diagnosis is important in the treatment of rotator cuff injury pre-operatively. For this reason, we tried to investigate the value of the Ellman classification in making the right operation decision. We aimed to find the intra- and inter-observer reliabilities of the Ellman classification through MRI scans instead of arthroscopic views in this study. It was hypothesized that the Ellman classification would be reproducible with high reliability on MRI evaluation.

MATERIAL AND METHODS

After obtaining the approval of the Research Ethics Committee (Date: 06/04/2022-decision number: 63/63/07), 313 patients, who underwent arthroscopic shoulder surgery by the senior author between 2019 and 2022 years, were retrospectively reviewed for this cross-sectional descriptive study.

The exclusion criteria were full-thickness cuff rupture (n=216), labral pathologies without cuff tears (n=38), suboptimal MRI views (poor quality MRI views) (n=2), patients who have received injection therapy for the same shoulder in the 3 weeks before MRI (n=7), patients whose preoperative MR views could not be reached (n=2), and degenerative arthritis (n:3) (Fig 1).

Pre-operative MRI scans (T2-weighted axial, T1 and T2-weighted oblique coronal, and T1 and T2-weighted oblique sagittal sections in video format) of 45 (14%) patients, with confirmed partial rotator cuff rupture in previous arthroscopic surgeries (performed by the senior author), were obtained from Picture Archiving and Communication Systems (PACS) records. All MRI scans were done with 1.5 Tesla (Siemens Magnetom Aera, Erlangen, Germany) and performed at 2 mm intervals. MRIs of all patients were performed using the same protocols and sequences. Arthroscopic views were not included in this study, as it was aimed to evaluate the Ellman classification validity on MRI.

MRI scans of 45 skeletally mature patients (23–54 years) of both genders were opened in separate tabs on the Fonet Dicom Viewer v4.1 (Fonet Bilgi Teknolojileri A.Ş., Gölbaşı, Ankara, TR) window and the name tags on the images were hidden by the program interface. The names written on the tab were closed by sticking paper to that area of the screen. Observers were asked to categorize MRI scans according to Ellman‘s classification of location (joint, bursal, and intra-tendinous) and grade (<3 mm [<25%], 3–6 mm [25–50%], and >6 mm [>50%]). Ellman classification was presented to the observers before MRI scans of each patient (Table 1). To determine the grade, distance measurements were made with measurement tools integrated into the same viewer software.

The observers (n=8) who have at least five years of experience were divided into two groups those who regularly perform rotator cuff operations (mini-open or arthroscopic) and those who do not. There were four orthopedic surgeons less experienced in rotator cuff operations in the first group and four more experienced orthopedic surgeons in the second group. Radiologists specializing in the musculoskeletal system are not always available in hospitals. Orthopedic specialists often have to undertake this task, depending on their area of interest. Therefore, orthopedists were preferred instead of radiologists as observers in this study.

Table 1. Ellman classification

Grade (thickness)		Location	
I	<3 mm (<25%)	A	articular side
II	3–6 mm (25–50%)	B	bursal side
III	>6 mm (>50%)	C	intratendinous

Table 2. Demographic data

	Male	Female	P value
Age mean±SD (range)	38.5±8.5 (23–49)	40.1±6.2 (26–54)	.170
Dominant/ Non-dominant arm (n)	12	19	.560
Total (n)	17	28	

SD: Standard deviation

Each observer made separate evaluations from the others. They were asked to re-evaluate the MRI scans six weeks later, without access to their previous answers. The order of tabs opened via viewer software has been changed and the procedures to hide the patient's names were repeated exactly. by an orthopedic surgeon who was not included in the study. Reliability evaluation was performed within and among the groups. It was also evaluated if the surgeon's experience increased the reliability of the classification.

Statistical analysis

SPSS 24 version was used for statistical analysis (IBM Corp., Armonk, New York, USA). Fleiss kappa (κ) coefficient was used for the inter-observer reliability and Cohen kappa (κ) coefficient for the intra-observer reliability.[4,10] A κ value is always between 0 and 1; the higher k value indicates a better correlation. The κ values were graded as slight (0–0.2), fair (0.21–0.40), moderate (0.41–0.60), substantial (0.61–0.80), and almost perfect (0.81–1).[1] In addition, Chi-Square tests were used to compare categorical data. Shapiro Wilk test was applied to the measurements to be evaluated for normality analysis and Mann-Whitney U analysis was used because there was no normal distribution. Post hoc power analysis was performed using the G*power 3.1.9.7 program (Heinrich-Heine-Universität Düsseldorf, Germany).

RESULTS

Twenty-eight (62%) of the patients whose MRI scans were evaluated were female and their mean age was 40.1±6.2 (26–454) years. The mean age of men was 38.5±8.5 (23–49) years (p=0.170). Thirty-one (69%) of the injuries were in the dominant arm (p=560). All patients in the study underwent surgical treatment. (Table 2) When the observers were evaluated, the less experienced group had 6.0±0.8 (5–7) years of surgical

Table 3. Inter-observer reliability values

	Set 1				Set 2			
	Location Fleiss κ (95% CI)	**Int**	**Grade Fleiss κ (95% CI)**	**Int**	**Location Fleiss κ (95% CI)**	**Int**	**Grade Fleiss κ (95% CI)**	**Int**
Less experienced (n=4)	**.513** (.470–.556)	Moderate agr.	**.388** (.345–.431)	Fair agr.	**.407** (.364–.450)	Moderate agr.	**.380** (.337–.423)	Fair agr.
Experienced (n=4)	**.562** (.518–.706)	Moderate agr.	**.464** (.420–508)	Moderate agr.	**.632** (.587–.677)	Substantial agr.	**.443** (.399–.487)	Moderate agr.
Total (n=8)	**.414** (.394–.434)	Moderate agr.	**.339** (.319–.359)	Fair agr.	**.383** (.363–.403)	Fair agr.	**.337** (.317–.357)	Fair agr.

agr: agreement, int: interpretation, CI: confidence interval

Table 4. Intra-observer reliability values

		Location Cohen κ (95% CI)	Interpretation	Grade Cohen κ (95% CI)	Interpretation
Less experienced	1	**.834** (.765–.903)	Almost perfect agr.	**.746** (.656–.836)	Substantial agr.
	2	**.759** (.675–.843)	Substantial agr.	**.535** (.435–.635)	Moderate agr.
	3	**.729** (.642–.816)	Substantial agr.	**.733** (.647–.819)	Substantial agr.
	4	**.665** (.572–.758)	Substantial agr.	**.623** (.527–.719)	Substantial agr.
Experienced	5	**.927** (.877–.977)	Almost perfect agr.	**.764** (.682–.846)	Substantial agr.
	6	**.896** (.848–.954)	Almost perfect agr.	**.810** (.729–.891)	Almost perfect agr.
	7	**.759** (.675–.843)	Substantial agr.	**.791** (.711–.871)	Substantial agr.
	8	**.795** (.718–.872)	Substantial agr.	**.764** (.682–.846)	Substantial agr.

CI: confidence interval, agr: agreement

Table 5. Mean intra-observer reliability values

	Location	Interpretation	Grade	Interpretation
Less experienced (n=4)	0.747	Substantial agr.	0.659	Substantial agr.
Experienced (n=4)	0.844	Almost perfect agr.	0.782	Substantial agr.
Total (n=8)	0.795	Substantial agr.	0.721	Substantial agr.

*agr: agreement

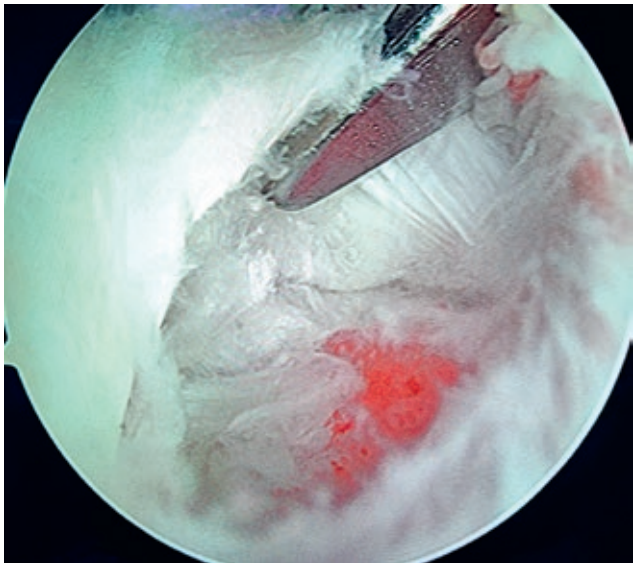

Fig. 4. Example of a patient diagnosed with Ellman grade IIIB with the highest concordance; a – T2-weighted oblique coronal MRI section, b – arthroscopic view of the same patient.

experience and a mean age of 35.7±1.2 (34–37) years, while the more experienced group had 9.7±1.7 (8–12) years of surgical experience and 38.7±1.71 (37–41) years the mean age (p=0.007–0.03, respectively).

Fleiss kappa statistics were used in the inter-observer evaluation. In the less experienced group (n=4), both location assessments resulted in moderate agreement (**κ=0.513–0.407**, respectively), in addition to both the grade assessments in fair agreement (**κ=0.388–0.380**, respectively). In the more experienced group (n=4), a moderate agreement was seen in the first and substantial agreement in the second in the location evaluations (**κ=0.562–0.632**, respectively), in addition to both the grade assessments in moderate agreement (**κ=0.464–0.443**, respectively). When all observers were examined, it was seen that there was moderate agreement in the first location evaluation (**κ=0.414**); however, there was moderate agreement in all other evaluations in both groups (**κ=0.339–0.383–0.337**, respectively) (Table 3).

The intra-observer reliability values of location evaluation were determined between Cohen's κ of **0.665** and **0.927** for 8 observers. These values indicated almost perfect agreement for three observers, and substantial for five. In the grade evaluation, the κ values were found to be between **0.535** and **0.810**. These values indicated almost perfect agreement for one observer, substantial for six, and moderate for one (Table 4).

The mean intra-observer reliability of groups at the end of two evaluations made at six-week intervals is shown in Table 5. The location assessment in the more experienced group resulted in almost perfect agreement (**κ=0.844**) and all other assessments resulted in substantial agreement. In both parameters evaluated, the results of the more experienced group were better than the less experienced group. When all observers were evaluated, it was seen that there was substantial agreement in both evaluations (**κ=0.795–0.721**, respectively).

Table 6. The tear subtypes according to arthroscopy and Ellman classification

		Grade (thickness)			
		I (<3 mm)	II (3–6 mm)	III (>6 mm)	Total (n)
Location	A (articular)	7	10	4	21
	B (bursal)	3	11	6	20
	C (intra-tendinous)	2	1	1	4
	Total (n)	12	22	11	45

Table 7. Intra-observer evaluation on the basis of groups according to the arthroscopically determined Ellman classification

		Cohen κ (95% CI)					
		IA	**IIA**	**IIIA**	**IB**	**IIB**	**IIIB**
Less experienced	1	.800	.863	.667	.500	.542	.778
	2	.432	.759	1.0	.500	.365	.778
	3	.588	.487	.636	.143	.773	1.0
	4	.447	.326	1.0	.143	.461	1.0
Experienced	5	.417	.846	.385	1.0	.676	1.0
	6	.731	.487	1.0	.500	.645	1.0
	7	.600	.636	.385	.400	.527	.778
	8	.806	.762	1.0	.400	.522	1.0
Mean		**.602** (Substantial. agr.)	**.646** (Substantial. agr.)	**.759** (Substantial. agr.)	**.448** (Moderate agr.)	**.564** (Moderate agr.)	**.917** Almost perfect agr

CI: confidence interval, agr: agreement

The definitive Ellman subtypes of the patients included in the study as determined by arthroscopy are given in Table 6. For patients with diagnoses of IA, IIA, IIIA, IB, IIB, and IIIB confirmed by arthroscopy, additional diagnostic-based intra-observer evaluation was performed. The number of patients in the IC, IIC, and IIIC groups (intra-tendinous tears) (2, 1, 1, respectively) was not eligible for statistical evaluation based on diagnosis but were included in the total values. However, seven out of eight observers (except for one in the less experienced group) were found to have reached the correct diagnosis of an intra-tendinous tear in at least one evaluation. From oblique coronal MRI sections from patients in the study, figure 2 shows an example of an intra-tendinous tear (grade IIIC) and figure 3 shows an example of an articular surface tear (grade IIIA). MRI evaluation of stage IIIB (bursal surface, >6 mm) patients resulted in an almost perfect intra-observer agreement (**κ=0.917**) (Fig. 4a/4b). On the other hand, a moderate agreement was seen in stage IB patients and constituted the lowest agreement group (**κ=0.448**) (Table 7).

Power (1- *b*) in post hoc analysis was calculated as **0.951** (n=45), effect size d=0.5, and *a* err prob =0.05).

DISCUSSION

A classification system must be valid, reliable, and reproducible. It should establish a standard terminology for both surgeons and researchers (16). The correct identification of the tear configuration is crucial for selecting the correct repair technique. In our study, in which we evaluated the Ellman classification, which is frequently used in arthroscopic diagnosis, we investigated its intra-observer and inter-observer reliability on MRI scans. Although the mean intra-observer evaluation results were substantial agreement (κ=0.795–0.721, respectively), inter-observer evaluation results were fair agreement (**κ=0.339–0.383–0.337**, respectively) except for the first location evaluation (κ=0.414).

Controversy continues in the treatment of partial cuff tears. Treatments differ if a partial rotator cuff tear is on the articular surface, bursal surface, or interstitial. There are some suggestions for this pathology such as partial debridement, completing the tear and treating it like a full-thickness tear, and in-situ type repair as defined by Snyder (8, 14). Therefore, correct diagnosis is important in treatment. In clinical practice, MRI is the most used imaging method together with examination tests in the diagnosis of rotator cuff ruptures. We planned this study, considering that the reliability analysis of the Elman classification, which is frequently used in partial rotator cuff ruptures, is necessary based on MRI views. We tried to investigate the value of the Ellman classification in making an accurate operation decision rather than its success in arthroscopic diagnosis. Tissue quality, MRI quality and section thickness, and mediolateral and anteroposterior extension of tears can be counted as limitations over MRI in this classification.

In the study of Kuhn et al. (7), twelve experienced surgeons who perform more than 30 rotator cuff repairs per year were asked to evaluate arthroscopy videos of 30 patients with partial and full-thickness rotator cuff tears according to cuff tear classifications. In this study, the observers agreed on the tear side (articular or bursal) for partial-thickness rotator cuff tears but disagreed when classifying its depth. We used multiple choice answers like Kuhn‘s; however, in our study, unlike this study, evaluation was made on isolated MRI scans. Intra-observer agreement was examined as well as inter-observer agreement; since the participants were not only experienced surgeons, but the orthopedic surgeons also that have observed the data were divided into two groups in line with the surgeon‘s experience levels, and comparisons were made accordingly. This helped the study to be on a heterogeneous group in terms of experience. In the present study, in addition to grade, evaluation of the location also showed low reliability (κ=0.317–0.434). It was thought that the quality of the

MRI images might be related to the slice thickness and the direction of the planes. It is necessary to use two plans together to determine the localization of the partial rupture.

Schiefer et al. (12), in their MRI evaluation-based study of Goutallier's classification, reported that intra-observer consistency was not associated with duration of experience or frequency of evaluation, additionally, the inter-observer agreement was high in both radiologists and orthopedists. Based on these data, they suggested that Goutallier's classification can be used with a high level of consistency by evaluating MRI views. In our study, inter-observer evaluation results were fair agreement (**κ=0.337–0.383**) except for the first location evaluation (**κ=0.414**). We thought that the reason for this situation is that the evaluation of the fatty degeneration and atrophy of the rotator cuff by MRI gives better results compared to the evaluation of the degree or location of the partial rotator cuff tear. However, unlike that study, in our study, in which we evaluated the Ellman classification on MRI, it was shown that intra-observer agreement was related to experience. (**κ=0.665–0.834, 0.759–0.927**, respectively).

Recently, Brockmeyer et al. (2) showed that the diagnostic accuracy of MRI with or without clinical tests in detecting partial-thickness tears of the rotator cuff is limited. In our study, MRI scans were used rather than an arthroscopic view. Therefore, this finding may be the main reason for the weakness in the evaluation of the Ellman classification on MRI scans. In particular, the inter-observer evaluations of our study support this information (**κ=0.337–0.414**).

Spencer et al.[15] evaluated inter-observer agreement in the detection and interpretation of rotator cuff tears by MRI views, without using any classification system for partial tears. They concluded that experienced shoulder surgeons had good agreement in the assessment of full-thickness rotator cuff tears and moderate agreement in the location assessment of partial-thickness rotator cuff tears, but poor agreement in estimating the grade of these tears. Similar to this study, in our study, a higher agreement was observed in the location assessment of both groups than in the grade assessment, and as a contribution to this knowledge, it was shown that this agreement was lower in less-experienced surgeons than in more-experienced surgeons.

In this study, it was observed that the intra- and inter-observer reliability of the Ellman classification, which should be evaluated during the arthroscopic intervention, was not at a perfect level when only MRI scans were evaluated. Similarly in a study by Lee et al. (2); 27 orthopedic surgeons were asked to evaluate the shoulder arthroscopy videos of 10 patients operated on for partial rotator cuff tears according to Snyder classification. The inter-observer evaluation was found to be a moderate agreement between both experienced and inexperienced surgeons. In our study, agreement in the less experienced group (**κ=0.380–0.513**) was found to be lower than in the more experienced group (**κ=0.443–0.632**). This study also showed that arthroscopy views have a positive effect on the result.

Since arthroscopic validation of non-operated patients could not be performed, only operated partial rotator cuff ruptures were included in the study. Such a restriction has been introduced due to patients who were evaluated as having partial rupture in MRI and who could be found to have total rupture during the operation.

Preoperative patient examination along with MRI evaluation could be added to a prospective study. However, considering the outcome obtained from the study of Brockmeyer et al. (2), which was mentioned before, we decided that this was not necessary, in the planning part of our study.

The present study has a limitation regarding the MRI technique. Since MRI scans are performed at 2 mm intervals as a standard, clear localization and grade definition of the tears may not be possible. Prospective planning would be more appropriate for thinner-section MRIs.

CONCLUSIONS

Although intra-observer reliability was satisfactory, the Ellman system used in the classification of partial rotator cuff tears was not found to be useful by using only MRI views because of fair inter-observer reliability except for the first location evaluation, which was moderate agreement.

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