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MRI findings of traumatic and degenerative rotator cuff tears and introduction of the "cobra sign"

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Background: A rotator cuff tear (RCT) is a common shoulder diagnosis and its etiology may be acute, traumatic, or chronic degenerative. Differentiation between the 2 etiologies may be important for multiple reasons, but remains difficult based on imaging. Further knowledge about radiographic and magnetic resonance findings to distinguish traumatic from degenerative RCT is needed.
Methods: We analyzed magnetic resonance arthrograms (MRAs) of 96 patients with traumatic or degenerative superior RCT, which were matched according their age and the affected rotator cuff muscle into the 2 groups. Patients older than 66 years of age were excluded from the study to avoid including cases with pre-existing degeneration. In the case of traumatic RCT, the time between the trauma and MRA had to be less than 3 months. Various parameters of the supraspinatus (SSP) muscle-tendon unit were assessed (tendon thickness, presence of a remaining tendon stump at the greater tubercle, magnitude of retraction, layer appearance). The retraction of the 2 SSP layers were individually measured to determine the difference of retraction. Additionally, edema of the tendon and muscle, the tangent- and kinking-sign as well as the newly introduced Cobra-sign (bulging of the distal part of the ruptured tendon with slim configuration of the medial part of the tendon) were analyzed.
Results: Edema within the SSP muscle (sensitivity 13%, specificity 100%, $P = .011$) or the tendon (sensitivity 86%, specificity 36%, $P = .014$) are more frequent in traumatic RCT. The same association was found for the kinking-sign (sensitivity 53%, specificity 71%, $P = .018$) and the Cobra sign (sensitivity 47%, specificity 84%, $P = .001$). Even though not statistically significant, tendencies were observed toward thicker tendon stumps in traumatic RCT, and greater difference in retraction between the 2 SSP layers in the degenerative group. The cohorts had no difference in the presence of a tendon stump at the greater tuberosity.
Conclusion: Muscle and tendon edema, as well as tendon kinking appearance and the newly introduced cobra-sign are suitable MRA parameters to distinguish between traumatic and degenerative etiology of a superior RTC.

Rotator cuff tears (RCT) are frequently seen in the outpatient clinic. Symptomatic RCT create a painful and disabling condition for each individual who suffers from it. It may also result in a socioeconomic burden for insurance companies, doctors, and their patients who sometimes struggle to identify whether the origin of the disease is traumatic or degenerative and what the resulting treatment cost coverage should be.[12,13,15] A clear distinction between the 2 etiologies is rarely possible. This is because the natural wear of the rotator cuff over a patient's life span can be symptomatic or asymptomatic.[4] The clinical importance for a classification is given by the different treatment strategies, its urgency, and therapeutic outcome.[7]

The clinical challenge after a shoulder injury is the inability to objectively judge the state of the rotator cuff (RC) before the traumatic event. The diagnosis is based on the patients' report of the trauma mechanism, as well as risk factors, such as patient age and unspecific radiographic signs. Advanced fatty infiltration of the

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study. Ethical approval for this study was obtained from the local ethical committee (Cantonal Ethics Committee Zürich, BASEC No. 2020-02647).

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muscle and reduced acromiohumeral distance have shown to be associated with long-standing injury to the RC and is indicative of a pre-existing tear if detected shortly after a trauma.[1,2,11,15] Imaging of an injured shoulder can potentially help to analyze the original cause of a torn RC but little data are available in the current literature.[9,10,18] Signs of tendon kinking, edema in the ruptured muscle, and a difference in the grade of muscle atrophy are proven to show a difference between the entities.[11] However, the few previous investigations consider native magnetic resonance imaging findings only, while literature is lacking studies using the more sensitive magnetic resonance arthrograms (MRA) instead.[8]

We analyzed MRAs in 2 homogenous patient groups with either traumatic or degenerative RCT in order to find different morphological aspects. We were also looking for a specific tendon distention in the ruptured tendon, what we have called "cobra-sign." The hypothesis was that there are distinguishing features, such as the cobra-sign, in the radiographic findings on MRAs.

Materials and methods

A retrospective, single center study was performed comparing MRAs of patients with traumatic and degenerative superior full-thickness RCTs who underwent surgery at a specialized university shoulder unit. The traumatic group suffered a traumatic RCT, whereas degenerative group had a degenerative cause of the RCT. The 2 groups were matched by age and ruptured rotator cuff muscle. The study was approved by the responsible investigational review board and all patients participating in this study had a signed informed consent.

Inclusion criteria for the traumatic group were patients that reported a relevant trauma to the shoulder and underwent surgery between 2016 and 2019 at our institution. A relevant trauma mechanism was defined as trauma known to cause RCTs. Simple lifting traumas were therefore excluded.[10] Furthermore, they had to have an asymptotic shoulder joint prior to the trauma. For inclusion, the MRA had to be taken less than 3 months after the trauma.

In the degenerative group, an age- and affected tendon-matched patient cohort was identified, who underwent shoulder surgery for RCT in the same institution. Patients in this group needed to present with a history of at least 1 year of constant shoulder pain before the MRA. Furthermore, the absence of trauma to the affected shoulder was ensured.

Figure 1 Tendon kinking-sign: a distal curling of the tendon end as a sign of an acute traumatic RCT. The red (◯) circle indicates the part of the SSP tendon that shows kinking. *RCT*, rotator cuff tear.

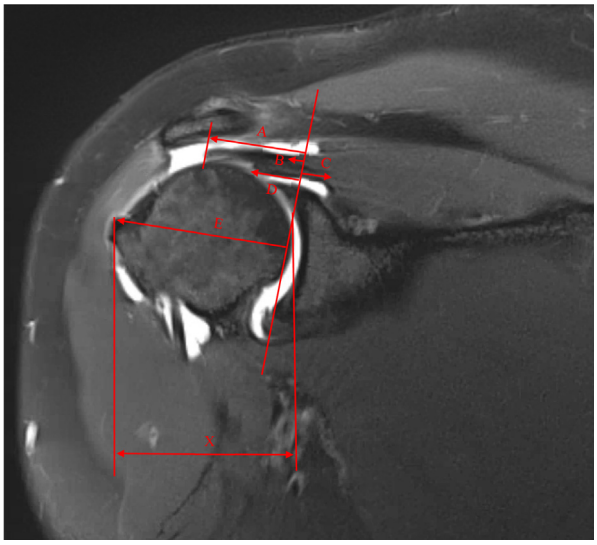

Figure 2 The detailed analysis of the SSP tendon was calculated with a perpendicular line to the glenoid surface at the biggest diameter of the humeral head (**X**) resulting as baseline for all further measures. From there, all measures were taken perpendicular from the baseline, SSP bursal sided layer (**A**) and its musculotendinous junction (**B**), as well as the articular sided SSP layer (**D**) and its musculotendinous junction (**C**). With those measures, all the measures were calculated, tendon layer difference (**A**–**D**), tendon retraction depending on head size (**E**–**A**), ratio of tendon to humeral head ((**A**–**B** + **C**–**D**)/**E**). *SSP*, supraspinatus.

General exclusion criteria where patients older than 66 years of age, muscle atrophy of more than Grade II assessed by the Goutallier classification in the ruptured muscle as well as previous operation on the affected shoulder.[6]

MRA analysis

Initially, established radiographic parameters such as the intramuscular and intra-atendinous edema, tangent sign, tendon

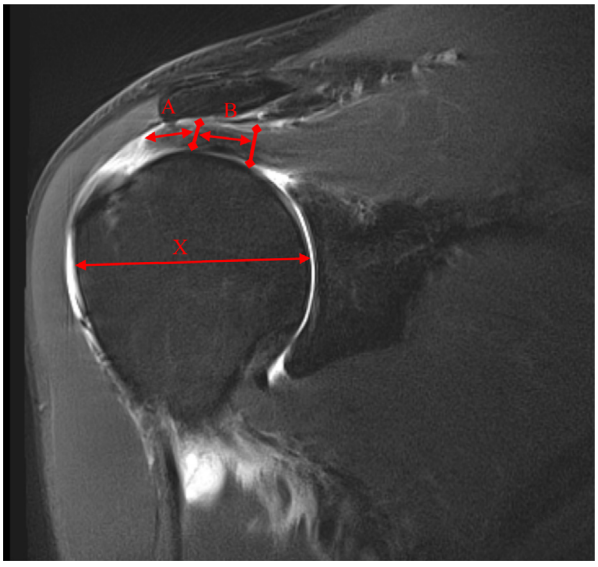

Figure 3 The tendon thickness was measured at two different points (**A** and **B**). Measurement **A** was at 10 mm to the distal end of the SSP tendon, **B** was set at 20 mm to the distal end. The tendon was measured in the plane with the maximum diameter of the humeral head **X**. *SSP*, supraspinatus.

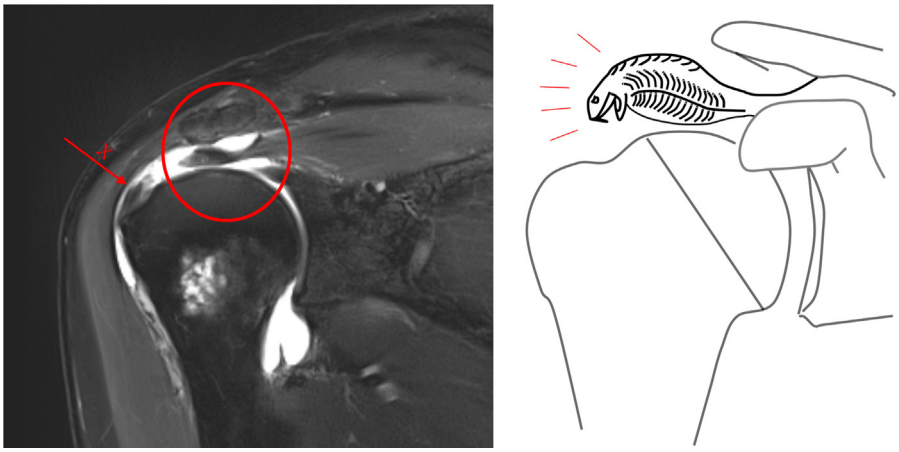

Figure 4 *Left*: (◯): cobra-sign was the appearance of a distal thickening of the SSP tendon. X: (↑) indicating a humeral tendon stump. *Right*: drawing of the correlation of the tendon stump with a cobra snake. *SSP*, supraspinatus.

kinking, and an existing supraspinatus (SSP) tendon stump at the greater tubercle (Fig. 1) were documented.[9,17] Furthermore, newly implemented measurements of the ruptured SSP tendon stump (Fig. 2) were analyzed. Those analyses were performed only in case of a present SSP lesion, which is known to be the case in most patients with traumatic RCT.[3] With these measurements, the retraction of the tendon could be measured as a ratio of the head size, and the musculotendinous transition, which then allowed the tendon length to be calculated, similar to the retraction measure of Meyer et al[14] (Fig. 2). Additionally, the thickness of the tendon was measured at 10 mm and 20 mm proximal to the distal end of the rupture (Fig. 3). All measurements were performed for both tendon layers of the SSP (articular- and bursa-sided) if present and were taken at the largest diameter of the humeral head for ideal reproducibility (Fig. 2).

Cobra sign

We assumed the tendon fibers to be increasingly elastic in acutely traumatized RCT, which may sometimes cause the tendon to "buckle back" and the tendon fibers to unwind. This assumption, together with the development of an intratendinous edema, may lead to a bulging appearance of the distal tendon stump and slim configuration of the proximal part of the tendon. Due to its resemblance to the head and body ratio of an upright cobra snake we called the new parameter a cobra-sign (Fig. 4).

All images for the entire MRA analysis were analyzed blinded to the etiology and also blinded to the presumption of belonging to these new aspects, as well as blinded to the patient's history, by a musculoskeletal specialized radiologist (R.E.) and a fellowship-trained shoulder surgeon (P.B.).

Ethical approval for this study was obtained from the local ethical committee (Cantonal Ethics Committee Zürich).

Table I
Patient demographics.

	Trauma	Degenerative	*P* value
Patients (n)	48	48	
Age (y)	54.7 ± 7.6	55 ± 5.6	.708
Right shoulder (n)	33	30	.519
Dominant shoulder (n)	33	32	.827

Data are given as mean ± standard deviation unless otherwise indicated.

Statistics

Statistical analysis was performed with IBM SPSS version 27 (IBM Corp., Armonk, NY, USA). Chi-square testing was used for nominal data. Normal distribution was calculated using Kolmogorov-Smirnov testing. For normally distributed parameters, *t* testing was used, for values not normally distributed Mann-Whithney *U* test was used. Bonferroni correction of significance was calculated due to multiple variable measurement. Cohen's Kappa was used for inter-rater correlation calculation. Data are presented as mean ± standard deviation. The level of significance in all tests was set at $P < .05$.

Results

Forty-eight patients met the inclusion criteria for the traumatic group. Meaning, 48 patients with degenerative RCTs were matched. In both groups, the mean age was 55 years; 46% and 40% were female in the traumatic and the degenerative group respectively. The right and dominant shoulder was significantly more involved compared to the non-dominant side (Table I).

Analysis of the MRAs showed significantly more frequent edema to the muscle in the traumatic than in the degenerative group (31% vs. 7%, $P = .011$). This finding was highly specific, with a specificity of 100% and a 0% false positive rate. Tendon edema was also pointedly more frequent after traumatic RCT and showed a sensitivity of 86%. Tendon kinking was found to be more common in traumatic tears and showed itself to be rather specific with a specificity of 71% ($P = .018$). The same association showed the presence of the newly introduced cobra-sign, which seems to be another very specific feature ($P = .001$, specificity 84%). If the testing of the cobra-sign and the edema in the ruptured tendon are statistically combined, the value and significance can be increased even further ($P < .001$, specificity 89%, positive predictive value 81%).

No difference was seen between the groups when analyzing tendon stumps at the humeral head and the tangent sign (Table II). No significant difference was seen between the groups when measuring the SSP thickness at 10 mm or 20 mm proximal of the tendon rupture. At 10 mm, the traumatic SSP was 4.8 mm, whereas the degenerative was 0.6 mm thinner. At 20 mm, there was a difference of 1.2 mm between the 2 groups (N.S.). No significant difference was seen in tendon retraction between the 2 groups. No difference was seen between the groups when the 2 SSP layers were measured and especially their difference in retraction, though

Table II
Magnetic resonance arthrography I.

Variable	Trauma yes	No	Degenerative yes	No	Sensitivity	Specificity	*P* value	Bonferroni correction	Cohen's Kappa
Muscle edema	6	39	0	45	13%	100%	**.011**	0.154	**0.508**
Tendon edema	39	6	29	16	87%	36%	**.014**	0.196	**0.304**
Tangent sign	0	45	1	44	-	-	.315	-	**0.492**
Tendon kinking	24	21	13	32	53%	71%	**.018**	0.252	**0.319**
Humeral tendon stump	11	34	10	35	-	-	.803	-	**0.537**
Cobra sign	21	24	7	38	47%	84%	**.001**	**0.014**	**0.348**
Combined testing: Tendon edema + cobra sign	21	24	5	40	47%	89%	**<.001**		

All data are given in number of cases, except for *P* values and marked otherwise. Boldface type indicates statistical significance.

again a tendency towards greater difference between the SSP layers in the degenerative group. The only significant difference between the groups was seen in the ratio of the tendon to the humeral head (Table III).

Discussion

The most important findings of this study were (1) the proof of the previously described radiographic signs for an acute traumatic superior RCT on an MRA and (2) the introduction of the cobra-sign to distinguish between traumatic and degenerative RCTs.[2,11,17]

Patient's history and physical examination is typically prone to subjectivity from both the patient and examiner. More reproducible aspects are findings from the MRI. These so far had proven to poorly distinguish between the traumatic and degenerative cases. No detailed analysis of the ruptured tendon end with the sensitive MRA has yet been done.

In line with previous findings is the presence of intramuscular edema in traumatic RCT. This has been described as highly specific in the literature and reached a specificity of 100% in our study.[9,11] We added the analysis of an intratendinous edema. This has shown to be a rather sensitive sign of a traumatic tear. It is also in concordance with descriptions of intraoperative findings of traumatic RCTs, yet has never been analyzed on MRA.[3] It remains unclear why the edema in the ruptured muscle shows greater specificity and the edema in the tendon greater sensitivity. No difference between the groups were seen when analyzing the presence of a residual tendon stump at the greater tuberosity. We would have expected such a stump to be a sign of an acute traumatic tear, since transverse rupture patterns and injuries to the myotendinous junction are often associated with traumatic RCTs.[3,16]

Neither our study nor the previous literature could confirm the presence of a remaining tendon stump at the greater tuberosity to be a sign of an acute traumatic tear.[9] The formerly introduced kinking-sign, a distinctive wavy shape of the ruptured SSP tendon end indicating an acute traumatic tear, is in line with our investigation and remains a highly significant sign for the inference of a previously intact RC. This phenomenon was explained with an increased tendon elasticity which then coils up when traumatically ruptured. The elasticity could also explain the tendon end retraction in the traumatic group, although not significant, was greater than the retraction in the degenerative group. We therefore conclude that tendon retraction is a poor parameter for separating the groups.[11]

Table III
Magnetic resonance arthrography II.

Variable	Trauma	Degenerative	*P* value	Bonferroni correction
Tendon thickness at 10 mm	4.8 ± 2.6	4.2 ± 1.9	.220	-
Tendon thickness at 20 mm	6.0 ± 2.1	4.8 ± 2.6	.269	-
Tendon retraction	7.1 ± 8.2	5.3 ± 8.4	.289	-
Tendon layer difference	3.3 ± 4.9	3.6 ± 6.4	.828	-
Ratio of tendon to humeral head	1.42 ± 0.29	1.40 ± 0.42	**.011**	0.154

Data are given as mean ± standard deviation unless otherwise indicated. Boldface type indicates statistical significance.

All previously published studies analyzed small and inhomogeneous patient cohorts, with significant difference in age and degenerative changes such as muscle atrophy. This limits the comparability between the groups. In our study, we tried to homogenize the cohorts as much as possible. Therefore, we excluded patients older than 66 years and grouped them according to their age. Furthermore, we excluded higher degrees of fatty infiltration in the ruptured muscle. Fatty infiltration is one of the few already known indicators for a preexisting damage to an RC. It needs time to develop and is not present in the short period after an intact RC is torn.[5,11] It is obvious, that the analysis of the tangent sign in our study is negative in both groups.

Our examination confirmed several previously published typical MR findings. In addition, the thorough analysis of the SSP lesion revealed further findings, including the newly described cobra-sign, which we found to be a highly distinguishing characteristic and very sensitive for a traumatic superior RCT. Using the tendon edema and the cobra-sign in combination show an even higher statistical significance. Other analyzed parameters did not show statistical significance, but tendencies were observed. One was the tendon end thickness of the torn SSP which was larger in the traumatic tears. Likewise, the difference between the tendon layer retraction of the torn SSP, which was bigger in the degenerative group.

A limitation of the study is its retrospective design. A prospective analysis would allow to perform certain procedures in a more standardized way, for example systematic intraoperative arthroscopically documentation in order to compare rupture patterns in different mechanisms of trauma or MRA aspects. As in the other studies, the mechanics of the trauma must be asked of the patient, which is a possible source of bias. However, unlike similar studies, we used narrower inclusion criteria and excluded patients of older age with possible unknown predegenerated condition of the RC such as possible asymptomatic RCT or patients with progressed fatty infiltration. Furthermore, we matched the 2 according to age and ruptured muscles.

Conclusion

The results of this study show that MRA may be used to differentiate between traumatic and degenerative RCTs. The cobra-sign was added to the well-established and hereby confirmed aspects

of a torn SSP tendon such as intramuscular or intratendinous edema and the kinking-sign, of which all indicate a traumatic RCT.

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