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ORIGINAL STUDY

The Acromion Index
Reliability in radiographic and magnetic resonance imaging

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The present study evaluates the inter-rater reliability (IRR) of the Acromion Index (AI) in radiographic (x-ray) and magnetic resonance imaging (MRI), the correlation between both types of imaging and the reliability of the AI as a predictor of rotator cuff tears (RCT).

116 patients who suffered a partial or total rotator cuff and/or long biceps tear, an impingement syndrome and/or calcific tendinitis and who were surgical treated in our clinic were included in this study.

We were able to confirm the excellent inter-rater reliability of the AI in x-ray (p = 0.969) and could also show an excellent IRR in MRI (rho = 0.97). However, due to more single extreme AI in MRI, the Pearson's correlation showed only an average correlation between both types of imaging (p = 0.391). No significant correlation (p = 0.35) of the AI and patients without (AI 0.709, SD 0.07) and with (AI 0.695, SD 0.07) arthroscopic evidence of a RCT could be found. However, when grouping the patients according to their AI, we could show that an AI ≥ 0.76 leads to a 76% presence of a RCT and an AI < 0.75 only leads to a 54.9% presence of a RCT in shoulder arthroscopy.

The AI has an excellent IRR in x-ray and MRI. However, a clearer definition of the AI calculation in MRI is needed in order to improve the only moderate correlation between both types of imaging. By grouping patients according to their AI we discovered an increase in the probability of RCT with decreasing AI. This could lead to a more parable rather than linear correlation of the AI and RCT showing that there is a possible ideal force vector of the deltoid muscle and a change of the AI in either direction leads to harm of the rotator cuff tendons. Further studies with a greater number of patients are needed to prove this hypothesis.

Keywords: Acromion Index ; Acromion Index x-ray ; Acromion Index MRI ; radiographic predictor rotator cuff tear ; MRI predictor rotator cuff tear ; predictor rotator cuff tear.

INTRODUCTION

The anatomic configuration of the shoulder girdle and its association with the occurrence of shoulder injuries has long been a topic of interest in the scientific literature. Especially the impact of the

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osseous shape of the acromion on rotator cuff tears (RCT) and impingement syndrome (IS) has been investigated by many authors who have defined a broad range of radiographic predictors to objectify these impacts *(6)*. In 2006, Nyffeler et al. introduced the Acromion Index (AI) – today known as an excellent radiographic predictor of RCT and IS *(2,3)*. Although since then, many authors have proven the reliability of the AI in radiographic imaging, a transfer and test for validation in magnetic resonance imaging (MRI) is still missing *(1,9,10,16)*. This may be important as MRI has become the primary form of imaging in rotator cuff associated pathology and the use conventional X-rays in these cases has come into question. Thus, we have conducted this study using preoperative imaging as well as intraoperative evidence of RCT of a large patient cohort to confirm the inter-rater reliability in radiographic imaging, to evaluate the inter-rater reliability in MRI and prove a possible correlation of both types of imaging and arthroscopic evidence of RCT.

PATIENTS AND METHOD

184 patients who suffered a partial or total rotator cuff and/or long biceps tendon tear, an impingement syndrome and/or a calcific tendinitis and who were surgical treated in our clinic between 01 January 2010 and 01 July 2013 were included in this retrospective study. Preoperative radiographic and MRI imaging were available for all patients.

30 patients with evidence of osteoarthritis in either the preoperative imaging or due to intraoperative arthroscopic findings and 34 patients with a history of previous shoulder surgery had to be excluded due to a potential natural or iatrogenic alteration of AI relevant anatomic structures. Furthermore, we had to exclude 12 patients with low quality imaging in either the preoperative x-ray or MRI. As the combination of osteoarthritic changes and a history of previous shoulder surgery was present in eight cases, a total number of 68 patients had to be excluded reducing the number of patients included in this study to 116.

Two experienced orthopaedic consultants of our clinic were commissioned to calculate the AI for all 116 patients as defined by Nyffeler et al. as the ratio of the glenoacromial and glenohumeral distance: Three parallel lines were drawn starting with a vertical line connecting the supra- and infraglenoid tubercle, followed by one line at the most lateral aspect of the acromion and one line at the most lateral aspect of the proximal humeral head (Fig. 1). The glenoacromial and glenohumeral distances were then measured and divided by each other *(17)*. The larger the extension of the acromion, the higher the AI.

Both examiner (E1 and E2) were using the same diagnostic programme (Centricity Universal Viewer; GE Healthcare; Little Chalfont, United Kingdom) and measuring tools (CwApiTool; GE Healthcare; Little Chalfont, United Kingdom) saving their corresponding results rounded to the next millimetre in respective Excel-Sheets.

For the radiographic calculation, only true a.p.-x-rays with a neutral positioned arm were used and available in all cases. For the calculation in MRI, we used a coronar-view and preferably T1-weighted imaging for a better differentiation of the cartilage/osseous glenoid. This T1-weighted image was available in 92 of 116 patients (79.3%) and was replaced by T2-weighted or TSE PDW sequences in the remaining cases.

Arthroscopic evidence of RCT was added based on the respective operative report of each patient. Neither examiner was involved in the surgical treatment, so

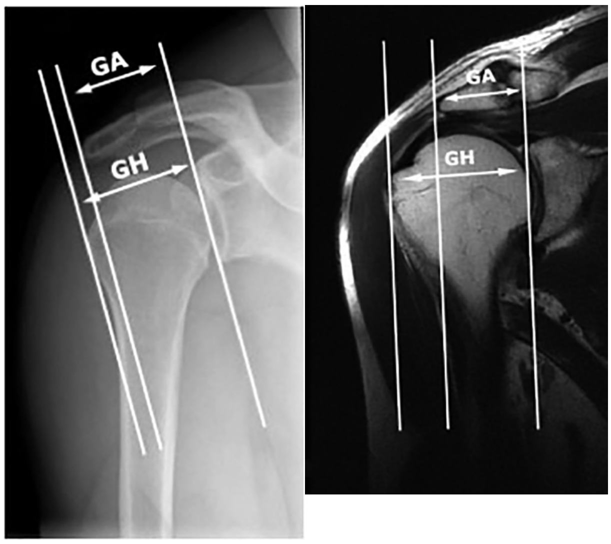

Fig. 1a and 1b. – AI measurements in radiographic (1a) and magnetic resonance imaging (1b): GA = glenoacromial distance; GH = glenohumeral distance no previous knowledge about intraoperative findings was present. The Kologorov-Sminrov test, the t-test, Pearson's correlation and Spearman's rank correlation were used to discover and prove possible statistical significances among this data. In addition, we gained an ethics committee approval for this study.

RESULTS

Results of 116 patients – 41 female (35.3%) and 75 male (64.7%) – with an average age of 56.5 years (minimum: 23y; maximum: 87y) were obtained. The right shoulder was affected in 72 cases (62.1%) and the left shoulder in 44 patients (37.9%).

For radiographic imaging, E1 calculated an average AI of 0.70 (SD 0.08), E2 of 0.71 (SD 0.08), leading to a Pearson's correlation of p = 0.941 – classified as an excellent examiner correlation. The normal distribution of all radiographic measurements was proven with the Kologorov-Sminrov test (p = 0.904). The inter-rater reliability (IRR) of 0.969 (95% CI: 0.955 – 0.978) was excellent, confirming that the calculation of the AI in radiographic imaging is reliable and examiner independent.

In MRI-imaging, E1 calculated an average AI of 0.62 (SD 0.15), E2 of 0.64 (SD 0.11). However, the normal distribution of all measurements was not given with a Kologorov-Sminrov test of $p < 0.001$. Consequently, Spearman's rank correlation was used and showed again an excellent IRR (rho = 0.97).

The Pearson's correlation of the average AI in radiographic imaging and MRI was p = 0.391 showing only an average correlation between both types of imaging (Fig. 2).

We also tested for a correlation of the radiographic AI and the actual arthroscopic evidence of a RCT present in 69 patients – 18 female (26.1%) and 51 male (73.9%):

The 69 patients with a rotator cuff tear had an average AI of 0.709 (SD 0.08), the remaining 47 patients with no tear had an average AI of 0.695 (SD 0.07), leading to a t-test of p = 0.35 showing no significant difference in the AI of patients with or without intraoperative evidence of a RCT. However, the 47 patients with no RCT were part of a patient collective with other shoulder pathologies that required shoulder arthroscopy and thus are not representing a healthy control group.

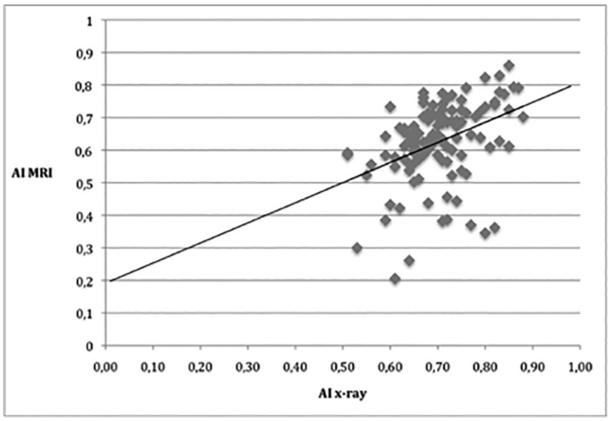

Fig. 2. – Correlation of the average AI in x-ray and MRI

Applying the point-biserial correlation coefficient we were able to prove that age has a significant impact on arthroscopic evidence of a RCT ($p < 0.001$).

Post hoc, we clustered all 116 patients according to their measured radiographic AI into four groups. We were able to show that in patients with an average AI ≥ 0.76 19 out of 25 patients (76.0%) had an actual RCT, compared to only 50 out of 91 (54.9%) with an AI ≤ 0.75. Again, we have discovered an increase in arthroscopic evidence of RCT with decreasing AI (Table I).

Table I. – Patients grouped according to AI showing a 76% chance of a RCT in patients with an AI ≥ 0.76

Acromial Index (AI)	Total number of patients	Patients with rotator cuff tears	Percentage of patients with rotator cuff tear (RCT)
≤ 0.65	33	20	60.6%
0.66 – 0.70	27	16	59.3%
0.71 – 0.75	31	14	45.2%
≥ 0.76	25	19	76.0%

DISCUSSION

Various radiographic predictors of rotator cuff tears have already been described and have led to controversial discussions. Bigliani et al. introduced the Acromion Type and later added the Acromion Slope. Both were long known as reliable radiographic predictors of RCT. However, further studies have disproven the initial published correlation of the described acromion types and the occurrence of

RCT *(3,6-8,14,15)*. The Acromial Tilt, a correlation of the acromial and coracoid positional relation with the occurrence of RCT has also been disproven and shown as insignificant *(2,4)*. Banas et al. have shown a correlation of the corresponding angle of the acromion subsurface and the glenoid surface with the incidence of RCT known as the Lateral Acriomal Angle. Despite its significance for the detection of RCT, no significant differentiation between patients with or without impingement syndromes can be made *(4,5)*. The Acromial Coverage Index sets a correlation of the acromial coverage of the humeral head and the incidence of RCT. However, the definition and measurement of the index leaves out a possible prominent greater tuberosity *(13,19)*. The Acromion Index defined by Nyffeler et al. is the first radiographic predictor showing a significant correlation between the osseous configuration of acromion, glenoid surface and humeral head and the occurrence of rotator cuff tears as well as impingement syndromes *(17)*. Since its first publication in 2006, many authors have proven the reliability and validation of the AI *(3,4,9,10,12,17,18)*. Musil et al. have concluded that the AI is currently the best available predictive radiographic parameter for RCT and IS *(16)*. Nyffeler et al. have also described the pathomechanism behind the AI: The more equal the glenoacromial and glenohumeral distance are, the steeper is the force vector of the deltoid muscle pulling the humeral head more cranial and less medial, decreasing the subacromial space, compressing the supraspinatus muscle under the acromion which subsequently leads to more friction and an increased risk of RCT and IS (Figure 3a and 3b) *(17)*.

We were able to confirm the excellent reliability of the AI in radiographic imaging (p = 0.969) and have proven for the first time an excellent IRR in MRI (rho = 0.97). However, we have also discovered an on average smaller AI in MRI (MRI 0.68, x-ray 0.70), showing more single extreme results and a greater standard deviation (MRI SD 0.13, x-ray SD 0.08) (Fig. 4a and 4b).

Following the instructions for radiographic imaging, we calculated the AI with all relevant structures shown on one slide in a coronar-view. However in MRI, the lateral acromion often

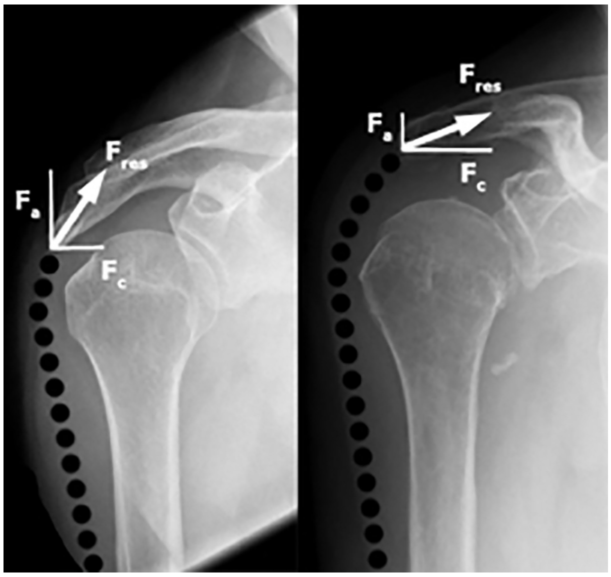

Fig. 3a and 3b. – A high AI (a) results in a steeper force vector (Fres) of the deltoid muscle leading to a decreased subacromial space and an increased risk of RCT and IS compared to shoulders with a low AI (b) *(17)*

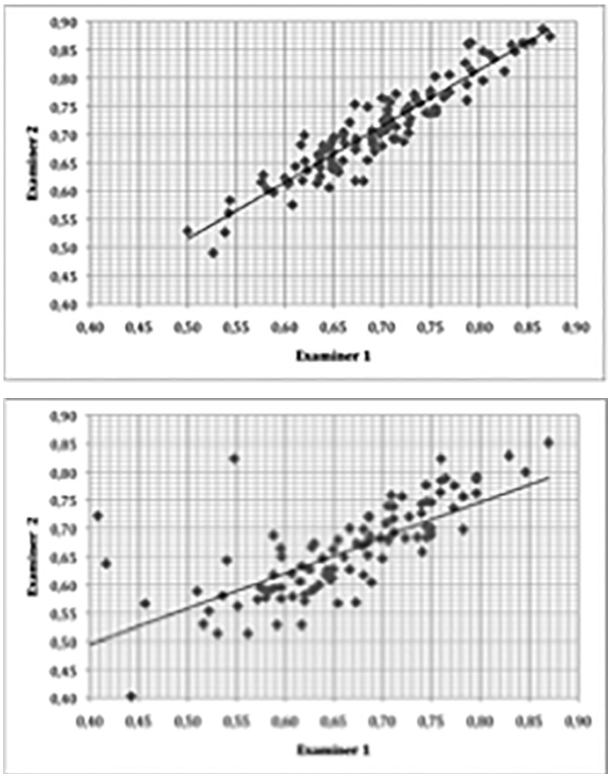

Fig. 4a and 4b. – A high AI (a) results in a steeper force vector (Fres) of the deltoid muscle leading to a decreased subacromial space and an increased risk of RCT and IS compared to shoulders with a low AI (b) (17) appeared to be more ventral than the vertical line through the glenoid tubercle leading to a false-low glenoacromial distance resulting in an on average lower AI. A longer acquisition time, the lack of standardised slice-thicknesses and different types of scan-weighting in MRI added more measurement obscurities (Fig. 5a and 5b).

In radiographic imaging, all relevant osseous structures can be clearly differentiated in one image allowing an easy measurement of all required distances resulting in the excellent inter-rater reliability and a low SD. Another fact that needs to be taken into account is that the available x-rays were all done in a standing patient position whereas MRI scans are done in a supine lying position, resulting in a possible shift of relevant osseous structures. The on average lower AI in MRI corresponds with the results of Kim et al and Lee et al. They too have applied AI in MRI, however were not following Nyffelers instructions and used a more oblique view rather than a coronar-view leading to average AI of 0.666 and 0.67 respectively. Their studies also lacked a radiographic comparison, e.g. a calculation of the radiographic AI in their patients *(11,12)*. The correlation of the AI in x-ray (0.70) and MRI (0.63) using the Pearson's Correlation is 0.391 - showing only a moderate correlation.

No significant correlation ($p = 0.35$) between patients without (AI 0.709, SD 0.07) and with (AI 0.695, SD 0.07) intraoperative evidence of a RCT could be found. However, when grouping the patients according to their AI, we could show that an AI ≥ 0.76 leads to a 76% presence of a RCT and an AI < 0.75 only leads to a 54.9% presence of a RCT in shoulder arthroscopy. However, our control group does not represent a healthy cohort, but patients who were admitted to our clinic and surgical treated because of other shoulder injuries.

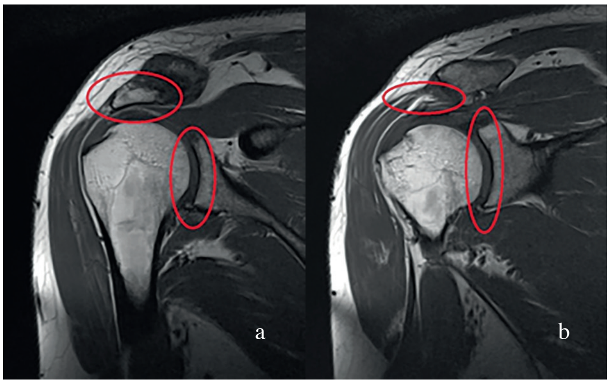

Fig. 5a and 5b. – Difficulties of the AI calculation in MRI: The superior and inferior glenoid tubercle are perfectly pictured in Figure 5a – however, the lateral extension of the acromion is missing in this slide but seen in Figure 5b where again the glenoid cavity is not fully displayed

By grouping patients according to their AI we also discovered an increase in the probability of RCT with decreasing AI. This could lead to a more parable rather than linear correlation of the AI and RCT showing that there is a possible ideal force vector of the deltoid muscle and a change of the AI in either direction leads to harm of the rotator cuff tendons. However, further studies with a greater number of patients are needed to prove this hypothesis.

CONCLUSIONS

We have confirmed the excellent IRR of the AI in radiographic imaging and for the first time proven the excellent inter-rater reliability in MRI. However, we have also shown the difficulties in the MRI-AI calculation: A longer acquisition time, the lack of standardised slice-thicknesses, different T1-/T2-weightings and an additional variety in the scan quality lead to on average smaller AI with more single extreme results and a greater standard deviation resulting in only a moderate correlation between the AI in both types of imaging. A clear definition for the AI calculation in MRI is needed – addressing T1/T2-weighting, the view as well as the position of the patients arm is needed in order to improve this correlation. We have also shown that the radiographic AI and its correlation with intraoperative evidence of RCT is not as linear as previously thought but follows a more parabolic correlation. Further studies are needed to investigate these findings.

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