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# *Radiographic characteristics of the acromion process as a predictive factor of partial rotator cuff tears*

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Injuries of the shoulder joint make up to 55 % of all large joint injuries, among which the rotator cuff tears is the most common. Partial rotator cuff tears diagnosis is a difficult task for the traumatologist. **Purpose** of this study is evaluation radiographic characteristics of the acromion in patients with partial rotator cuff tears. **Material and methods** Fourteen patients with verified partial rotator cuff tears and 14 patients with chronic instability of the shoulder joint were selected for retrospective analysis of illness history data and radiological results. The first (index) group consisted of 11 men and three women; the second (control) group consisted of 13 men and one woman. Patients with partial rotator cuff tear had it from the subacromial space. Radiographs of the shoulder joint were taken in standard projections (anteroposterior, Y-shaped) in this study. The following criteria were evaluated: lateral acromial angle (LAA), acromial index (AI), critical angle of the shoulder joint (CSA), size of the subacromial space and type of acromial process according to Bigliani. **Results** Significant age difference was found between the groups. There was no statistical difference between groups in LAA and AI. For CSA and size of the subacromial space, a significant difference was found between the groups. Dependence on the type of the acromial process was not found; the prevalence of types 2 and 3 of the acromial process according to Bigliani in the group of partial rotator cuff tears was observed. **Conclusion** There is an anatomical difference between patients with rotator cuff tears and chronic instability of the shoulder joint. Significance of the criteria of the critical shoulder angle (CSA) and the size of the subacromial space as a prognostic factor in partial rotator cuff tears was proven.

**Keywords**: partial tear, rotator cuff, shoulder joint, critical shoulder angle

## INTRODUCTION

Injuries of the shoulder joint are among the most common injuries of large joints, ranging from 16 to 55 %. Among them, tears of the rotator cuff are the most common pathology [1, 2].

Some tears occur due to injury, but most are the consequence of degenerative changes. The etiology of the lesion is multifactorial, influenced by age, tissue hypovascularization and microtrauma [3]. The association of the morphological characteristics of the scapula and the degenerative tears of the rotator cuff was proved. Neer described osteophytes of the anterior acromial surface of the scapula and their leading role in rotator cuff tears [4]. Bigliani and colleagues classified the types of the acromion and showed the prevalence of rotator cuff tears in with the hooked type of the acromion process [5].

In 1995, Banas revealed a relationship between the inclination of the articular surface of the scapula in the frontal plane and the rotation cuff tendon tear and identified a criterion of the lateral angle of the acromion process of the scapula (LAA, lateral acromial angle) [6]. In 2006, Nyffeler presented the acromial index criterion (AI, acromial index), which assesses the lateral size of the acromion process of the scapula relative to the humerus and the articular surface of the scapula [7]. Assuming that the larger lateral size of the acromion process of the scapula will verticalize the action vector of the deltoid muscle and thereby increase the load on the tendons of the rotator cuff. In 2013, Moor introduced the criterion of the critical angle of the shoulder joint (CSA, critical shoulder angle), which combines an estimate of the inclination of the articular surface of the scapula and the lateral size of the acromion process. In his work, Moor came to the conclusion that CSA values > 35 degrees are characteristic of degenerative full-layer ruptures of the rotator cuff, and CSA values < 30 degrees of osteoarthrosis [8].

The main mechanism of partial rotator cuff tears from the side of the subacromial space is the subacromial impingement syndrome [4]. Schneeberger and colleagues created a model of subacromial

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impingement in rats according to which, the rupture always occurred from the side of the subacromial space [9]. Schneeberger identified two mechanisms of the lesion: destruction of tendon fibers due to friction of the scapula on the acromion process and an increase in pressure on the tendon tissue, as a result of which degenerative changes develop gradually. Fukuda in its histological study confirmed similar changes and mechanisms of development [10].

MRI and MR-arthrography are the most popular methods in the diagnosis of non-full-thickness tears of the rotator cuff, showing sensitivity and specificity of up to 81 and 91.7 %, 85.9 and 96 %, respectively [11, 12]. However, radiography of the shoulder joint is the most accessible and basic method for examining patients with musculoskeletal disorders.

According to Fukuda, tears from the side of the subacromial space occur in 27 % of cases among all non-full-thickness tears [13]. According to the literature, such tears result in the most pronounced pain and often require surgical treatment [14]. Tears from the side the subacromial space are accompanied by a more pronounced tendinosis, and also with a small gap depth it is very difficult to differentiate the MRI signal between tendinosis, tendinopathy or rupture [15]. Kong observed that the degree of tendinosis had a direct impact on the progression of the tear. Thus, patients with severe tendinosis developed the progression of the tear 7.64 times more often than patients with mild tendinosis [16].

The LAA, AI, CSA criteria are based on the biomechanics of the shoulder joint and evaluate the effect of the anatomy of the scapula on the formation of a rotator cuff tear. It has been proven that the anatomy of the scapula may accelerate age-related degeneration of the tendons [17, 18].

All previously published work focused on full-thickness degenerative tears of the tendons of the rotation cuff, while these criteria have never been applied to patients with partial tears.

The **purpose** of this study was to assess the radiological characteristics of the acromion process of the scapula in patients with partial rotator cuff tears (PRCT) from side of the subacromial space. Our hypothesis was that the available criteria (LAA, AI, CSA, size of subacromial space) will also be reliable for to predict partial rotator cuff tears from the side of the subacromial surface.

## MATERIAL AND METHODS

The study is a retrospective analysis of medical records, findings of radiological methods and magnetic resonance imaging of patients treated at the European Sports Traumatology and Orthopedics Clinic (ECSTO, Moscow). An arthroscopic revision of the shoulder joint was the “gold” standard of diagnosis.

Out of 63 patients diagnosed with "partial rotator cuff tear" who underwent surgical treatment in the clinic from 2014 to 2017, 14 patients were included in the study, three women and 11 men. The inclusion criteria were a degenerative non-full-thickness tear of the rotator cuff from the side of the subacromial surface, verified by MRI and arthroscopic revision; high-quality radiographs in standard anteroposterior (AP) and Y-shaped projections. The exclusion criterion was the low quality of radiographs, evident trauma in the history, pronounced tendinosis according to magnetic resonance imaging. All tears from the side of the subacromial space were of grades 2–3 according to Ellman (**Fig. 1**).

The control group included patients operated on for Bankart lesion, with arthroscopically verified absence of rotator cuff tear from the side of the subacromial space and high-quality preoperative radiographs in standard projections (anteroposterior, Y-shaped). The control group consisted of 14 patients, 13 men and one woman.

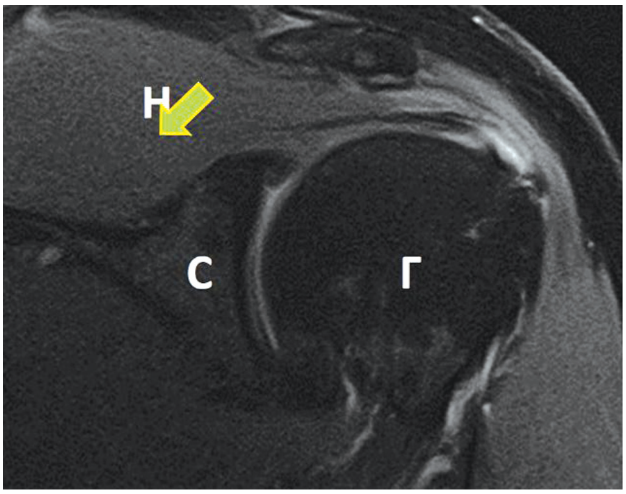


**Fig. 1** Example of partial rotator cuff tear from the side of the subacromial space of grade 3 according to Ellman (L is the head of the humerus; C is the articular process of the scapula; H is the muscular belly and tendon of the supraspinatus muscle; arrow shows the tear zone)

All patients in the control and main group underwent surgical treatment with arthroscopic method according to standard methods. All operations were performed in the "beach chair" position of the patient or in the lateral decubital position, depending on the preferences of the surgeon. The first step was to perform diagnostic arthroscopy, during which the shoulder joint and the subacromial space were examined from standard arthroscopic ports (anterior, posterior). Accurate assessment of the pathology was carried out, special attention was paid to the rotator cuff tendons.

На рентгенограммах, выполненных в передне-задней проекции, определяли критерии LAA, AI, CSA и размер субакромиального пространства по описанным авторами методикам.

LAA, AI, CSA criteria and the size of the subacromial space were determined in the AP radiographs with the methods described by the authors.

The LAA (lateral acromion angle) criterion was evaluated on standard AP radiographs of the shoulder joint by determining the angle between the lines drawn parallel to the lower surface of the acromion process of the scapula and the upper-lower border of the scapula (**Fig. 2**).

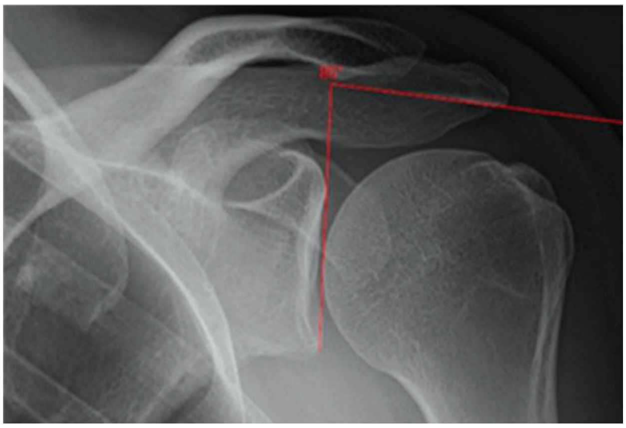

**Fig. 2** Determination of LAA on the AP radiograph of the shoulder joint according to the method described by Banas [6]

AI was calculated using the formula: AI = GA / GH, where GA is the distance from the articular surface of the scapula to the lateral edge of the acromion process of the scapula; GH is the distance between the articular surface of the scapula and the lateral edge of the humeral bone [7]. Initially, a line was drawn connecting the upper and lower borders of the articular process of the scapula, then a parallel line was drawn through the lateral edge of the acromion process of the scapula and, parallel to it, the line through the most lateral point of the humeral head (**Fig. 3**). The values of GA and GH were obtained by constructing a perpendicular to these lines.

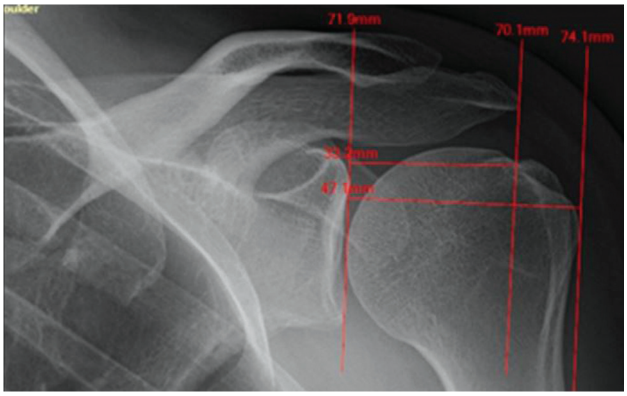


**Fig. 3** Determination of AI on the AP radiograph of the shoulder joint according to the method described by Nyffeler [7]

The CSA (critical shoulder angle) criterion was evaluated on standard AP radiographs of the shoulder joint. The angle was estimated between two lines: a line connecting the upper and lower borders of the articular process of the scapula, and the line connecting the lower border of the articular surface of the scapula with the lateral edge of the acromion process of the scapula (**Fig. 4**).

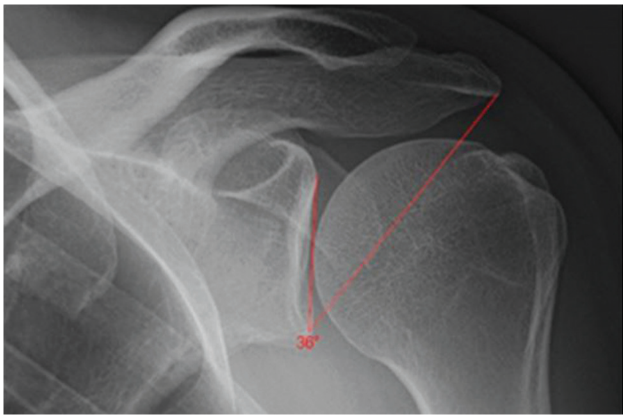

**Fig. 4** Determination of CSA on the AP radiograph of the shoulder joint according to the method described by Moor [8]

To estimate the size of the subacromial space in the AP radiographs, the conventional technique was used [19]. Initially, a line was drawn parallel to the lower surface of the acromion process of the scapula; then a line was drawn through the highest point of the humeral head, parallel to the first line. Then the perpendicular was dropped, and the length of the perpendicular was considered the size of the subacromial space (**Fig. 5**).

In radiographs taken in the Y-shaped projection, the type of the acromial process of the scapula according to the Bigliani classification was determined (**Fig. 6**).

At the preoperative stage, all patients underwent MRI of the shoulder joint in one center (ECSTO, Moscow) on a high-field system with a magnetic field strength of 1.5 Tesla. The study protocol consisted of three mutually perpendicular projections (oblique coronary, oblique sagittal and axial), using impulse sequences in a T2 weighted image (WI) in the gradient echo mode – FFE_T2W, proton-weighted density images-TSE PDW and using the suppression effect signal from adipose tissue – TSE PD SPAIR, with a slice thickness of 3 mm.

All the data were introduced into a standardized MS Office Excel table. For comparison of qualitative variables, the Spearman's coefficient was used; for comparison of quantitative variables, the Mann-Whitney and Cruskell-Wallis criteria were used. Statistical processing was performed in the SPSS program.

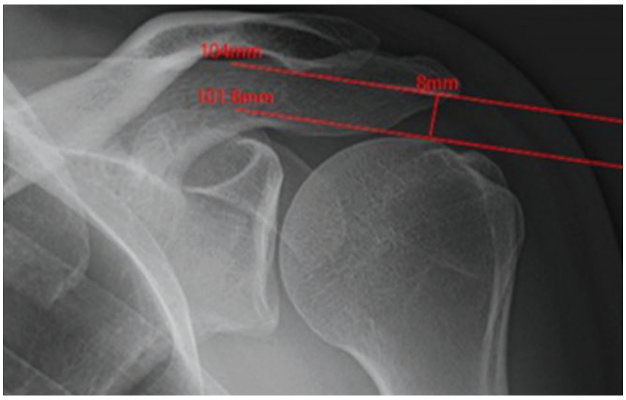


**Fig. 5** Determining the size of the subacromial space on the AP radiograph of the shoulder joint [19]

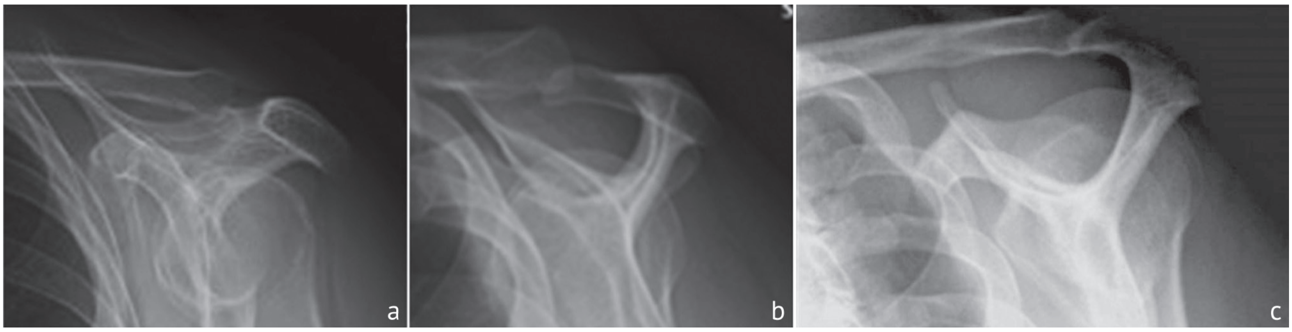


**Fig. 6** Types of the acromion process of the scapula according to Bigliani: a flat; b curved; c hooked

RESULTS

The groups were comparable in age, physical activity, sex and affected side.

The data obtained for LAA, AI, CSA and the sizes of the subacromial space are presented in Table 1 and in box-plot graphs (**Fig. 7**).

The distribution of patients by the anatomical type of the acromion process of the scapula did not depend on gender and age in both groups. In the PRCT group, the Bigliani curved and hooked types (types 2 and 3) of the acromion process prevailed (71 %) while in the control group, types 2 and 3 were found in 42 % of patients (**Fig. 8**).

No dependence was found on gender, type of acromion process of the scapula and age ($p > 0.05$ for all values) for LAA, AI, CSA and the sizes of the subacromial space. For the CSA criteria and the size of the subacromial space, a significant difference ($p < 0.05$) between the groups was found. In contrast, AI and LAA were not statistically different in the groups. Figure 6 presents the results of testing the hypotheses (**Fig. 9**).

Table 1

Results for LAA, AI, CSA and subacromial space sizes

| Criterion | Group | Results | |
|---|---|---|---|
| | | **Median** | **Interquartile range** |
| **LAA** | group 1 | 78.50 | 75.50 – 85.00 |
| | group 2 | 84.50 | 80.00 – 87.00 |
| **AI** | group 1 | 0.67 | 0.64 – 0.72 |
| | group 2 | 0.65 | 0.61 – 0.67 |
| **CSA** | group 1 | 36.00 | 35.00 – 37.75 |
| | group 2 | 32.00 | 31.00 – 32.75 |
| **Subacromial space** | group 1 | 8.00 | 7.63 – 8.50 |
| | group 2 | 9.50 | 9.00 – 10.00 |

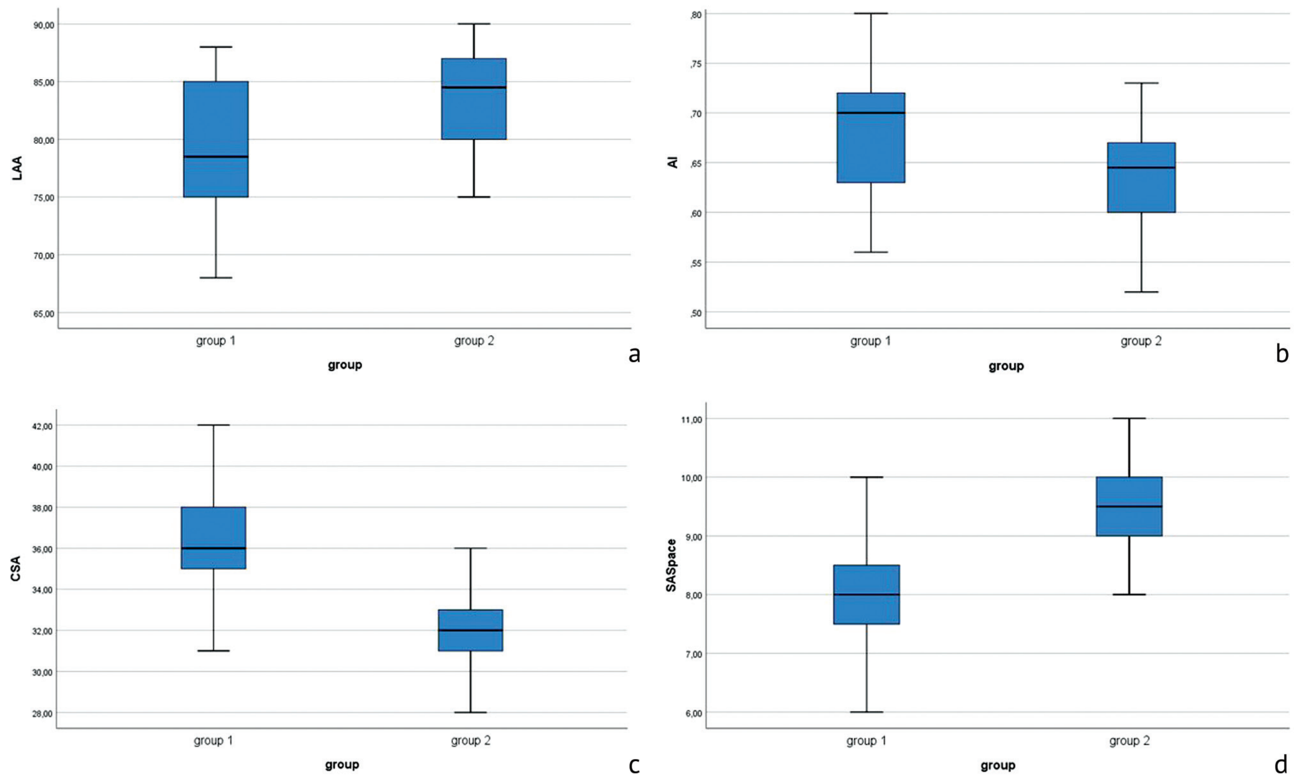


**Fig. 7** Values of the LAA (a), AI (b), CSA (c) and the sizes of the subacromial space (d) in both groups

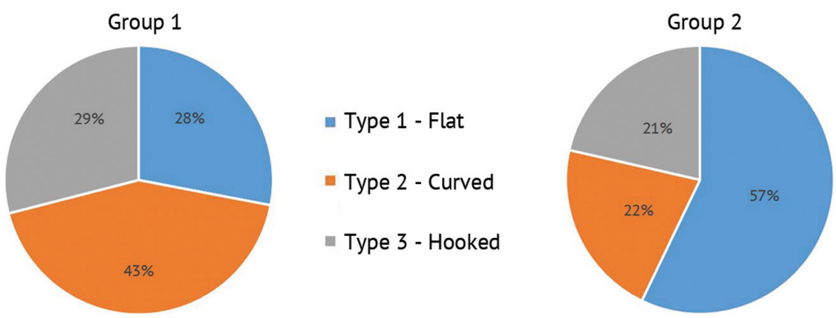


**Fig. 8** Types of acromion process in groups (%)

| | Nil hypothesis | Test | Value | Solution |
|---|---|---|---|---|
| 1 | AI distribution is similar for group categories | Mann-Whitney U for independent samples | .104[1] | Null hypothesis accepted |
| 2 | LAA distribution is similar for group categories | Mann-Whitney U for independent samples | .062[1] | Null hypothesis accepted |
| 3 | CSA distribution is similar for group categories | Mann-Whitney U for independent samples | .000[1] | Null hypothesis rejected |
| 4 | SASpace distribution is similar for group categories | Mann-Whitney U for independent samples | .000[1] | Null hypothesis rejected |

Asymptotic significance is derived. The level of significance is .05; [1] – exact significance of the criterion is given

**Fig. 9** Results of testing the hypotheses of equality of the criteria AI, LAA, CSA and the size of the subacromial space (SASpace) in both groups

Moreover, the study assessed the accuracy, sensitivity, specificity, predictive value of a positive response and predictive value of a negative response for AI, LAA, CSA and the size of the subacromial space. The results are presented in Table 2.

Among all patients with a value of CSA > 35°, 85 % had a non-full-thickness tear of the rotator cuff according to MRI and arthroscopic revision data.

A direct correlation between CSA and AI, an inverse correlation between CSA and the size of the subacromial space, and an inverse correlation between CSA and LAA were also revealed (**Fig. 10**).

Table 2

Results of Accuracy, Sensitivity, Specificity, Predictive Value of Positive Response (PVPR), and Prognostic Value of Negative Response (PVNR) for AI, LAA, CSA criteria and subacromial space sizes

| Criterion | Sensitivity | Specificity | PVPR | PVNR | Accuracy |
|---|---|---|---|---|---|
| AI | 71 % | 67 % | 62 % | 67 % | 64 % |
| LAA | 50 % | 86 % | 78 % | 63 % | 68 % |
| CSA | 79 % | 86 % | 85 % | 80 % | 82 % |
| Subacromial space size | 90 % | 72 % | 64 % | 93 % | 79 % |

| | | | CSA | SASpace | LAA | AI |
|---|---|---|---|---|---|---|
| Ро Спирмена | CSA | Correlation rank coefficient | 1.000 | – .610** | – .570** | .729** |
| | | (two-way) | | .001 | .002 | ,000 |
| | | N | 28 | 28 | 28 | 28 |
| | SASpace | Correlation rank coefficient | – .610** | 1,000 | .425* | – .339 |
| | | (two-way) | .001 | | .024 | .078 |
| | | N | 28 | 28 | 28 | 28 |
| | LAA | Correlation rank coefficient | – .570** | .425* | 1.000 | – .485** |
| | | (two-way) | .002 | .024 | | .009 |
| | | N | 28 | 28 | 28 | 28 |
| | AI | Correlation rank coefficient | .729** | – .339 | – .485** | 1.000 |
| | | (two-way) | .000 | .078 | .009 | |
| | | N | 28 | 28 | 28 | 28 |

** – correlation is significant at the level of 0.01 (two-way); * – correlation is significant at the level of 0.05 (two-way)

**Fig. 10** Spearman correlation table for LAA, AI, CSA and subacromial space size (SASpace) values

## DISCUSSION

We did not find works on the prognostic value of radiological criteria for partial rotator cuff tears in the literature.

For the study of this issue, the patients who underwent arthroscopy of the shoulder joint were included into the index (with tears) and control (without tears) groups. It was known that the control group individuals did not have rotator cuff tears (according to MRI and arthroscopy findings).

There are many works that associate the anatomy of the scapula with degenerative tears of the rotator cuff. Most of them revealed a direct relationship between the lateral size of the acromion process of the scapula, articular surface of the scapula tilt, its inclination and the development of a full-thickness degenerative rupture of the rotator cuff [6, 7, 8, 20, 21].

The LAA and AI criteria presented do not perceive the shoulder joint as a single system [6, 7, 8]. We obtained LAA values comparable to the results of other studies [6, 22, 23]. We did not find significant difference between the groups. Similar results were obtained in the work of Hamid as no relationship was found between the large lateral size of the acromion process (LAA) of the scapula and rotator cuff tears [22]. Considering the data obtained and consistent with the literature data, it can be concluded that the LLA is not valuable for predicting partial rotator cuff tears from the side of the subacromial space.

We did not reveal any significant difference by studying AI criterion in the groups. The median AI was 0.67 in the group of partial rotator cuff tears and 0.645 in the control group. The AI value equal to 0.64 according to Nyffeler is typical for an intact shoulder joint, and 0.73 for a full-thickness rupture of the rotator cuff [7]. Our results in this regard contradict the work of Nyffeler. However, our findings are similar to the results of Ames and colleagues, who reported the absence of a significant difference in AI in 115 patients with rotator cuff injuries, impingement syndrome or Bankart lesion [24] with AI variation from 0.685 to 0.694.

We found significant difference in CSA between the groups. Thus, the CSA median in the tear group was 36°, and in the instability group it was 32°. Cherci found the CSA was 33° in the instability group and the CSA was 32.1° in the group of healthy patients according to Spiegl. Interestingly, Miswan in his work also used patients without clinical manifestation of the pathology in the shoulder joint and a verified absence of rotator cuff injury as a control group and found the CSA value of 33.1º for this group and 39.4º for the rotator cuff tear group [25].

According to Cherchi, CSA > 35º has a sensitivity of 53 % and a specificity of 74 % in the diagnosis of degenerative rotator cuff tears; among all patients with CSA > 35º, 68 % had a rotator cuff tear, as Cherchi reported [20]. According to other data, the sensitivity of CSA is 80 % and the specificity is 75 %, exceeding the values for AI and LAA which are 78 % and 71 %, 65 % and 69 %, respectively. According to data published by Moor, 84 % of the examined subjects had rotator cuff tears, and Spiegl's study reported 79 % [8, 26]. We obtained sensitivity and specificity values for the CSA of 79 % and 86 %, respectively, an accuracy of 82 %, and for the size of the subacromial space, these values were 90 %, 72 %, and 79 %, respectively. These two criteria have the greatest accuracy, sensitivity and specificity among the studied parameters.

According to the literature, acromion process types 2 and 3 are characteristic of degenerative tears of the rotator cuff. In our work, the prevalence of types 2 and 3 of the acromion process of the scapula was observed in the group of patients with partial tears of the rotator cuff, but no statistically significant difference was found.

A statistically significant difference in the size of the subacromial space between the groups of patients was also found, which confirms the role of the subacromial impingement syndrome in the development of partial rotator cuff tears [4].

CSA has the strongest correlation links among all the criteria, thus confirming that it is the most universal criterion. CSA is the most accurate and easily reproducible criterion. The limitations of the method include a high dependence on the quality of radiographs and a complex method of reproduction on MRI [26].

Our work is not without limitations, including a retrospective study design, small groups of patients, and one researcher who measured the criteria. Nevertheless, the work shows a significant relationship between the non-full thickness rotator cuff tear and the radiographic anatomy of the acromion process of the scapula.

## CONCLUSION

• A significant difference in the anatomy of the acromion process was revealed between the groups of patients with partial rotator cuff tears and Bankart lesion.

• The significance of the criteria (CSA, critical shoulder angle) and the size of the subacromial space as a prognostic factor in partial rotator cuff tears were proven.

• The significance of the acromial index (AI) and the lateral acromial angle (LAA) as a prognostic factor in partial rotator cuff tears was not confirmed.

• Further study is required in this area and inclusion of more patients in the analysis.

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