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The utility of indirect imagistic signs in the diagnosis of anterior cruciate ligament ruptures

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Abstract

We conducted a retrospective study, between 2013 and 2018. The study was conducted by analyzing the comparative imaging of two groups of patients. The two groups comprise 42 patients, 14 women and 28 men aged between 17 and 70 years old, to whom objective variables of statistical relevance were tracked. The results of this study show that there is a significant correlation between an angle value of less than 45° and the rupture of the anterior crossed ligament.

Keywords: anterior crossed ligament, knee, nuclear magnetic resonance.

Introduction

The knee joint is the largest joint of the human body and is one of the major joints that take over the weight of the entire body. Many traumas, inflammatory and tumoral processes occur at this level because it is less protected than other joints [1, 2].

The anterior cruciate ligament (ACL) has an important role in biomechanics of the knee and its injury is very frequent, especially in the young, active population. In the USA, the statistics have shown that the prevalence of ACL rupture per year is between 100 000 and 200 000, and the annual incidence in the general population is up to 3500, although the actual incidence may be higher. In Romania, results from the *National Arthroplasty Register* suggests that there is an increased incidence in ACL tears, which leads to an increasing number of ACL surgeries for reconstruction of this important structure of the knee.

In order to asses a diagnosis, along with the clinical examination, imagistic methods for precise diagnostic are required. However, the anatomical position of the ACL within the intercondylar area makes difficult the visualization and the assessment of the injured ligament.

The anterior crossed ligament has an oblique upward backward and outward direction and it is inserted into the anterior intercondylian area of the tibia through its lower part, and by the upper extremity on the posterior side of the lateral condyle [3]. The anterior crossed ligament has a major role in the biomechanics of the knee, thus explaining why the traumas of the anterior crossed ligament are the most common.

The primary role of nuclear magnetic resonance (NMR) in the management of a patient with an anterior crossed ligament rupture consists of allowing the setting of a diagnosis as accurate as possible. NMR has a sensitivity of 90–98% for anterior crossed ligament ruptures, and it allows the physician to identify the bone lesions that are present in approximately 90% of cases. The diagnosis of anterior crossed ligament rupture may be performed both on direct signs that appear on the NMR image as well as on the indirect ones [4].

The therapeutic approach must be personalized, targeted in function of the clinical and imagistic aspects.

The attitude must take, with great attention, into account, all the present comorbidities, associated pathologies, the medical and family history and the heredo-collateral antecedents.

The risk factors must be known and evaluated and the therapeutic approach must be ethical with the lowest number of adverse events encountered [5, 6].

Aim

The aim of this paper is to verify the sensitivity and specificity of the sign (angle between the anterior crossed ligament and the tibial plate) by checking whether there

is a correlation between a value of less than 15° and the rupture of the anterior crossed ligament.

⯈ Patients, Materials and Methods

The present study follows the utility of the value of the angle between the anterior crossed ligament and the tibial plateau in the diagnosis of ruptures of this ligament.

It is a retrospective study that was performed by comparative imaging analysis of two groups of patients. The two groups comprise 42 patients, both women (33%) as well as men (67%), aged between 17 and 70 years old, to whom variables of objective statistical relevance were followed.

All 42 patients were hospitalized at the Clinic of Orthopedics and Traumatology II, Emergency County Hospital, Timişoara, Romania, presenting knee traumatisms. Of the 42 patients, 21 had an anterior crossed ligament rupture, indicated by magnetic resonance imaging (MRI) and arthroscopically confirmed, and 21 had no ligament damage. All the patients conducted MRI and arthroscopy for the affected knee.

Clinical evaluation of the patients

The arthroscopic exploration of the affected knee was performed in the Clinic of Orthopedics and Traumatology II, Emergency County Hospital, Timişoara, using the ConMed Linvatec LS 7700.

Imagistic investigations

Imaging exploration trough magnetic resonance (MR) was performed using the Magnetom Essenza 1.5 T MRI system. All of the MR images were analyzed by measuring the angle of the tibial plate, in the image where the anterior crossed ligament is best viewed. This angle was measured using a goniometer.

Statistical analysis

Statistical iterations were performed with the Statistical Package for the Social Sciences (SPSS) software. For the demonstration of the statistical differences of the averages of the values of the angles of the two groups of patients, the Student's *t*-test for independent groups with equal variants was used. The variances are statistically significant when the significance coefficient (*p*) is lower than 0.05. If the variants are not statistically different (*p*>0.05) they can be considered equal.

⯈ Results

Following imaging investigations, the next results were obtained: of the 21 patients enrolled in the group of non-ruptured anterior crossed ligament, 14 patients had the right knee affected and seven patients had the left knee affected (Table 1).

Table 1 – *Distribution of patients in the group of those who did not rupture of anterior ligament, depending on the affected knee*

Affected knee	No. of cases	Percentage
Right	14	67%
Left	7	33%
Total	21	100%

After measuring the angle formed by the anterior cross ligament with the tibial plate, it has been noted that of the 21 patients included in the group, 16 of them had a value greater than 45° of this angle, while five patients had an angle value lower than 45° (Figure 1).
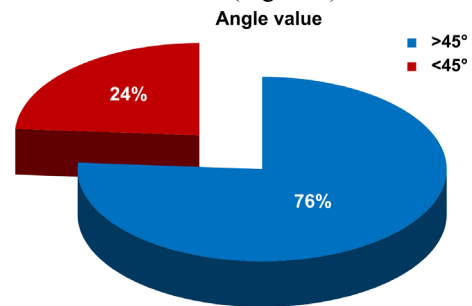

Figure 1 – *Distribution of patients in the non-ruptured group of previously cross-ligated ligaments based on the value of the ligament angle formed by the tibial plateau.*

By analyzing the group of patients with anterior crossed ligament rupture, it has been observed that 67% of them had the right knee affected and 33% had the left knee affected (Figure 2).
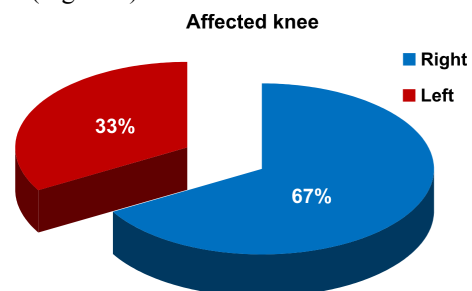

Figure 2 – *Distribution of patients in the group of those with previously cross-linked ligament depending on the affected knee.*

After measuring the angle formed by the ACL with the tibial plateau, two patients out of 21 had a value greater than 45° of this angle, representing 10% of the total batch, and 19 had an angle value of less than 45°, representing 90% of the total group (Table 2).

Table 2 – *Distribution of patients in the group of those with previously cross-linked ligament, depending on the affected knee*

Angle value	No. of cases	Percentage
>45°	2	10%
<45°	19	90%
Total	21	100%

The average of the angles values measured in the batch of patients without an anterior crossed ligament rupture is 45.76° with a standard deviation of 6.252 and a standard error of 1.364, while the average angular values measured in the batch of patients with anterior crossed ligament rupture is of 35.48° with a standard deviation of 8.34 and a standard error of 1.82 (Table 3).

After a statistical comparison of the two groups of patients in terms of the exact value of the angle between the anterior crossed ligament and the tibial plate, it was found that the differences between them were significant (*p*=0) (Table 4).

The difference between the averages of the two batches in terms of the value of the angle, statistically significant as shown in the previous table (Figure 3).

Analyzing the value of the angle between the anterior crossed ligament and the tibial plateau, we can conclude that a greater than 45° value is found in 76% of the patients without an anterior crossed ligament rupture, and a value of less than 45° is found in 90% patients with rupture of this ligament (Table 5).

Table 3 – *Average angles, standard deviation, and standard error of the average*

Groups	No. of subjects	Mean	Standard deviation	Standard error of the average
No ligament rupture	21	45.76°	6.252	1.364
With ligament rupture	21	35.48°	8.34	1.82

Table 4 – *Mean difference*

	t value	Significance coefficient	Mean difference	Standard error	Minimum value	Maximum value
Exact angle value	4.522	0	10.286	2.275	5.677	14.894
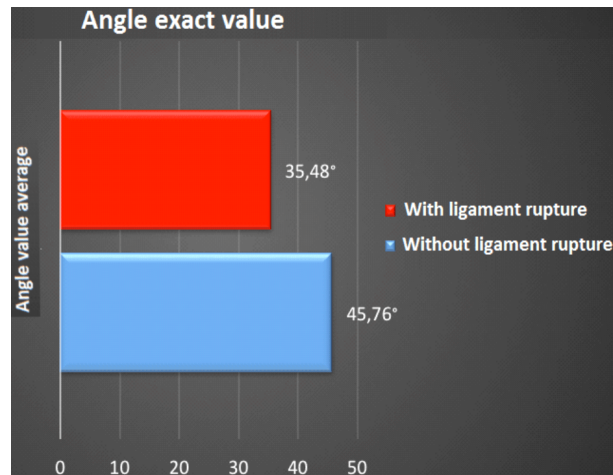
Figure 3 – *Difference between angular mean values.*

Table 5 – *Angle value*

Angle value	Ligament rupture (percentage)	
	No	*Yes*
>45°	76%	10%
<45°	24%	90%
Total	100%	100%

We can say that the present study has a sensitivity of 90% and a specificity of 76%.

A Pearson's correlation was used to demonstrate the correlation between the anterior crossed ligament rupture and a value less than 45° of the angle formed by this ligament with the tibial plateau. This is a linear connection between two variables. The correlation coefficient (r) is between -1 and +1. When $r=0$, there is no correlation. When there is a good correlation ($r>0.5$), it is statistically significant ($p<0.001$).

By statistically analyzing the correlation between the ACL and a value less than 45° of the angle between this ligament and the tibial plate, a correlation coefficient r of 0.674 and a significance coefficient p of 0 can be found, indicating that there is a high correlation between an angle of less than 45° and the rupture of the anterior crossed ligament (Table 6).

Table 6 – *The statistical correlation between the angle value and the anterior cruciate ligament rupture*

Pearson's correlation based on angle value	
Correlation coefficient – r	0.674
Significance coefficient – p	0

It was measured on the MR image in which the anterior crossed ligament is best visualized by the angle formed by it with the tibial plateau. This angle was 54° (Figure 4), indicating that when the anterior crossed ligament is integral this angle has a value greater than 45°.

On the MR image in which the anterior crossed ligament is best visualized, the angle formed by it with the tibial plateau was measured. This angle was 20° (Figure 5), indicating that when the anterior crossed ligament is broken this angle is less than 45°.

Figure 4 – *Left-knee MRI: the angle between the anterior cruciate ligament and the tibial plateau.*
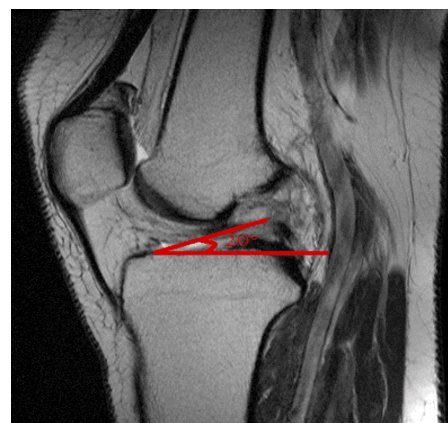

Figure 5 – *Right-knee MRI: the angle between the anterior cruciate ligament and the tibial plateau.*

⧉ Discussions

The history of the injury and the clinical examination are usually enough for the diagnosis of ACL lesion. Most frequent applied tests to diagnose these tears are the anterior drawer test, Lachman test and pivot shift test, but

they are influenced by the degree of patient cooperation and by the clinical experience of the doctor. With a range between 84% to 98.4% in chronic ACL insufficiency, pivot shift test is considered to have a high sensitivity for detecting the ACL injury. A range between 35% and 98.4% have been shown for the test specificity, the lowest values appear in the awake patients, and the highest values in the anesthetized patients [7–9]. Although, the single most sensitive and specific sign of ACL tear remains an abnormal appearance of the ACL on sagittal images.

The ACL tears' primary signs are: non-visualization of the ligament, ACL substance disruption by increased abnormal signal intensity, abnormal ACL axis, abrupt angulation or a wavy appearance of the ligament. On sagital images, if the axis of the ACL is more horizontal than the Blumensaat line (the line projected between the intercondylar roof), is considered abnormal. A sensitive and specific sign for ACL tear is an angle less than 45° of the long axis, although this quantification is considered unnecessary by the authors [10, 11].

The indirect signs, as were described in the journal Radiology, are: angle between lateral tibial plateau and ACL less than 45° (90% sensitivity, 97% specificity); angle between Blumensaat line and ACL more than 15° (89%, 100%); bone contusions in lateral compartment (54%, 100%); position of posterior cruciate ligament (PCL) line (52%, 91%); PCL angle less than 107° (52%, 94%); PCL bowing ratio more than 0.39 (34%, 100%); posterior displacement of lateral meniscus more than 3.5 mm (44%, 94%); anterior displacement of tibia more than 7 mm (41%, 91%); and lateral femoral sulcus deeper than 1.5 mm (19%, 100%).

In case of focal edema and hemorrhage, the ACL tear is replaced by liquids or blood, and it is not visible. An interstitial tear (or delaminated tear) is a partial tear appearing as an enlargement of the ACL, with increased internal signal intensity, and visible intact fascicles at the radiological examination. The differential diagnostic of these appearances has to be made with the mucoid degeneration of the intact ACL.

As the sagittal and coronal images are significant for determining the primary signs of the ACL tear, the axial images should be given the same consideration. The proximal ACL, which is an elliptical hypointense band, could be fragmented, attenuated, replaced by hemorrhage, completely or partially, or moved away from the sidewall of the intercondylar eminence [12].

Secondary signs of an ACL tear are described by the MRI findings. Although these signs have a limited sensitivity [13–15], an ACL disruption is not excluded in their absence. In ACL injury, certain signs have more than 80% specificity [16, 17]. As a result, they may lead for a certain diagnosis of the tear in the absence of the primary signs.

Segond fractures and pivot-shift bone bruises are considered high specific signs for ACL injury.

⊟ Conclusions

The results of this study show that there is a significant correlation between an angle value of less than 45° and the rupture of the anterior crossed ligament. Due to the increased sensitivity of this study, it can be argued that

the presence of this sign indicates the rupture of the ACL. The primary signs are used for the diagnosis, while the secondary signs are used more likely in the chronic cases. A lower value of the study specificity compared to its sensitivity suggests that the absence of this indirect imaging sign does not exclude the rupture of the ACL. The presence of the indirect signs corroborates the diagnosis of ACL tear, due to the high specificity, but the absence of these signs does not exclude the diagnosis of ACL lesion.

Conflict of interests
The authors declare no conflict of interests.

Author contribution
Sorin Dan Chiriac has equal contribution and thus shares first authorship.

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