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Original Research Article

There is a Relationship between Narrow Inter-Condylar Notch and Anterior Cruciate Ligament Rupture: A Case-Control Study

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Abstract: Our objective was to study the influence of the inter-condylar notch (ICN) geometry on the risk of anterior cruciate ligament (ACL) rupture. We conducted a retrospective and comparative case-control study. Our series has included 80 patients divided into two groups. The patients in group 1 (40 cases) had unilateral ACL rupture. Group 2 included 40 patients with a healthy ACL. The geometry of the notch was evaluated through the Notch width Index (NWI), the notch shape index (NSI) and the notch height index (NHI). The primary judgment criterion is a lower NWI in group 1. These parameters have been calculated on SHUSS radiography of the knee and on frontal MRI cross section. The comparative analysis of the three parameters of the inter-condylar notch has shown that the average NWI (radiological and MRI) and NHI of group 1 were lower than those of the Group 2 with a statistically significant difference. The difference between the NSI averages for the two groups was not statistically significant. We have found a correlation between the values of the radiological NWI and the values of the NWI (MRI). In conclusion, a narrow inter-condylar notch in width (NWI < 0.22) or height (NHI < 0.44) represents a risk factor of ACL rupture. The threshold, from which we talk of a pathological ICN, must be adapted to the population concerned because studies have shown a variation of measurements between different ethnic groups.

Keywords: Anterior cruciate ligament, rupture, inter-condylar notch, risk factor, function, surgery.

INTRODUCTION

The reconstruction of the anterior cruciate ligament (ACL) has undergone a considerable evolution in the recent years. However, despite this progress, we note a frequency of iterative plasties ruptures and a frequency in the bilaterality of the ACL rupture (2 to 9.5%) [1, 2]. Risk factors of the anterior cruciate ligament rupture are multiple, some are extrinsic, and others are intrinsic: anatomical, hormonal, neuromuscular, or related to the age, gender and ligament hyperlaxity.

The objective of our work was to study the influence of the inter-condylar notch (ICN) geometry on the risk of rupture of the anterior cruciate ligament.

MATERIALS AND METHODS

We conducted a retrospective and comparative case-control study conducted over a period of two years, from January 2015 until December 2016.

We conducted our study on a sample of 80 patients divided on two groups: Group 1 included 40 cases of ACL ruptures. Group 2 included 40 patients having a healthy ACL.

We included in group 1 all active patients aged less than 40 years, having no medico-surgical history of lower extremities, presenting unilateral ACL rupture confirmed by MRI and arthroscopy, whose record includes a shuss incidence and frontal MRI cross section passing by the popliteal dimple.

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We included in group 2 all active patients aged less than 40 years, who had consulted for post-traumatic knee pain, having an intact ACL on MRI, whose record includes the above radiological assessment.

We excluded from both groups all the files that are missing the above radiological assessment. We excluded also all patients with radiographic evidence of osteoarthritis.

We have collected for all the patients of both groups: the age, gender, the affected side, the mechanism of the trauma and the level of sport activity.

On the schuss radiography (Figure 1) and the frontal MRI cross section passing by the popliteal dimple (Figure 2), we have achieved the following measurements: the width of the inter-condylar notch (a), the width of the femoral epiphysis (b), the height of the inter-condylar notch (c) and the height of the femoral epiphysis (d).

Fig-1: Schuss radiography showing the width of the inter-condylar notch (AA') and the width of the femoral epiphysis (BB').

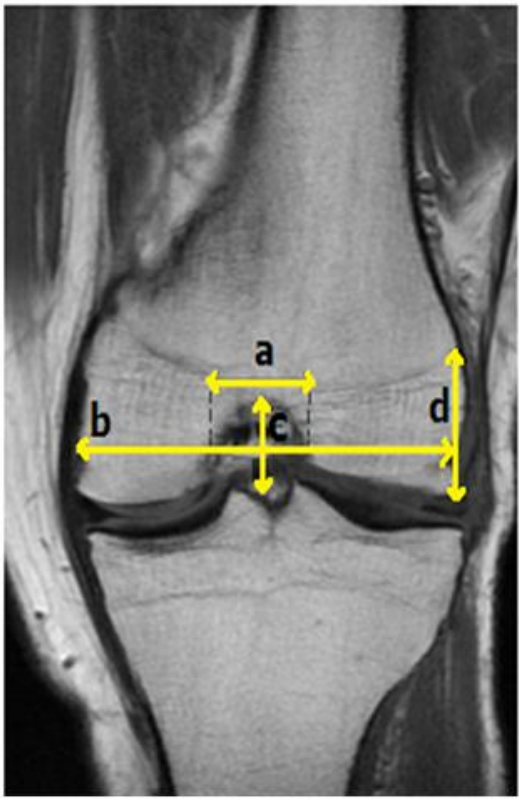

Fig-2: Coronal cross section passing by the popliteal dimple; (a) the width of the inter-condylar notch, (b) the width of the femoral epiphysis; (c) the height of the inter-condylar notch; (d) the height of the femoral epiphysis.

From these measurements, we have calculated the following ratios

- The "notch width index" (NWI) corresponds to the ratio of the width of the inter-condylar notch divided by the width of the femoral epiphysis. The NWI was the main judgment criterion.
- The "notch shape index" (NSI) corresponds to the ratio of the width of the inter-condylar notch divided by the height of the inter-condylar notch.
- The "notch height index" (NHI) corresponds to the ratio of the height of the notch divided by the height of the femoral epiphysis.

The data was analyzed using SPSS software version 22.0.
In all statistical tests, the threshold of significance was fixed at 0.05 (p=0.05).
There is no conflict of interest in our work.

RESULTS

Our series has included 80 patients: 75 men and 5 women. The gender ratio (M/F) was 39 for Group 1 and 9 for the group 2. The average age was 30.95 years for the group 1 and 34.9 years for the group 2.

Group 1 patients all had broken ACL, 30% of who were isolated. In 57.5% of the cases in group 1, there was an associated meniscal lesion and in 12.5% of cases, we noted Chondropathy lesions. All the patients in group 2 had an intact ACL. Only 10% of the patients had a healthy knee. 80% have presented a meniscal lesion and 10% had Osteochondritis.

The comparative analysis of the parameters of the ICN geometry had shown that the average NWI of group 1 was less than the average NWI of group 2 and that the average NHI of group 1 was less than the average NHI of group 2 (Table 1). The differences were statistically significant. The relative risk was 2.

Table-1: Comparative analysis of the parameters of the inter-condylar notch geometry

	Group	N	Average	Min	Max	Standard deviation	P-Value
NWI (Rx)	G1	40	0,22	0,16	0,32	0,390	0,002
	G2	40	0,24	0,17	0,29	0,240	
NWI(MRI)	G1	40	0,21	0,15	0,28	0,033	0,012
	G2	40	0,23	0,18	0,28	0,021	
NSI	G1	40	0,973	0,60	1,85	0,246	0,095
	G2	40	0,971	0,62	1,40	0,198	
IHE	G1	40	0,44	0,30	0,60	0,060	0,006
	G2	40	0,49	0,37	0,70	0,075	

The difference between the NSI of the two groups was not statistically significant. We have found a statistical correlation between the NWI (Rx) and the NWI (MRI) (Table 2).

Table-2: Correlation matrix between the parameters of the inter-condylar notch geometry

	NWI(Rx)	NWI(MRI)	NSI	IHE
NWI (Rx)	1	0,519	0,163	0,024
NWI (MRI)	0,519	1	0,301	0,198
NSI	0,163	0,198	1	-0,259
IHE	0,024	0,301	-0,259	1

The correlation between the values of the NWI (Rx) and the values of the NWI (MRI) was high (p value = 0.0001) with a linear regression (Figure 3).

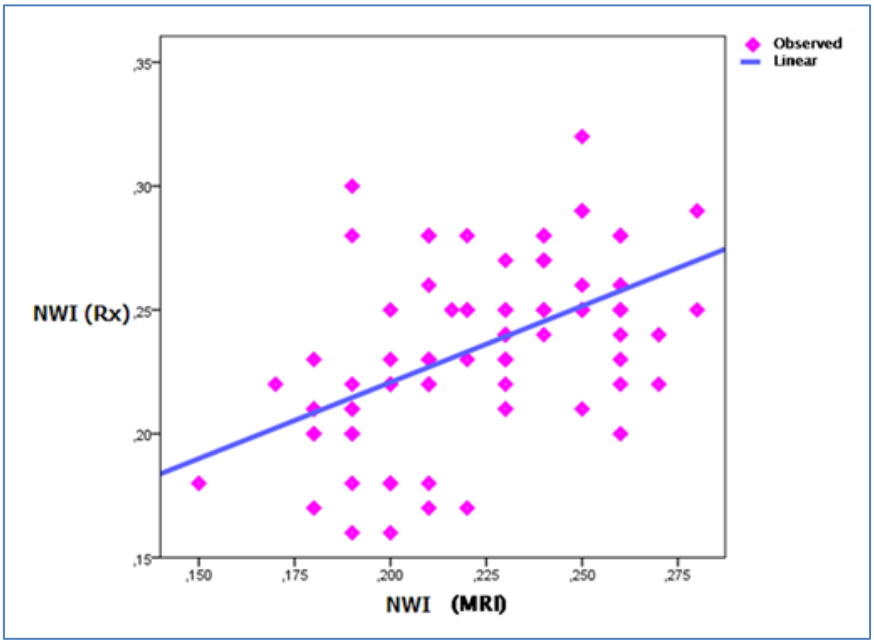

Fig-3: Correlation between the values of the NWI (Rx) and the values of the NWI (MRI)

DISCUSSION

Our study has shown that a narrow inter-condylar notch (NWI < 0.22 and/or NHI< 0.44) represents a risk factor of ACL rupture. The relative risk was 2.

Palmer [3] was the first who mentioned, in 1938, the existence of a pathological relationship between the LCA and the ICN. Since then, several authors have found a relationship between a narrow notch and the risk of ACL rupture, based on NWI measurement in most of the time. Among the authors who are interested in studying the complex geometry of the ICN, some have performed their measurements on clichés of imaging (standard X ray, Scannographic and MRI cross sections of the knee) [4-7], others have made arthroscopic measurements [8, 9] and few have made Cadaveric measurements [10, 11].

Souryal [12] has defined, in 1993, the "notch width index" (NWI) to measure the size of the inter-condylar notch. He concluded that a low NWI (less than 0.20) represents a predictive factor of rupture of the ACL. Several authors [4, 5, 7, 9, 12, 13, 14] have subsequently confirmed these findings by using this index, whether on standard radiographs of the knee, Scannographic cross sections or MRI.

The most recent meta-analysis is that of Chao Zeng [7] published in 2013. This author concluded that a narrow notch with a low NWI (radiographic and MRI) is a risk factor for ACL rupture.

In contrast, Herzog [15] TEITZ [16] and Gupta [17] have not found a relationship between the NWI (radiological and MRI) and the occurrence of ACL lesions. They concluded that the notch width cannot alone explain all the ACL ruptures.

As the NWI does not give a complete picture on the complex geometry of the ICN, the studies have used other measurement settings: the reverse notch width index (RNWI)[18], the notch shape index (NSI)[11], the notch height index (NHI)[19], and the notch area index (NAI)[11]. They have also identified angles to better understand this geometry: the notch sagittal angle (NSA) and the notch transverse angle (NTA) [20].

Tillman [11] in 2002, was the first to identify the "notch shape index" (NSI) as a form parameter. He found that a square notch, in the form of wave or tightly bound on all or a part of its height would be related with a risk of ACL rupture. He has also shown that the NSI is lower among women than among men and that the ICN fewer rounded expose them to the risk of ACL rupture.

Alsaeed [21] has also concluded that a low NSI is strongly linked to the "form A", which is the more prone to the ACL rupture, according to the study of Carola and van Eck [22].

In our study, we have not found a significant difference between the NSI of the two groups (p = 0,972). This result was also found by Khalil Mourched [23].

We have also calculated the notch height index (NHI), which has been studied only in 2008 by Ben Hamida [19]. The results of the latter were consistent with ours. In fact, we have found a statistically significant relationship between a low NHI and the rupture of the ACL.

Although several authors have found a strong correlation between the NWI and the rupture of the ACL, the limit value of the NWI, from which we consider an ICN as narrow, remains variable. In fact, Souryal [12] concluded that the NWI limit was 0.20. Sonnery,[17] Domzalski,[4] and Hoteya [24] have concluded that the limit values of the NWI were respectively equal to 0.21, 0.24 and 0, 25. Uhorchok [25] and Laprade [13] have found smaller values (respectively 0.18 and 0.19). Therefore, the anatomy of the ICN varies with race or ethnicity. In this sense, Shelbourne,[26] has found that the African athletes and black Americans had broad ICN compared to white Americans, which makes these more susceptible to ACL lesions.

However, Shelbourne has shown in another study [8] that the geometry of the ICN is not responsible in itself of the rupture of the ACL, but rather, a narrow notch simply reflects the small ACL it houses. That is to say; an ACL of small volume is a risk factor for its rupture. This hypothesis has been also reported by Simon [27] and Choudhari [28]. But, Muneta [14], in a Cadaveric study has shown that the diameter of the ACL was identical regardless of the size of the notch. This explains that the rupture of the ACL is in relation with a narrower notch and not with the size of the ACL.

Taking account of this intrinsic risk factor, the prevention of the ACL rupture begins with the identification of subjects at risk. We recommend for pivot sports, a systematic radiological screening evaluation for this anatomical risk factor. This evaluation contains: a Schuss incidence to assess the inter-condylar notch. It is a simple way to identify athletes with risk of ACL rupture since we have found that the correlation between the values of the NWI (Rx) and the values of the NWI (MRI) was high (p value = 0.0001) with a linear regression (Figure 3).

We do not recommend, for those athletes at risk, pivot sports. We recommend applying intensive prevention programs of ACL ruptures for these athletes. Several prevention programs have been published and evaluated [29]. The most recognized are FIFA 11 and FIFA 11+. The prevention programs must be applied for both the affected Knee and for the contralateral knee, because the risk of ACL ruptures in the contralateral knee is double that in the ipsilateral

knee according to the systematic review made by Rick [30].

Several authors have recommended the notch-plasty during the ACL Ligamentoplasty in case of a narrow ICN [13, 15, 27] For Souryal [12] the notch plasty must be systematic; and for Carola [22], the double bundle ligamentoplasty is not recommended in case of a narrow notch.

CONCLUSION

A narrow inter-condylar notch with a NWI < 0.22 and/or a NHI< 0.44 represents a risk factor of ACL. Sports Medicine must identify this anatomical risk factor. The threshold, from which we talk about a pathological ICN, must be adapted to the population concerned because studies have shown a variation of measurements between the different ethnic groups. It is important to take this factor into account, in the primary prevention, in the surgical technique (notch plasty if necessary) and in the postoperative follow up (rehabilitating both knees); in order to obtain the best results for the ligamentoplasty, to limit the risks of iterative rupture, and to prevent risk of rupture of the contralateral ligament.

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