Profile of Knee MRI Morphometric Risk Factors for Anterior Cruciate Ligament Tear at Dr. Soetomo General Academic Hospital

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Abstract

Objective: Anterior Cruciate Ligament (ACL) tear can decrease quality of life especially in athlete. The physical athletic activities are external factors for ACL tear. There are also internal factor and one them is anatomical factor. Therefore, it is necessary to determine the knee morphometric risk factor profile for ACL tear.
Materials and Methods: This is a descriptive observational retrospective study with case-control design. The study data consisted of the patient's medical records and knee joint MRI study results which were collected through consecutive sampling. Morphometric variable measurements in the form of Notch Width (NW), Notch Width Index (NWI), α -angle, Q-angle (Quadricep angle) and Medial Tibial Posterior Slope (MTPS) were assessed by two assessors. Afterwards, the mean value of each variable was determined.
Results: In ACL tear group, the mean±SD value for NW, NWI, Alpha angle, Q-angle and MTPS was 2.02±0.21, 0.27±0,02, 37.97±4.69, 11.06±3.21, and 9.24±2.73, respectively, while in non-ACL tear group the mean±SD value was 1.97±0.23, 0.29±0.02, 35.59±4.52, 12.03±4.08 and 7.70±3.53, respectively.
Conclusion: The mean NWI and Q-angle values in ACL tear group were smaller than in non-ACL tear group. The mean NW, Alpha angle, and MTPS values in ACL group were greater than in non-ACL tear group.

Keywords: Anterior Cruciate Ligament (ACL) Tear, Risk Factor, Knee Joint Morphometric, MRI

1. Introduction

Anterior Cruciate Ligament (ACL) tear is one of the most common knee ligament abnormalities found in athletes, its incidence ranges from 29-38 per 100,000 people.[1–3] As a result, in the short term it might cause instability and in the long term it might cause degenerative process of knee joint. The most common type of ACL injury mechanism is non-contact type, due to pivoting movement, when the knee is slightly flexed and in valgus position then the femur undergoes external rotation as in foot maneuver movement during ball dribbling.[4–8] Risk factors for ACL tears are divided into internal factors (anatomical, hormonal, neuromuscular and genetic factors) and external factors (exercise type, footwear, environment). Identification of these risk factors in athletes will be useful to adjust the type of training for each individual according to their anatomical variation for minimizing ACL tear incidence.[1,7,9–14] Previous study reported that anatomical factors that play some roles in ACL tear were femurotibial alignment, narrow intercondylar notch, type A stenotic notch, medial tibial plate depth, and steep lateral tibial slope. However, various measurement techniques and methods of these anatomical factors are still debatable.[1,2,9–11,13,15–17,18] This study aims to provide an overview of anatomical risk factor characteristics in knee joint MRI study.

2. Materials and Methods

This is a descriptive retrospective observational study with case-control design conducted at Dr. Soetomo General Academic Hospital, Surabaya, Indonesia, from July 2018 to January 2021. Inclusion criteria were knee MRI study results in patients with clinical knee injury, knee pain and suspected ligament tear, aged 10 to 50 years with accessible medical records. Patients with tibial plate or femur deformities, suboptimal positioning, or incomplete data were excluded. There were 5 variables in this study, which were NW, NWI, Alpha-angle, Q-angle and MTPS. These variables were assessed by two musculoskeletal radiologists with more than 10 years of experience. The results from the two assessors then averaged to determine the mean value for each variable.

The NWI is a ratio of bicondylar width to notch width as measured on coronal PD sequence of MRI at the intersection level between Posterior Cruciate Ligament (PCL) and ACL or at the level of popliteal sulcus of lateral femoral condyle[3]. As shown in Figure 1.

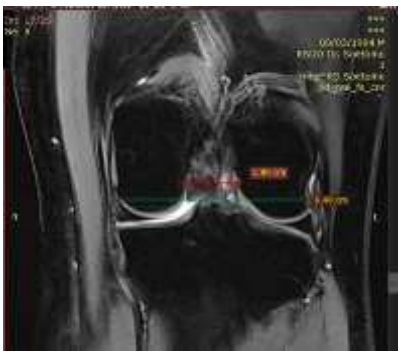

Figure 1. NW and NWI measurement illustration on coronal image. The green line is the bicondylar width (BCW) and the red line represents NW calculated at the projection where the popliteal sulcus of lateral femoral condyle is visible. Notch Width Index (NWI) is obtained from NW divided by BCW.[3]

The Q-angle is an angle formed by the line that intersects the center of patellar bone and the center of tibial tuberosity in coronal projection with mediolateral longitudinal axis of femur.[3] As showed in Figure 2.

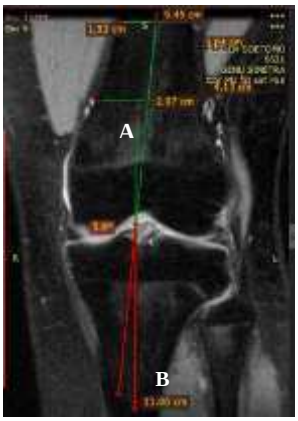

Figure 2. Quadriceps angle. The red angle is the angle formed by the intersection of the line that passes through the center of patellar bone and tibial tuberosity (AB line) with mediolateral axis of femur.[3]

The α-angle is an angle formed by the anteroposterior longitudinal axis of femur and Blumensaat line.[3,4] As described in Figure 3.

Figure 3. Illustration of α-angle. The red angle formed by the axis of femur and the intercondylar roof or Blumensaat line (AB line) in sagittal section.[3]

Medial tibial posterior-inferior slope is an angle formed by a line that is perpendicular to the anteroposterior axis of tibia, with the line passes through the medial side of tibial plate at the highest point of condyles in sagittal section.[3] As ilustrated in Figure 4.

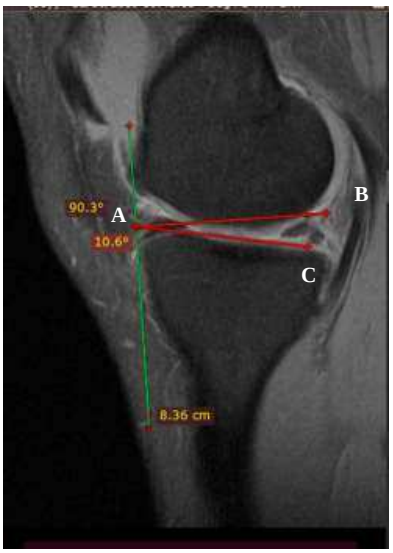

Figure 4. Medial Tibial Posterior Slope. The angle formed by a line perpendicular to the axis of tibia (AB line) and the medial tibial slope (AC line).[3]

3. Results

The study samples consist of 82 patients, which were divided into case (ACL tear patients) and control group (non-ACL tear patients) with equal number of patients. The interobserver suitability test was conducted for NW, NWI, Alpha angle, Q angle, and MTPS, where the kappa values for each varibles was 0.976 means very strong, 0.752 means strong, 0.854 means strong, 0.830 means strong and 0.805 means strong, respectively.

Table 1. Demographic characteristics of samples

Characteristics	ACL Tear	
	Yes (N=41)	No (N=41)
Gender		
Male	31 (75.6 %)	21 (51.2 %)
Female	10 (24.4 %)	20 (48.8 %)
Age group		
10-20	14 (34.1 %)	18 (43.9 %)
21-30	19 (46.3 %)	15 (36.6 %)
31-40	4 (9.8 %)	6 (14.6 %)
41-50	4 (9.8 %)	2 (4.9 %)

In this study, it was found that ACL tear occurred more frequency in men than women with a percentage of 75.6% in the case group. Most ACL tear patients belonged to 21-30 years group. As described in Table 1.

The ACL tear group were then divided into total and partial ACL tear groups, where there were 27 (66%) and 14 (34%) patients, respectively. As showed in Figure 5.

Figure 5. Diagram of total and partial ACL tear groups

The most common secondary signs in the case group were PCL buckling in total ACL tear group and bone contusion in partial ACL tear group with 26 and 3 patients, respectively. As described in Table 2.

Table 2. Secondary sign characteristics in Partial and Total ACL tear

Secondary Sign	ACL Tear	
	Partial (N=14)	Total (N=27)
Bone Contusion	3	8
Anterior tibial translation	2	10
PCL buckling	2	26

The mean (mean±SD) in the case group for NW value isc2.02±0.21; NWI value is 0.27±0.02; α-angle value is 37.97±4.69; Q-angle is 11.06±3.21 and MTPS value is 9.24±2.73. The NW, α-angle and MTPS values in the case group were higher than the control group, while the NWI and Q-angle values in the case group were smaller than the control group, as described in Table 3.

Table 3. Characteristics of morphometric variable values in ACL tear and non-ACL tear group

Variable	ACL Tear	
	Yes (N=41) Mean±SD	No (N=41) Mean±SD
NW	2.02±0.21	1.97±0.23
NWI	0,27±0.02	0.29±0.02
α-angle	37.97±4.69	35.59±4.52
Q angle	11.06±3.21	12.03±4.08
MTPS	9.24±2.73	7.70±3.53

The ACL group then was divided into two subgroups, partial and total tear group. The total tear group had lower NW, NWI, Q-angle and MTPS values than the partial group. Meanwhile, the α-angle value was higher in the total tear group compared to the partial tear group as showed in Table 4.

Table 4. Characteristics of morphometric variable values in the total and partial ACL tear group.

Variable	Tear ACL	
	Partial Mean±SD	Total Mean±SD
NW	2.04±0.23	2.00±0.20
NWI	0.28±0.19	0.27±0.02
α-angle	36.56±5.06	38.69±4.40
Q angle	12.26±3.69	10.44±2.80
MTPS	10.38±2.28	8.65±2.79

4. Discussion

Knee MRI morphometric risk factors which are internal risk factors for ACL tear was studied in this research, including NW, NWI, α-angle, Q-angle and MTPS. When an individual has a morphometric risk factor, both internal and external factor modification could be conducted as a follow-up. For internal factors, the supporting muscles of the knee joint could be strengthened, one of which is the quadriceps muscle, therefore the knee will become more stable and the ACL load will be reduced. The modifiable external factor

is the reduction of movements that have a high risk of causing ACL tears such as pivoting, jumping movements, and sudden stops. Training that is devoted for good and correct technique in performing these movements will also help prevent ACL tears.[19,20]

In this study, it was found that ACL tear was found more in men than women. This finding is consistent with previous studies from Prince et al and Zeh et al, which stated that in immature (young) skeletal group, ACL tear in men, avulsion fractures, and partial tears were more likely to be found.[11,21] However, this finding was inconsistence with a study from Bayer et al, which stated that the risk of ACL tear was three to six times greater in women compared to men.[10] This could be due to the fact that men have more external predisposing factors, and in this study the number men samples was higher compared to women samples.

The age group with the highest incidence of ACL tear was the 21-30 years age group. According to previous studies from Zeh et al and Shen et al, ACL tear incidence was most common in the 3rd decade of life.[11,15]This could be caused by high activity in this age group, both risky activities such as sports that require a lot of jumping, landing or sudden changes in position, as well as general activities but with a high risk of contact trauma.[8]

The most common secondary or indirect sign found in this study was PCL buckling, which is an abnormal orientation of the PCL, for totalACLtear and bone contusion for partial ACL tear. Total or partial ACL tear will cause loosened ligaments resulting in angular abnormalities formed by the PCL. In addition, a greater force is needed for causing the tibia and femur bone to collide with each other and bone contusion to occur.[11,15,21–23] Another cause is the undetermined period of time between ACL tear incidence and MRI examination, therefore when an MRI examination was performed, bone contusion finding have disappeared.

NW and NWI value was assumed to be valuable for estimating ACL volume and could indicate impingement in ACL.[1,9–11,15,16]The hypothesis in a study from Bining et al stated that the smaller the intercondylar notch, the greater the force imposed on the ACL midsubstance, which will increase the risk of injury.[24] In this study, mean NW for non-ACL tear group was higher ACL tear group. This was in accordance with previous studies from Shen et al and Shaw et al, where they did not find a significant difference for NW value between ACL tear and non-tear group.[1,15]The NWI value in this study showed that the case group had a lower NWI value compared to the control. In a systematic review study by Bayer et al, Domzalski et al, Shaw et al, Zeh et al, Volkan et al, the NWI value was also referred to as an important factor for ACL tear evaluation..The NWI cut off value stated in Shen et al study for NWI was 0.25.[1,9–11,16,1818]

The case group had a larger α-angle value with a mean value of 37.98±4.69 than the control group, with a mean value of 35.59±4.52. This result was consistent with previous studies results, which found that the case group had a mean α-angle value of more than 38.5 degrees[15], 60 degrees[18], and 70 degrees[25], which were greater than the control group. The ACL position will be flattened causing large α-angle value, therefore it might cause greater friction in the ACL accompanied by ACL impingement from the anterior side due to intercondylar dysplasia.[15]

Smaller Q-angle value with a mean value of 11.06±3.2 was found in the ACL tear group than the control group, with a mean value of 12.03±4.08. The Q-angle in ACL tear indicates the inferior extremity alignment and indicates that the valgus shape of knee joint in the case group had a smaller mean value compared to the control group.[10,17] It is inconsistent with study by Bayer et a and Sac et al which found that larger Q-angle can increased dynamic valgus and high abduction loads of the knee.[10,17]

The case group had a lower MTPS score with a mean value of 9.24±2.73 than the control group, with a mean value of 7.7024±3.53. The MTPS value in this study indicates that a greater value indicate the steeper the tibia surface. This will result in a decrease in anteroposterior stability, which is characterized by an increase in femorotibial translation quantity and an increase in ACL mechanical load. This finding is consistent with a study from Han et al, Andrade et al, Zeh et al, Shen et al, Volkan et al, Huang et al, Bayer et al, Priono et al study, where they reported a significant correlation between an increase in MTPS value with ACL tear incidence.[2,9–11,13,15,18,26] They also found that the case group had a mean MTPS value of more than 14.4 degrees.[8]

Between total and partial tear groups, it was found that NW, NWI, Q-angle and MTPS values were smaller in total tear group than in partial tear group. Meanwhile, the α-angle was found to be higher in total tear group than partial tear group. This was not in accordance with a study from Saxena et al, where they found that the inclination angle of the intercondylar roof, which is referred in this study as the α-angle, had a lower value in total tear group compared to partial tear group.[14]

Limitations of this study are: first, the total number of female and male samples were not the same, with large gap. Secondly, the ACL tearing mechanism of contact and non-contact was not assessed in this study and third, the ACL tear diagnosis was not proven on all samples by arthroscopy as a gold standart, which may cause misclassification bias. Future studies with more samples and similar men and women composition are needed. Furthermore, sample selection more homogeneous population will minimize external factors. The misclassification bias of independent variables could be minimized by increasing the number of MRI assessors to increase the result accuracy.

5. Conclusion

The highest ACL incidence was found in men (75.6%) in the 21-30 years age group (46.3%). The most common type of ACL tear was total ACL tear, with 27 samples (66%), with the most common secondary signs being PCL buckling (PCL orientation abnormality) in total ACL tear and bony contusion in partial ACL tear.

The profile of knee MRI morphometric risk factors for ACL tear at Dr. Soetomo General Academic Hospital are as follows: First, mean NWI and Q-angle values in ACL tear group were smaller than in non-ACL tear group. Secondly, the mean NW, Alpha angle, and MTPS values in ACL tear group were greater than in non-ACL tear group.

Ethical Clearance

This study was conducted in accordance with the Declaration of Helsinki. This study was approved by the 100 Medical Research Ethics Committee of Dr. Soetomo General Hospital, Surabaya. All participants included had given their written informed consent to participate in this study during admission.

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Conflict of Interest

Nil

Abbreviations :

ACL	: Anterior Cruciate Ligament
PCL	: Posterior Cruciate Ligament
NW	: Notch Width
NWI	: Notch Width Index
α-angle	: Alpha angle
Q-angle	: Quadricep angle
MTPS	: Medial Tibial Posterior Slope
MRI	: Magnetic Resonance Imaging

PD sequence : Proton Density sequence
BCW : Bicondylar width

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