Radiological Study of Anterior Cruciate Ligament of the Knee Joint in Adult Human and its Surgical Implication

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Abstract Anterior cruciate ligament (ACL) is considered as an intra-capsular extra-synovial ligament, primarily responsible for resisting anterior displacement of the tibia on flexion and extension. Magnetic resonance imaging (MRI) has been applied to musculoskeletal patho-anatomy and has been shown to be an effective tool for definition and characterization of knee pathology, regarding the knees subjected to MRI examination, measurement was done for length from femoral to tibial attachment site and thickness at the mid-portion. Comparison between the data obtained in the present study with data obtained from Kowen results there is variable length and thickness. Concluded that for the anterior cruciate ligament the length and thickness of the native ACL played an important role for choosing the type of graft and for the preparation of the graft and dimensions of the native ACL have to be considered in graft selection for anatomic ACL reconstruction.

Keywords MRI, ACL , Knee Joint, Measurement

anterior cruciate ligaments for the sake of perfect surgical reconstruction of the torn ligament.

Single bundle (SB) ACL reconstruction may not adequately restored normal knee kinematics, particularly tibial rotation, also had shown that anatomic double bundle (DB) reconstruction restored better knee kinematics compared to SB reconstruction alone (5).

Over years, an increased understanding of technical issues of graft selection, placement, tension, and fixation as well as of postoperative rehabilitation had lead to improved outcomes from ACL reconstruction. The standard technique for anterior cruciate ligament reconstruction was currently arthroscopic single bundle (SB) reconstruction with autografts (graft was taken from the patient) such as bone-patellar tendon-bone (BPTB), medial hamstring tendons (semitendinosus and gracilis), or the quadriceps tendon. The single bundle reconstruction technique had mainly focused on the restoration of the antero-medial bundle while giving limited attention to poster-lateral bundle. Thus single bundle ACL reconstructions were successful in restoring anterior stability to the knee, but not rotational stability (6)

1. Introduction

Anterior cruciate ligament (ACL) has two identifiable bands, the antero-medial band (AMB) and the poster-lateral band (PLB) according to their insertion on the tibial spine (1)

Anatomy is the basis of orthopedic surgery; so the anterior cruciate ligament reconstruction was governed by this concept so when native anatomy was closely restored; superior outcome can be achieved (2).

Restoration of the knee kinematics, rotational stability with native ligament orientation, origin and insertion depended on anatomic anterior cruciate ligament reconstruction, and their surgical techniques must be correspondingly evolved to achieve these goals (3).

In anterior cruciate ligament reconstruction orthopedic surgeons prefer to use fixed graft length and thickness, so due to the individual variation of the structure of the patient knee, failure of reconstruction was liable to occur (4); so the aim of this work was to achieve MRI description of the

2. Materials and Methods

Twenty knees MRI (contained 20 ACL) of Sudanese persons with no previously detected knee pathology were collected from Diagnostic Radiology Department, Khartoum Teaching Hospital (University Hospital in Sudan), without any history of anterior cruciate ligament injury or surgery in order to evaluate normal anatomy. The inclusion criteria for the study population consisted of completed growth (closed epiphyseal plates), and no previous injury or knee surgery, knee MR images sagittal plane (T2-Weighted Image) were reviewed by radiologist, and only knees with an intact cruciate ligaments were included. Knees that displayed evidence of notch hypoplasia or stenosis, or partial or complete ACL deficiencies were excluded.

The studied persons wear a hospital gown or clothes without metal zippers or snaps and removed any metal which can cause blurry images; the person lay down on a narrow

table that slides into a large tunnel like scanner.

The length of each bundle was defined as the distance between the central points of the femoral and tibial attachments, also the thickness was measured at mid-portion (fig 1), the scans is measure digitally with Soft-ware programmed With the Osirix Medical Imaging Software Version1.7.1.

Figure 1. Image of MRI sagittal plane showing the way of computerized anterior cruciate ligament measured 3.7 cm length and 0.8 cm thick.

Statistical study :

This is a prospective study targeting to find variability in measurement of the anterior cruciate ligament between MRI sample and Kowen (7) parameter of anterior cruciate ligament.

- i. The collected data were revised, coded, tabulated and introduced to a personal computer using Statistical Package for Social Science (SPSS 15.0.1 for windows; SPSS Inc, Chicago, IL, 2001). Data were presented and suitable analysis was done according to the type of data obtained for each parameter.
- ii. Descriptive statistics:
 - Mean, Standard deviation ($\pm$ SD), minimum and maximum values (range) for numerical data.
- iii. Analytical statistics:
 1. One-Sample T Test was used to test whether the mean of a single variable differs from a specified constant.
 - P- value: level of significance-
 - P>0.05: Non significant (NS).
 - P< 0.05: Significant (S).
 - P<0.01: Highly significant (HS).

3. Results

In the present study, the anterior cruciate ligament length and thickness obtained from the MRI (T2MRWI) of the knee sagittal plane and calculated by certain measurement tools built in the system of the machine, the minimum length of

ACL was 3.1cm (Fig. 2) and the maximum ACL length was 4.4 cm (Fig. 3) while the mean length was 3.7 cm (table.1).

Figure 2. Image of MRI sagittal plane showing anterior cruciate ligament with a minimum length measuring 3.1 cm.

Figure 3. Image of MRI sagittal plane showing anterior cruciate ligament with a maximum length measuring 4.4 cm.

Regarding thickness of ACL, it was found minimum thickness was 0.5 cm (Fig.4) and the maximum thickness was 1.2 cm (Fig.5) while the mean thickness was 0.8 cm (table.1).

The ratio of ACL length /thickness was found to be minimum 3.20 and maximum 7.17 with a mean ratio of 4.87 (table.1)

Table 1. Statistics description of radiological length, thickness and length / thickness of ACL among MRI study group;

	Mean	$\pm$ SD	Minimum	Maximum
ACL length	3.70	0.42	3.10	4.40
ACL thickness	0.80	0.18	0.50	1.20
ACL length / thickness	4.87	1.29	3.20	7.17

Figure 4. Image of MRI sagittal plane showing anterior cruciate ligament with a minimum thickness measuring 0.5 cm.

Figure 5. Image of MRI sagittal plane showing anterior cruciate ligament with a maximum thickness measuring 1.2 cm.

Measurement study of radiological ACL length showed

that the mean length was 3.7 cm (table. 1; fig 6), which did not show variability in measurement of Kowen (7) ACL length and P value was 0.297 (table. 2).

Radiological ACL thickness measurement showed that the mean thickness was 0.8 cm (table. 1; fig 6). It was show variable different in measurement of Kowen (7) ACL thickness and P value was 0.001 (table. 3).

Table 2. Statistics of comparison between Radiological length and Kowen (7) length of ACL;

	Radiological length		Kowen et al. (2013)	t	P	Sig
	Mean	±SD	Mean			
ACL length	3.7	0.416	3.8	1.07	0.297*	NS

*One sample T test

Table 3. Statistics of Comparison between Radiological thickness and Kowen (7) thickness of ACL;

	Radiological thickness		Kowen et al.	t	P	Sig
	Mean	±SD	Mean			
ACL thickness	0.800	0.180	0.6	4.95	0.001*	HS

*One sample T test

Using the one sample-Test, The mean radiological ACL thickness was variable different measurement from Kowen (7) ACL thickness.

4. Discussion

Athletes who participate in high demand sport like football and basket ball require reconstruction of anterior cruciate ligament by auto graft mostly obtained from hamstring tendons. Reconstruction of the torn ACL produced better knee stability during daily activities and strenuous activities than non surgical treatment especially in active individuals. The outcome of reconstructed ligament and its ability to meet the desirable knee kinematics depended on how much of the ligament anatomy was matched, a result which was concluded by Martins (2).

Figure 6. Showing the radiological mean of the ACL length, thickness and ratio of ACL length/thickness

Aglietti (8) recommended double bundle ACL reconstructions instead of single graft procedures because single graft reconstructions increased failure rate with return of the pivot shift phenomena. On the other hand Asagumo (9) in his clinical study did not support this recommendation and reported that single graft ACL reconstructions had a high success rate in restoring knee stability without the added complexity of double bundle surgery that required two grafts and two femoral and tibial tunnels.

Zantop (10) concluded from his study that if the graft was too long, the tibial plug would protrude from the tunnel and if the graft was too short, the graft would be buried deep in the tunnel and in both cases, fixation with interference screw might not be possible. Therefore, the Length and thickness of the native ACL played an important role for choosing the type of graft and for the preparation of the graft.

The present radiological measurement study of ACL showed that the mean length was 3.7 cm which did not show variable difference of Kowen (7) ACL length this because Tajima (4) described range between 3.2-3.8 cm, the distances between attachments of the ACL fibers varied with motion of the knee. According to the tensioning pattern, the distance for the antero-medial bundle increased with flexion; however the length of the PL bundle was decreased at 90° of flexion when compared with full extension.

Radiological ACL thickness measurement showed that the mean thickness was increased to become 0.8 cm, which show variable difference of Kowen (7) ACL thickness, however Shelbourne and Liotta (11) studied ACL reconstruction with patellar tendon graft to document the normal range of patellar tendon thickness and to determine if using thicker graft, as an ACL graft postoperative outcome will be affected, he concluded that an abnormally thicker patellar tendon should not preclude the use of this involved tendon as a graft source for ACL reconstruction.

The method of imaging played a great role in retrieving the accurate data, so Katahira (12) reported that increased diagnostic accuracy prescribing oblique coronal images parallel to the long axis of the ACL of an oblique sagittal image obtained as described above (double oblique sequence), however Aglietti (8) reported that improved ACL visualization in the knee in mild (17-30°) flexion in part, because of decreased partial voluming of the proximal ACL with the intercondylar roof.

Recently, with technological development of radiological machines, new era emerged to visualize the cruciate ligaments well; Hashemi (13) was the first team to publish paper on 3 D reconstruction to extract important information regarding the length, cross sectional area, and volume of the ACL. The accuracy and repeatability of measurements obtained by this method were acceptable.

The selection of cases in the present radiological study was randomly selected, where age and sex were not put in consideration. The data collection error was significant as reported by Chandrashekar (14) who found that the anterior cruciate ligament in women was smaller in length, cross sectional area, volume, and mass when compared to that in

men.

5. Conclusions

In conclusion, the current work suggests that pre surgical planning could be improved by doing MRI to the normal knee joint before reconstructing torn ligament of other knee to improve the outcome and the dimensions of the native ACL have to be considered in graft selection for anatomic ACL reconstruction.

Future prospective studies should be done to compare at huge number of MRI collected with good randomized and blinded method in order to evaluate the accurate method to retrieve anthropometric measurements.

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