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Original Article

ACL ideal graft: MRI correlation between ACL and humstrings, PT and QT☆

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ABSTRACT

Objective: The objective of this study was to measure in MRI scans, the size of the origin, insertion and length of the anterior cruciate ligament and possible graft for reconstruction surgery in case of injury. Besides this, there was a cross between statistical data to test the hypothesis of proportional relationship between these anatomical extent.

Materials and methods: 52 MRI examinations performed between 2008 and 2011 were valued at random in a longitudinal retrospective epidemiological study. To measure the width of the ACL was used coronal oblique to the length of the sagittal section, for inserting the tibial coronal femoral insertion and was also used oblique coronal section.

Results: The average diameter of the ACL was 4.80 mm (3.1–8.3 mm), with a length of 3.8 cm (2.85–4.5 cm). The origin ranged from 9.7 mm to 15.4 mm. The average insertion on the tibia was 13.3 mm. The average diameter of the semi-tendinous was 4.38 mm and the average diameter was 3.42 mm gracilis. The quadriceps presented diameter of 7.67 mm, a length of 35.34 mm and 4.54 mm patellar tendon diameter and 26.62 mm in average length.

Conclusion: These data provide important information for the pre-operative surgeon, facilitating preoperative planning and providing viable alternatives and avoiding inadequate grafts.

Enxerto ideal para ligamento cruzado anterior: correlação em ressonância magnética entre LCA, isquiotibiais, tendão patelar e tendão quadríceps

Palavras-chave:
Anatomia

RESUMO

Objetivos: Mensurar em exames de ressonância magnética (RM) o tamanho da origem, a inserção e o comprimento do ligamento cruzado anterior (LCA) e seus possíveis enxertos para cirurgia de reconstrução em caso de lesão. Além desse, fez-se o cruzamento

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Espectroscopia de ressonância magnética
Ligamento cruzado anterior

estatístico entre os dados para testar a hipótese de relação proporcional entre essas medidas anatômicas.

Materiais e métodos: Foram feitos 52 exames de RM entre 2008 e 2011 e avaliados de maneira aleatória em um estudo epidemiológico longitudinal retrospectivo. Para a mensuração da largura do LCA foi usado o corte coronal oblíquo, para o comprimento o corte sagital, para a inserção tibial o corte coronal e para a inserção femural o corte coronal oblíquo.

Resultados: O diâmetro médio do LCA foi de 4,80 mm (3,1–8,3 mm) e o comprimento de 3,8 cm (2,85–4,5 cm). A origem variou entre 9,7 mm e 15,4 mm. A inserção média na tíbia foi de 13,3 mm. O diâmetro médio do semitendíneo foi de 4,38 mm e o diâmetro médio do grácil de 3,42 mm. O quadríceps apresentou diâmetro de 7,67 mm e comprimento de 35,34 mm e o tendão patelar 4,54 mm de diâmetro e 26,62 mm de comprimento médio.

Conclusão: Os dados obtidos fornecem informações pré-operatórias importantes para o cirurgião, facilitam o planejamento pré-operatório, apresentam opções viáveis e evitam enxertos inadequados.

Introduction

Because of the high incidence of anterior cruciate ligament (ACL) injuries among the population, these have been the subject of many recent studies.[1–7] The ACL has the function of the main stabilizer for anterior translation of the tibia and has secondary participation in limiting the internal rotation of the knee.[3,4,8]

The ACL has its origin in the posterior portion of the lateral femoral condyle. It has an intra-articular and extrasynovial path and is inserted laterally and anteriorly to the medial tibial spine. The model that is most accepted today comprises two bands and was created by Girgis et al.[6] In this, an anteromedial (AM) band emerges more proximally and posteriorly to the femur, while the posterolateral (PL) band is more distal and anterior. The bands are twisted along their path in the intercondylar region and their insertion in the tibia follows the order that gives them their name: anteromedial to AM and posterolateral to PL.

Because of the instability caused by ACL injury and the possible comorbidities consequent to its rupture, such as chondral lesions, meniscal lesions and possibly early osteoarthrosis, the recommended treatment is surgical, with ligament reconstruction.[9,10]

Several graft sources have now been shown to be effective for ACL reconstruction. Choosing the ideal graft is done on an individual basis according to the patient's profile and the nature of the injury, in addition to the surgeon's personal experience. Grafts derived from the quadriceps tendon and from the flexors have emerged as alternatives to patellar grafts, following studies relating to anterior knee pain and comorbidities in the donor site.[11–14] Controversy still exists with regard to choosing the ideal graft, and it has been shown in the literature that one of the main factors in making the decision is the final width of the graft. Grafts of widths less than 7 mm tend to fail more easily, while wider grafts are safer.[12,13,15]

Some studies have attempted to demonstrate possible predictive factors for the diameters of the grafts generally used in surgical reconstruction procedures, among ACL measurements.[12,16–19] In our review of the literature, we did not find any article that attempted to establish a relationship between the characteristics of the ACL and its possible grafts.

The first objective of this study was to measure the sizes of the origin and insertion and the length of the ACL among the population of Curitiba, using magnetic resonance imaging (MRI) examination. The possible grafts for reconstruction of the ACL were measured. The second objective of this study was to cross-correlate between these data and test the hypothesis that there would be a proportional relationship between the ACL measurements and their possible grafts.

Materials and methods

After approval had been obtained from the Ethics Committee by means of the "Platform Brazil" website, following ethics assessment under presentation certificate number (CAAE) 01338212.5.0000.0100, we gathered data from examinations performed between November 2011 and January 2012. Also, 52 MRI examinations performed between 2008 and 2011 were reviewed in a retrospective longitudinal epidemiological study.

The inclusion criteria were that the patients should be: (1) skeletally mature and aged under 40 years; (2) free from any previous ligament injuries or degenerative lesions.

The exclusion criteria were that the patients should not have: (1) an open growth plate; (2) previous surgery; (3) previous ligament injury; (4) hyper-slack ligaments; (5) degenerative diseases; (6) continuous corticoid use; or (7) intercondylar hypoplasia (width of the distal femur/condylar fossa < 0.2).

The variables in this study were measured in MRI examinations by a single medical radiologist. For this examination, a Siemens Magnetom Avanto 1.5t® machine was used. All the examinations were performed using the proton density technique with fat suppression.

To measure the width of the ACL, an oblique coronal slice was used. Two parallel lines were traced out: one at the start and the other at the end of the intercondylar region, and one line perpendicular to these. The measurement of the ACL width was obtained as half the length of this perpendicular line. For the length of the ACL, a sagittal slice was used, which

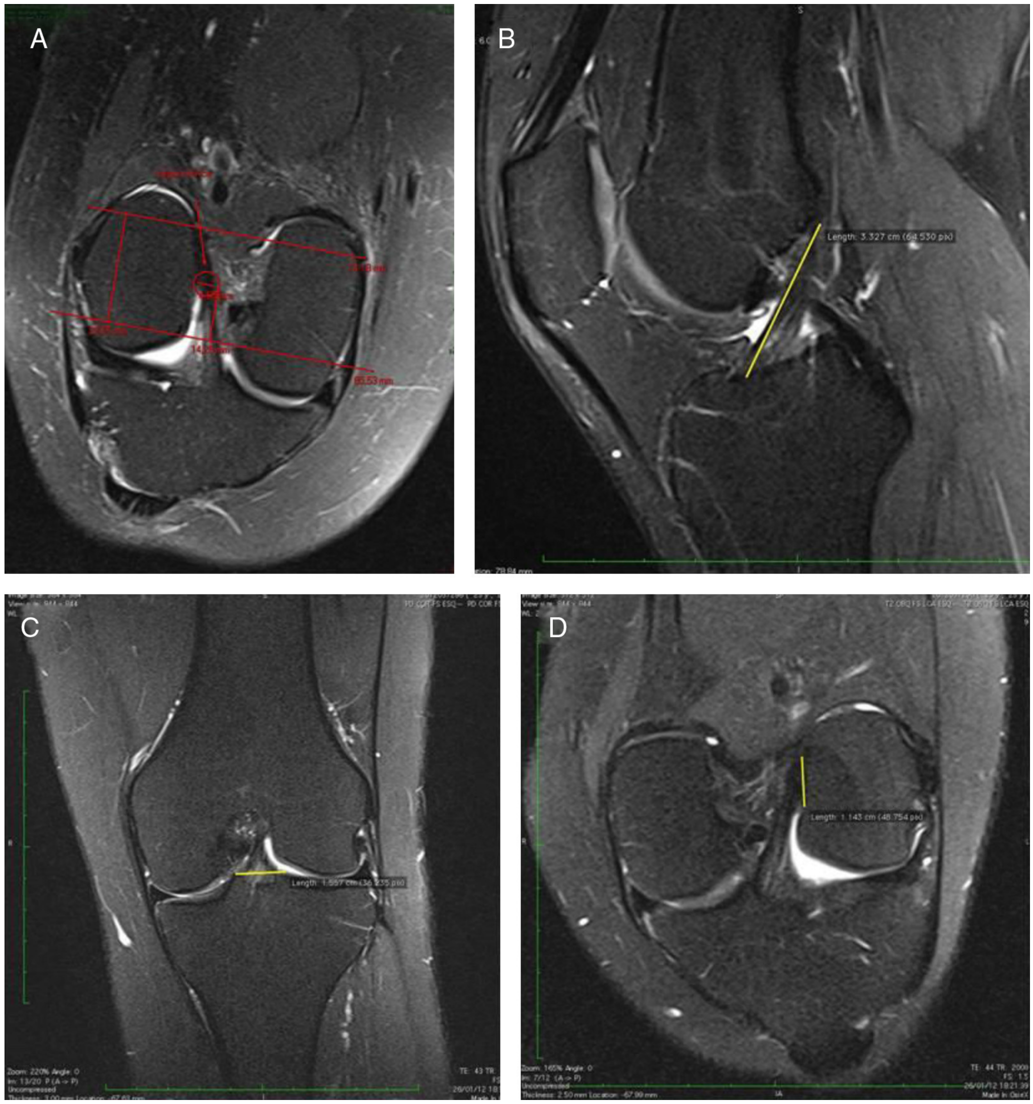

Fig. 1 – Measurement of the width of the ACL (A); measurement of the length of the ACL (B); measurement of the tibial insertion of the ACL (C); measurement of the femoral origin of the ACL (D).

showed the ACL along its greatest length. For the tibial insertion of the ACL, a coronal slice was used, which demonstrated the greatest thickness. For the femoral insertion, an oblique coronal slice was used (Fig. 1).

The tendons of the semitendinosus and gracilis were measured around their greatest diameter in the axial plane, using the medial epicondyle as the slice level (Fig. 2).

To measure the side-to-side length of the quadriceps tendon, an axial slice at the slice level of 3 cm proximally to the patellar insertion of this tendon was used. The anteroposterior diameter of the tendon was measured using a sagittal slice at the same slice level (Fig. 3).

To measure the side-to-side length of the patellar tendon, an axial slice at the slice level of halfway along the length of the tendon was used. The anteroposterior diameter of the tendon was measured on a sagittal slice at the same slice level. The length of the tendon was measured on a sagittal slice that demonstrated the greatest length of the tendon (Fig. 4).

Statistical methodology

To investigate linear associations between the variables, Pearson's correlation coefficient was estimated. This estimate was taken as evidence in evaluating the hypothesis of null correlation in the population.

p values less than 0.05 indicated statistical significance.

Results

Fifty-two MRI examinations covering 31 men and 21 women were assessed. The patients' mean age was 28 years, with a range from 18 to 36 years.

To evaluate the linear association between pairs of variables, Pearson's correlation coefficient was estimated among the variables under evaluation. For each pair of variables, the null hypothesis of linear correlation of zero was tested against

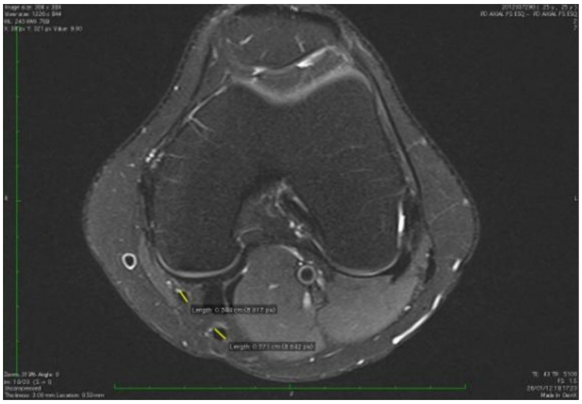

Fig. 2 – Measurement of the width of the tendons of the semitendinosus and gracilis.

the optional hypothesis of linear correlation differing from zero. In sequence, the correlation estimates and the *p*-values of the statistical tests were presented.

The mean width (diameter) of the ACL in the middle third of the intercondylar region was 4.80 mm (3.1–8.3 mm). The mean length of the ACL in the sagittal slices was 3.8 cm (2.85–4.5 cm). The origin of the ACL ranged from 9.7 mm to 15.4 mm, with a mean of 12.3 mm. The mean insertion of the ACL in the tibia was 13.3 mm, with a range from 9.1 to 17.5 mm.

The mean diameter of the semitendinosus was 4.38 mm, with a range from 3.4 to 7.2 mm. The mean diameter of the gracilis was 3.42 mm, with a range from 2.4 to 4.9 mm.

In relation to the quadriceps, the diameter was 7.67 mm, with a range from 5.5 to 9.9 mm. The diameter of the patellar tendon was 4.54 mm, with a range from 3.5 to 6.6 mm.

The length of the quadriceps tendon was 35.34 mm, with a range from 26.9 to 45.8 mm. The patellar tendon presented a mean length of 26.62 mm, with a range from 22.4 to 35.7 mm.

Data correlation

The correlation coefficients between the ACL measurements and the semitendinosus and gracilis tendons are expressed in Table 1.

The correlation coefficients between the ACL measurements and the patellar tendon are expressed in Table 2.

Fig. 3 – Measurement of the side-to-side length of the quadriceps tendon (A); measurement of the anteroposterior diameter of the quadriceps tendon (B).

Fig. 4 – Measurement of the side-to-side length of the patellar tendon (A); measurement of the anteroposterior diameter of the patellar tendon (B); measurement of the length of the patellar tendon (C).

Table 1 – Correlation of the ACL with the tendons of the semitendinosus and gracilis.

Variable	Correlation coefficient	*p*-Value
ACL femur		
Semitendinosus	0.317	0.022
Gracilis	0.364	0.008
ACL tibia		
Semitendinosus	0.064	0.654
Gracilis	0.072	0.611
ACL width		
Semitendinosus	0.119	0.400
Gracilis	0.122	0.390
ACL length		
Semitendinosus	0.346	0.012
Gracilis	0.334	0.015

ACL, anterior cruciate ligament.

The correlation coefficients between the ACL measurements and the quadriceps are expressed in Table 3.

Discussion

In correlating the ACL measurements among the population evaluated in this study, we found that the mean length was 38.13 mm (28.5–45), the mean femoral origin was 12.31 mm (9.7–15.4) and the mean tibial insertion was 13.30 mm (9.1–17.5).

No study has evaluated exactly the same measurements as in the present study, but Dienst et al.[4] found a mean length of 32 mm, with a range from 22 to 41, and width at the femoral origin ranging from 7 to 12 mm.

Duthon et al.[7] found that the mean size of the ACL was 30 mm (7–12), the femoral origin was between 11 and 24 mm and the tibial insertion was between 8 and 12 mm.

In the study by Zantop et al.[20] the mean value for the femoral origin was found to be 11 mm and the tibial insertion was approximately 13.2 mm.

Table 2 – Correlation between ACL and patellar tendon.

Variable	Correlation coefficient	*p*-Value
ACL femur		
Patellar tendon SS	0.438	0.001
Patellar tendon AP	0.283	0.042
ACL tibia		
Patellar tendon SS	0.233	0.096
Patellar tendon AP	0.173	0.221
ACL width		
Patellar tendon SS	0.415	0.002
Patellar tendon AP	0.099	0.487
ACL length		
Patellar tendon SS	0.451	0.001
Patellar tendon AP	0.476	<0.001

AP, anteroposterior; ACL, anterior cruciate ligament; SS, side-to-side.

Table 3 – Correlation between ACL and quadriceps tendon.

Variable	Correlation coefficient	*p*-Value
ACL femur		
Quadriceps SS	0.223	0.113
Quadriceps AP	0.272	0.051
ACL tibia		
Quadriceps SS	0.082	0.563
Quadriceps AP	0.269	0.053
ACL width		
Quadriceps SS	0.367	0.007
Quadriceps AP	0.309	0.026
ACL length		
Quadriceps SS	0.094	0.510
Quadriceps AP	0.370	0.007

AP, anteroposterior; ACL, anterior cruciate ligament; SS, side-to-side.

Some studies in the literature stand out through their attempts to seek predictive factors for possible grafts for use in reconstructing the ACL.[12,16–19] Xie et al.[17] analyzed 235 Chinese people with the aim of seeking a correlation between anthropometric factors, sports activity, age and gender and the length and diameter measurements of the flexor tendons. They found that the most important correlation between the diameter and length of the semitendinosus and gracilis were with the individual's height, gender and weight.

Along the same line of research, Tuman et al.[18] conducted a cohort study on 106 patients and concluded that height was the most important predisposing factor for flexor diameter, particularly in women.

In the study by Bickel et al.[21] there was an important correlation between summed ST and G areas and values greater than 18 mm^2 in axial MRI slices. According to these authors, this value would provide sufficient grafting in 88% of the cases.

In a study using MRI to attempt to predict the size of the flexor tendon graft, Wernecke et al.[16] recommended an area of 10 mm^2 for the gracilis tendon and 17 mm^2 for the semitendinosus tendon, for a quadruple graft.

We did not find any studies in the literature attempting to correlate the characteristics of ACL with their possible grafts, by means of MRI examinations.

There is no recommended standard for the level of the slice used for measuring possible grafts for the cruciate ligament. We found studies in the literature that used the same slices but with divergent reference points or levels.[11,12,16,22]

To measure the flexor tendons, Wernecke et al.[16] used the most prominent portion of the medial epicondyle as a reference point for the axial slice. Eriksson et al.[11] used a slice 5 cm from the knee joint and, in a study on adolescents, Bickel et al.[21] used the growth plate line as a reference point. Lastly, Rispoli et al.[22] used the upper pole of the patella as a parameter for its axial slice.

In our study, we used the medial epicondyle as a reference, within the same context as Wernecke et al.[16]

In measuring the patellar tendon, we used the same slice as used by Kartus et al.[12] in which the references were the intermediate point between the lower pole of the patella and the anterior tuberosity of the patella.

In relation to the quadriceps, it was not possible to measure its length because the imaging evaluated did not include slices close to the thigh, i.e. the site of origin. We established a reference point 3 cm from its insertion in the patella for the evaluation, because we believe that the proximal limit is muscular and that there is no precise point.

In our study, the morphological characteristic of the ACL that singly showed the greatest correlation with the possible grafts was the length of the ACL. However, there was no correlation with the side-to-side width of the quadriceps tendon.

Considering the individuality of each possible graft, we found interesting results. The flexor tendons showed strong correlation coefficients with the ACL insertion in the femur and its length. However, there was no correlation between the tibial insertion and the width of the ACL in the intercondylar region.

For the patellar tendon, the most faithful standards were the femoral origin and the length of the ACL. This last parameter is the one that best predicted the anteroposterior diameter of the tendon. For the side-to-side diameter, the coefficients for the femoral origin and length were equivalent. Neither the insertion of the ACL no its width in the intercondylar region showed any correlation.

The quadriceps tendon showed an important relationship with the width of the ACL in the intercondylar region. This variable was a good indicator both for the side-to-side diameter (greatest correlation) and for the anteroposterior diameter. However, the length of the ACL was the variable with the greatest correlation with the anteroposterior diameter.

Investigation of graft prediction factors is a field that still needs to be explored within our setting. We believe that individualization of each case with different variables, and with summing of the anthropometric and MRI data, may provide guidance in choosing the most precise and risk-free graft. Studies with larger samples are needed.

Conclusion

The measurements found among the population studied were similar to those in the literature, in relation to both length and origin and insertion.

We believe that in MRI examinations using routine slices, the best way of predicting the diameters of the flexor tendons and patellar tendon is through the length of the ACL. The width of the ACL is the best predictor for the quadriceps tendon. The length of the ACL is the single characteristic that has the best correlation with the possible grafts, while the tibial insertion is not a reliable parameter.

Our data provide important preoperative information for surgeons. They facilitate preoperative planning, provide viable alternatives and allow inappropriate grafts to be avoided.

Conflicts of interest

The authors declare that there were no conflicts of interest.

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