Technical Notes

A cadaveric study on the anatomy of anterior cruciate ligament in Vietnamese adults

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abstract

Objectives: To report the anatomical characteristics of the ACL in Vietnamese individuals.
Subjects and methods: Ten fresh knees were dissected to investigate the anatomical characteristics of ACL. The insertion position, length and diameter of ACL were measured.
Results: The average lengths of AM and PL bundle of the ACL were 30.6 mm and 25.6 mm, respectively. The average sizes of the femoral and tibial ACL attachment sites were 13.8 × 10.6 mm and 13.4 × 10.2 mm, respectively.
Conclusion: The anatomical characteristics of the ACL in Vietnamese individuals were reported.

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Introduction

Anterior cruciate ligament (ACL) is composed of two bundles, which act as the primary restraint to anterior tibial translation and guides the screw-home mechanism associated with knee extension. ACL injury is common, especially in sports. In the US, there are 100,000 to 200,000 ACL tears per year, with an annual incidence of about 1 in 3500.

In recent decades, ACL reconstruction surgery has a lot of development, start from open surgery, until now surgical arthroscopy absolute dominant. In recent years, surgeons are more interested in anatomical ACL reconstruction. They desire to restore the normal ACL anatomy as closely as possible. Therefore, to achieve a good outcome of ACL reconstruction, the knowledge of the anatomy of the ACL is very important. There are very few studies have precisely described the anatomical characteristics of ACL. The anatomy of the ACL varies by race. There is no literature on the ACL anatomy in Vietnamese individuals. In order to understand the anatomical characteristics of the ACL in Vietnamese and help to improve the ACL reconstruction surgery, we performed this study to report the ACL anatomy in the Vietnamese adults.

Materials and methods

Ten knees (five left and five right) that taken from the limb amputation of patients who had severe leg injury with an intact knee joint at Saint Paul Hospital and from fresh cadavers at the Medicine University of Ho Chi Minh city were dissected during the period from April to August 2016.

All of the knees were obtained from people aged 22–57 years without chronic knee condition, expression of knee degeneration (loss of cartilage), knee bone fracture (include the condyles of the femur and proximal tibia) and without ACL and PCL injuries (found by direct observation).

The distal femurs were cut at the level of the bursae of the quadriceps, and the proximal tibias were cut approximately 3 cm below the knee joint line. All soft tissues around the knee joint were removed to clearly expose the ACL and the meniscus (Fig. 1).

The knees were temporarily fixed at 90° with the Kirschner pins. The ACL femur attachment sites were observed and evaluated. The medial femur condyle was cut with a bone saw, PCL was flipped to observe the anatomy of the ACL.

We observed the two bundles of the ACL. We measured the length of the AM bundles with the knee at 90° flexion (as arthroscopic evaluation of the ACL typically occurs with the knee flexed to 90°) and measured the length of the PL bundles with the knee extended. The sizes of the ligaments were measured at the middle third of the ligaments, including the smallest and the largest diameter of the ligaments. All sizes were measured by a 150 mm

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Electronic Caliper (Model 500-181-20, Mitutoyo Corp., Kawasaki, Japan) with the resolution of 0.01 mm and the instrumental error of ±0.02 mm.

The anatomical characteristics of the femoral attachment site included: The location of the attachment site of the AM and PL bundle; the distance from the centre of the AM and PL attachment site to the posterior cartilage edge of the lateral femoral condyle; the distance from the centre of the AM and PL bundle attachment site to the articular cartilage edge of the lateral femoral condyle (Fig. 2).

The anatomical characteristics of the femoral attachment site included the following: location of the attachment site of the AM and PL bundle; distance from the centre of the AM and PL attachment site to the posterior cartilage edge of the lateral femoral condyle; and distance from the centre of the AM and PL bundle attachment site to the articular cartilage edge of the lateral femoral condyle.

The anatomical characteristics of the tibial attachment site of the ACL included the following: 1.) Distance from the centre of the AM and PL bundle attachment site to the retro-eminence ridge (RER) and 2.) Distance of the centre of these attachment sites to the anterior edge of the tibial plateau.

**Results**

There were ten knees from five people (three men and two women) with an average age of 45 years (range 22–57 years) in this study.

**Anatomy of the femoral attachment site**

The femoral attachment site of the ACL was an oval-shape zone, with an average size of 13.8 × 10.6 mm.

When observing the ACL from the front, with knees at 90°, we found the following: In the five right knees, the femoral attachment site stretched from 11 o’clock position counter-clockwise to 9 o’clock position. And in the five left knees, the attachment site stretched from 1 o’clock position clockwise to 3:30 position.

The attachment site of the AM bundle stretches from 11 o’clock to 9:30 position in four right knees and from 11 o’clock to 9 o’clock position in one right knee. This site stretched from 2:45 to 3:30 position in two left knees and from 3 o’clock to 3:30 position in three left knees. The anatomical distances of the femoral attachment site of the ACL were shown in Table 1.

The attachment site of the PL bundle stretched from 9:30 to 9 o’clock position in four right knees and from 9:45 to 9 o’clock position in one right knee. This site stretched from 2:45 to 3:30 position in two left knees and from 3 o’clock to 3:30 position in three left knees. The anatomical distances of the femoral attachment site of the ACL were shown in Table 2.

**Discussion**

Most studies have reported that the ACL is composed of two bundles: AM and PL. In many studies, the average length of the ACL is approximately 37 mm—41 mm. The length of the ACL varies depending on the knee position. In this study, the average length of the AM bundle of ACL with knees at 90° was 30.6 mm, and the average length of the PL bundle with the fully extended knee was 25.6 mm. These measurements are consistent with the results of many previous studies. Binh et al. reported that the average length of the AM and PL bundle of the ACL in 20 formalin soaked Vietnamese knees is 28.3 mm and 23.4 mm, relatively. But the the knee position when measuring was not reported.

Understanding the length of the ACL and each bundle will assist surgeons in arthroscopic ACL reconstruction surgery, especially in all-inside ACL reconstruction surgical technique. The ACL has been reported to have an average diameter of approximately 7–12 mm. However, the cross-sectional area of the medial third of the ACL is an ellipse, not a circle. We observed that the smallest and the largest diameter of the ACL averaged 3.8 mm and 7.7 mm, respectively. This result differs from that reported by Binh et al. from formalin-fixed cadavers. Knowing the size of the ACL will help the surgeons choose grafts for ACL reconstruction surgery.

The size of the femoral attachment site was described by previous studies. Binh et al. reported that the average size of this site is 17.3 mm × 9.1 mm. Musahl et al. reported that the average size is 18 mm × 11 mm. In our study, the average size of the femoral attachment site was 13.8 mm × 10.6 mm.

The position of the centre of the femoral attachment site of the ACL and its two bundles have also been described in many studies. In our investigation, the distances from the centre of

| Table 1 | The anatomical characteristics of ACL |
| --- | --- | --- |
| Anatomical characteristics | Average ± SD (mm) | Range (mm) |
| AM bundle length | 30.6 ± 2.1 | 27.1–31.7 |
| PL bundle length | 25.6 ± 2.0 | 20.0–29.4 |
| Smallest diameter | 3.8 ± 0.5 | 3.2–5.1 |
| Largest diameter | 7.7 ± 1.1 | 6.3–8.8 |
Table 2
The anatomical distances of the femoral attachment site of the ACL.

| Start point                               | End point                           | Average ± SD (mm) | Range (mm) |
|-------------------------------------------|-------------------------------------|-------------------|------------|
| The posterior cartilage edge of the lateral femoral condyle. | Centre of the attachment site       | 9.4 ± 1.1         | 6.8–11.1   |
|                                           | Centre of the AM bundle              | 6.3 ± 0.9         | 5.3–9.7    |
|                                           | Centre of the PL bundle              | 8.7 ± 1.3         | 6.6–11.3   |
| The inferior cartilage edge of the lateral femoral condyle. | Centre of the attachment site       | 6.3 ± 0.5         | 4.3–8.2    |
|                                           | Centre of the AM bundle              | 8.3 ± 0.5         | 6.9–9.3    |
|                                           | Centre of the PL bundle              | 2.7 ± 0.2         | 2.2–3.3    |
| The size of the attachment size           | Coronal plane                        | 10.6 ± 1.1        | 9.2–12.8   |
|                                           | Transverse plane                     | 13.8 ± 1.3        | 11.7–16.4  |

Table 3
The anatomical distances of the tibial attachment site of the ACL.

| Start point                               | End point                           | Average ± SD (mm) | Range (mm) |
|-------------------------------------------|-------------------------------------|-------------------|------------|
| RER ridge                                 | The posterior edge of the tibial attachment site | 8.7 ± 1.8         | 7.3–10.6   |
|                                           | Centre of the AM bundle              | 15.4 ± 1.2        | 11.8–19.4  |
|                                           | Centre of the PL bundle              | 11.2 ± 1.4        | 7.4–13.7   |
| The anterior edge of the tibial plateau   | Sagittal plane                       | 13.5 ± 1.5        | 11.1–17.7  |
| The size of the attachment site           | Coronal plane                        | 12.5 ± 1.1        | 8.3–16.0   |
|                                           |                                      | 11.1 ± 1.1        | 8.3–14.4   |

The ACL, the AM bundle and the PL bundle to the posterior cartilage edge of the lateral femoral condyle were 9.4 ± 1.1 mm, 6.3 ± 0.9 mm and 8.7 ± 1.3 mm, respectively. Peterson et al. reported that the distances from the centre of the AM and PL bundle of the ACL to the posterior cartilage edge of the lateral femoral condyle are 7.2 ± 1.1 mm and 10.0 ± 1.4 mm, respectively.6

The distances from the centre of the femoral attachment site of the ACL, AM bundle and PL bundle to the inferior cartilage edge of the lateral femoral condyle in our study were 6.3 ± 0.5 mm, 8.3 ± 0.5 mm and 2.7 ± 0.2 mm, respectively. Zantop et al. reported that the distances from the centre of the AM and PL bundle to the inferior cartilage edge of the lateral femoral condyle were 9.4 ± 1.8 mm and 3.5 ± 1.2 mm, respectively.1 The different results may be due to the various populations and measurement methods.

The tibial attachment site of the ACL starts from the posterior edge of anterior horn of the lateral meniscus, stretches toward the median and located medial to the lateral intercondylar tubercles. The tibial attachment site of the ACL is larger than the cross-section of the ACL. In our study, the average size of the tibial ACL attachment site was 13.4 ± 10.2 mm. This size in the Binh et al. study is 13.9 ± 12.1 mm,1 and in Petersen’s study, the size is 17.0 ± 11.5 mm.5

The centre the attachment site of the ACL and its two bundles are also described by many authors. In this study, we use the retro eminence ridge (RER) as an anatomical landmark to determine the position of the tibial ACL attachment site. We choose this landmark because it is a hard tissue and easy to observe during the surgery. The distances from the centre of the tibial attachment site of the ACL, the AM and the PL bundle to the RER in our study were 8.7 ± 1.8 mm, 15.4 ± 1.2 mm and 11.2 ± 1.4 mm, respectively. Petersen et al. reported that the distances from the centre of the AM and PL bundle attachment site to the RER were 17.5 ± 1.1 mm and 13.6 ± 1.3 mm, respectively.6 The distance from the centre of the tibial ACL attachment site to the anterior edge of the tibial plateau is 16.2 ± 1.7 mm.6 Zantop described this gap as being 16.0 ± 2.1 mm in length.2 We describe this distance as 13.5 ± 1.5 mm.

Mistakes in the femoral and tibial tunnel placement are the main cause of failure in the ACL reconstruction surgery. A thorough understanding of the anatomy of the femoral and tibial ACL attachment sites will help surgeons determine the location of the tunnels more accurately and therefore achieve better surgical results.6

Conclusion
The ACL was composed of two bundles: AM bundle and PL bundle, with the average lengths of 30.6 mm and 25.6 mm, respectively. The average lengths of the smallest and the largest diameter of the medial third of the ACL were 3.8 mm and 7.8 mm, respectively. The average sizes of the femoral and tibial ACL attachment site were 13.8 ± 10.6 mm and 13.4 ± 10.2 mm, respectively. The femoral ACL attachment site stretched from 11 o’clock to 9 o’clock position in the right knees and from 1 o’clock to 3:30 in the left knees.

Appendix A. Supplementary data
Supplementary data related to this article can be found at https://doi.org/10.1016/j.asmart.2018.05.001.

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