Radiographic analysis of the relationship of the lateral intercondylar ridge, Blumensaat's line, and posterior margin of the lateral femoral condyle

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Original Scientific Paper

RADIOGRAPHIC ANALYSIS OF THE RELATIONSHIP OF THE LATERAL INTERCONDYLAR RIDGE, BLUMENSAAT'S LINE, AND POSTERIOR MARGIN OF THE LATERAL FEMORAL CONDYLE

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SUMMARY – The aim of this study is to determine the radiographic position of the lateral intercondylar ridge (LIR) and its relationship with the Blumensaat line (BL) and the tangent to the posterior cortex (PCT) of the distal femur. On 35 femur specimens, the LIR was labeled by using a 1 gauge wire. A true lateral view with the distal femur was taken. On the taken plain radiographs, we measured angles that close between BL and LIR, PCT and LIR. We also measured the ratio in which LIR crosses the BL. The mean angle between BL and LIR was 70,130 (SD 12,690), and the mean angle that BL closes with PCT was 143,610 (SD 7,910). The point where LIR intersects the BL divides it in a 1:6 ratio. Using these radiological measurements will allow surgeons to quickly estimate the position of the LIR and also allow quick and convenient preoperative planning, intraoperative tunnel placement as well as postoperative analysis.

Keywords: *Anatomy, Anterior cruciate ligament, radiography*

Introduction

The osseous anatomy of the medial wall of the lateral femoral condyle still captures the interest of scientists and orthopedic surgeons, all with the goal to describe the femoral attachment of the anterior cruciate ligament (ACL). These osseous landmarks are especially important during ACL reconstruction surgery, where we can identify and use them to position the femoral tunnel. In a detailed description of the osseous anatomy of the femoral notch, Farrow et al. demonstrated that the lateral intercondylar ridge (LIR), also known as the "resident ridge", is an easily identifiable landmark and is present in the majority of skeletal specimens[1]. Anatomically, LIR represents the anterior border of the ACL and thus serves as a vital landmark during ARC reconstruction[1]. On a plain LL radiograph, ACL borders are not easily identifiable, including LIR. Today, the postoperative ACL femoral tunnel placement is assessed using the Bernard and Hertel grid in which we measure the deep-shallow and high-low ratios in relation to the Blumensaat line (BL)[2]. The aim of our study is to determine the radio-

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graphic location of the LIR in relation to the BL and to the posterior cortical tangent (PCT). We hypothesize that the LIR can be reliably located on a plain radiograph using the previously mentioned landmarks.

Methods

We analyzed 35 femur X-rays from the Department of Anatomy of the Medical University of Rijeka. Sex and age are unknown. Femurs in which we could not identify the LIR or had severe osteoarthritic changes were excluded from the study. On the top of LIR, we fixated with a transparent band and a 1 mm gauge copper wire. A true lateral x-ray of the femur was achieved with a combination of jigs and 90 degrees angle tools. The X-rays were converted to JPEG format and were analyzed using ImageJ software (ImageJ, U. S. National Institutes of Health, Bethesda, Maryland, USA, 2018). With ImageJ, we measured angles that close between BL and LIR, PCT and LIR. We also measured the ratio in which LIR crosses the BL. The ideal BL was determined by using a method described in our previous work (MI). We will be using terminology as if the knee is flexed 90 degrees as during arthroscopic surgery, as shown in Figure 1.

Results

The mean angle between BL and LIR is $70,13^0$ (SD $12,69^0$) with the median value of $69,8^0$ and a range of $55,22^0$ (Figure 2). The mean angle that BL closes with PCT was $143,61^0$ (SD $7,91^0$) with a median value of $145,44^0$ and a range of $28,89^0$ (Figure 3). In the next step, we determined where the LIR meets the BL and divided it into two parts: the deep and shallow parts. The deep portion of BL (distal to the point where LIR meets the BL) represents 14,66% (SD 6,76%) of the total BL length, making the ratio of the deep/shallow portion of the cross-section 1:6 (Figure 4).

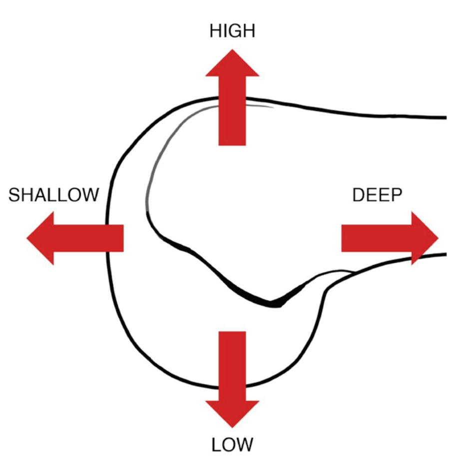

Figure 1. Orientation of the femur knee when flexed 90 degrees as during arthroscopic surgery.

Figure 2. Angle between lateral intercondylar ridge and Blumensaat line.

Figure 3. Angle between lateral intercondylar ridge and posterior cortex.

Discussion

According to the literature, 50% of ACL revisions occur due to technical difficulties during the procedure[3,4,5]. Garofalo et al. reported that 79% of ACL revision cases occur due to the malposition of the

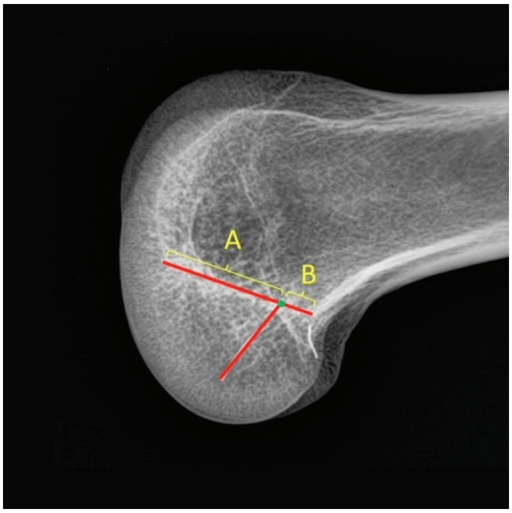

Figure 4. The cross-section between lateral intercondylar ridge and Blumensaat line divides the Blumensaat line in two parts: the shallow (A) part and the deep (B) part.

Figure 5. Lateral intercondylar ridge is not in line with the posterior femoral cortex on a true lateral radiograph.

femoral tunnel[6]. The MARS group (Multicenter ACL Revision Study) in their study confirmed the findings of Garofalo et al.[7] Another study, conducted by Odensten et al., showed that there is a significant difference in ACL strain if the femoral tunnel was placed outside the ACL footprint[8]. Markolf et al. reported that if the femoral tunnel is placed 5mm outside its native footprint, the straining forces are 62% higher[9]. Herbort et al. claim that the knee kinematics significantly changes if the tunnel deviates even less than previously shown from the footprint[10]. From the above-mentioned literature, we can clearly see that the correct femoral tunnel placement is crucial to a successful surgery, and it is considered the weakest link in ACL reconstruction[11,12,13].

There are a few suggested X-ray methods that are designed to help the surgeon determine the ACL femoral tunnel center[2,14,15]. One of the commonly used methods was developed and published in 1997 by Bernard and Hertel[2]. They used a grid layout that was perpendicular to the BL with which we can determine the tunnel center in two ratios: deep-shallow and high-low. However, the authors determined the grid with the assumption that the BL is a straight line. Yahagi et al. analyzed the roof of the femoral notch by cutting it in the sagittal plane and concluded that in 65% the posterior side of the roof had a hill distally and only 35% of roofs were completely straight[16]. This knowledge may have implications on the usability of the Bernard and Hertle method[2]. By analyzing true lateral femur x-rays, we also found that BL in majority of cases is not a straight line, although the results may not completely align, the main difference being in the methodology used (x-ray vs cadaveric study)[17].

Many authors agree that the most important intraoperative bony landmark for femoral tunnel placement is the LIR[18]. Although there are many studies that describe the LIR, there are just a few that analyze its placement by using plain radiography[1,17]. Farrow et al. using 20 specimens, calculated that the angle closed by LIR and BL is 75,5^{0}, and Gulan et al. on 12 cases got a median angle of 62,42^{0} (± 3,5^{0})[1,17]. In this study we used 35 specimens, and the median angle was 69,87^{0}. This difference could be attributed to the number of femurs used in the respective studies or the different methods of measuring the BL (Farrow et al. used a straight line for BL while Gulan et al. in the majority of the cases had the distal hill on the roof).

To better determine the LIR placement on the plan radiogram, besides the angle it closes with BL, we need to determine the point where these lines meet. In a cadaveric study conducted by Smiglieswski et al. the LIR meets the BL at its endpoint, meaning that LIR (and by extension the ACL midsubstance, according to the authors) is in line with the posterior femoral cortex[19]. In our study, we found that this was the case in only three femurs (8,6%), in all other cases the LIR meets the BL at its distal 14,66%. The main difference between those two studies is the method used: plain radiograph analysis vs a cadaveric study, also in the latter the authors didn't specify how they orientated the femur or do the condyles align (which would be the equivalent of a true lateral radiograph) (Figure 5). With those two measurements (LIR – BL angle and LIR – BL crossing) we can closely identify where the LIR is located on a plain radiogram. But one measurement that we couldn't find in the literature is the angle between the LIR and the PCT. This measurement, compared to the LIR – BL angle was more consistent, and had a smaller standard deviation, meaning that this angle could represent a more reliable alternative when defining the LIR position alongside the point where LIR meets the BL.

Conclusion

The position of the LIR could be defined on the plain radiography by using the above-described method. The proposed method allows the surgeon to quickly estimate the position of the LIR and also allows quick and convenient preoperative planning, intraoperative tunnel placement as well as postoperative analysis.

Conflict-of-interest statement

The authors have nothing to disclose.

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Sažetak

RADIOGRAFSKA ANALIZA ODNOSA LATERALNOG INTERKONDILARNOG GREBENA S BLUMENSAATOVOM LINIJOM I TANGENTOM STRAŽNJEG FEMORALNOG KORTIKALISA

L. Gulan, H. Jurdana, M. Franić i *G. Gulan*

Cilj ove studije je odrediti radiografski položaj lateralnog interkondilarnog grebana (LIR) u odnosu na Blumensaatovu liniju (BL) i tangentu stražnjeg kortikalisa (PCT) femura. Na 35 preparata femura lateralni interkondilarni greben označili smo bakrenom žicom debljine 1 mm. Na pravim postraničnim radiografskim snimkama femura odredili smo kut koji zatvaraju BL i LIR, te LIR i PCT. Također smo izračunali omjer u kojem LIR dijeli BL. Prosječni kut koji zatvaraju BL i LIR iznosi 70,130 (SD 12,690), a prosječan kut između BL i PCT 143,610 (SD 7,910). Točka u kojoj LIR sječe BL dijeli liniju u omjeru 1:6. Predloženom radiografskom metodom moguće je pouzdano odrediti položaj LIR-a što će omogućiti lakše planiranje zahvata, lakše i točnije postavljenje femoralnog tunela kao i poslijeoperacijsku analizu.

Ključne riječi: *Anatomija, Prednji križni ligament, radiografija*