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Authors: Jolanta Tomczyk, Maciej Rachalewski, Agnieszka Bianek-Bodzak, Marcin Domżalski

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Anatomical variations of knee ligaments in magnetic resonance imaging: pictorial essay

Anatomical variations of knee ligaments in MRI

Jolanta Tomczyk¹, Maciej Rachalewski¹, Agnieszka Bianek-Bodzak¹,³,⁴, Marcin Domżalski²

¹Department of Radiology, Isotopic Diagnostic and Therapy, Military Medical Academy Teaching Hospital- Central Veteran Hospital, Łódź, Poland
²Department of Orthopedics, Traumatology and Post-traumatic Rehabilitation, Military Medical Academy Teaching Hospital- Central Veteran Hospital, Łódź, Poland
³Department of Radiology Medical University of Gdansk, Poland
⁴Department of Applied Medical Techniques, Medical University of Lodz, Łódź, Poland

Address for correspondence: Jolanta Tomczyk, MD, Department of Radiology, Isotopic Diagnostic and Therapy, Military Medical Academy Teaching Hospital- Central Veteran Hospital, ul. Żeromskiego 113, 90–549 Łódź, Poland, tel: +48 781339848, fax: +48 42 639 34 02, e-mail: jol.tomczyk@gmail.com

Abstract

Evaluation with magnetic resonance imaging (MRI) is currently a gold standard for comprehensive posttraumatic assessment of the knee joint. Increasing availability of MR systems with stronger magnetic fields and new sequences results in higher resolution of images and thus allows imaging smaller and finer anatomical details, including different anatomical variations.

This article focuses on anatomical variations of knee ligaments, which can mimics pathological structures. Well-known and less common ligaments that are sporadically observed and may raise the most doubt will be discussed. Familiarity with those variations of ligaments is indispensable for precise MRI reporting to avoid misinterpretation as meniscal tears, loose bodies or mass lesions especially in cases. This paper is addressed to both
radiology and orthopaedics specialists. Illustrations show discussed ligaments in standard planes while, for less known ligaments, we add information on how to adjust planes to properly visualise a particular structure, which will hopefully facilitate finding and differentiating those structures in clinical practice.

**Key words:** knee, ligament, anatomical variation, magnetic resonance imaging

**INTRODUCTION**

Technological advancement of magnetic resonance imaging makes it the most precise method of assessing the knee joint. Availability of more powerful magnets and new sequences allows imaging very small anatomical details.

The knee, as the most weight bearing joint in the human body, is also the most commonly injured one. Evaluation with magnetic resonance imaging (MRI) is currently a gold standard for comprehensive posttraumatic assessment of the knee joint. Increasing availability of devices with stronger magnets and new sequences results in higher resolution of images and thus allows imaging smaller and smaller anatomical details, including different anatomical variations.

An anatomical variation is defined as a physiological structure that is not always present, or as a structure present in all cases but in different morphological forms.

Thorough knowledge of possible anatomical variations within the knee is essential to avoid misdiagnoses. This article reviews both well-known and less common ligamentous anatomical variations within the knee and focuses on those, which can be confused with pathological conditions or may simply cause uncertainty.

**OBLIQUE MENISCO-MENISCAL LIGAMENT**

The oblique menisco-meniscal ligament (OMML) (Fig.1) is a relatively uncommon ligament occurring in approximately 2–4% of knees [1, 2]. OMML runs from the anterior horn of one meniscus to the posterior horn of the other, passing along the tibial plateau between anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL). There are two types of OMML – medial and lateral – classified depending on the anterior horn of the meniscus from which they originate. On sagittal and coronal images, it can be misinterpreted
as either a centrally displaced meniscal tear or collapsed fibres from an ACL tear. In the absence of any other meniscal or cruciate abnormality, it is relatively straightforward to recognize as an anatomical variant, but in the presence of an ACL or meniscal injury it can be confusing. Tracing the welldefined ligament from medial to lateral compartments where it unites smoothly with the two menisci confirms the diagnosis.

**ANTERIOR OR TRANSVERSE INTERMENISCAL LIGAMENT**

The anterior (transverse) intermeniscal ligament (Fig. 2) is identified in about 94% of knees on arthroscopy and is noticeable in about 58% of knees subjected to magnetic resonance imaging [3, 4]. It runs from the anterior part of the convex edge of the lateral meniscus to the anterior horn of the medial meniscus. The ligament varies in thickness and may be absent in a few percent of knees. When the thickness of the attachments to the menisci is 3 mm or more, it is called the “cord-like” variation [5]. A sagittal section through the anterior horn at this position, where the anterior horn is typically reducing in size, can give the impression of a high signal cleft, or pseudo-tear, particularly with the “cord-like” variation [6].

In about 2% of knees there is also a similar posterior intermeniscal ligament connecting posterior horns of both the menisci [7].

The literature also describes cases of unilateral menisco-meniscal ligaments, which means that they run between the anterior and posterior horns of the same meniscus [8].

**MENISCO-FIBULAR LIGAMENT**

In cadaver studies the menisco-fibular ligament (MFL) (Fig. 3) was identified in 100% of specimens [9].

In studies based on magnetic resonance imaging MFL was found in 42–63% of knees [10]. MFL runs between one-third of the posterior lateral meniscus and the head of the fibula (anteriorly to the tendon of the popliteus muscle). The ligament is often better visible if fluid is present in the posterolateral joint compartment.

Similar to other ligaments with attachments at the meniscus, MFL may mimic meniscal tear. The menisco-fibular ligament is considered to be of key importance in positioning the lateral meniscus.
MENISCO-FEMORAL LIGAMENT

The menisco-femoral ligament (MfemL) (Fig.4) runs from the anterior horn of the lateral meniscus to the lateral part of the medial condyle of the femur or to the posterior cruciate ligament [11].

There are two types of MfemL called, depending on their position in relation to the posterior cruciate ligament (PCL), Humphrey’s ligament, running anteriorly to PCL, and Wrisberg’s ligament, running posteriorly to PCL [12]. The attachments of those two ligaments are separated, which supports the theory that those are two separate structures and not, as was previously thought, two branches of the same ligament [13].

Depending on the location of the attachment, MfemL is classified into three types:

— Type I (46%) the medial condyle of the femur
— Type II (31%) the proximal half of the posterior cruciate ligament (PCL)
— Type III (21%) the distal half of the posterior cruciate ligament (PCL) [14].

In the cadaver study by Gupte at al. of 2002 [11], at least one menisco-femoral ligament was found in 93% of the studied knee joints. The presence of Humphrey’s (anterior menisco-femoral) ligament was established in 74% specimens while Wrisberg’s (posterior menisco-femoral) ligament was found in 69% of specimens. Both the ligaments were present in 50% of specimens with the statistically significant prevalence of specimens derived from young individuals. The data may suggest that the absence or presence of only one ligament is associated with degenerative changes or sustained injuries.

Menisco-femoral ligament may mimic PCL damage or lateral meniscus rupture [15, 16]. The literature describes very rare cases of the anteromedial variation of the menisco-femoral ligament running from the anterior horn of the medial meniscus to the posterolateral part of the intercondylar fossa (parallel to the anterior cruciate ligament) [17]. The ligament may mimic the suprapatellar plica.

ARCUATE LIGAMENT

The arcuate ligament (Fig.5) is part of the posterolateral ligamentous complex of the knee. It is a Y shaped thickening of the posterolateral part of the joint capsule. It begins at the styloid process of the fibula and divides into two branches: the medial branch running along a curve above the popliteus muscle and attaching to the posterior part of the joint capsule to join the oblique popliteal ligament; the lateral branch running along the lateral part of the joint
capsule and attaching to the lateral condyle of the femur.

In the study by Munshi et al. [18] correlating MR arthrography, MRI and cadaver specimen examination, at least one branch of the arcuate ligament was found in 71% of cases.

The lateral branch was visible in 57% of specimens (present in 50% of cases with the fabella and 67% of cases without the fabella). The medial branch was visible in 57% of specimens (present in 75% of cases with the fabella and 33% of cases without the fabella).

**FABELLO-FIBULAR LIGAMENT**

The fabella is an additional bone typically occurring in the tendon or lateral head of the gastrocnemius muscle of the lower leg. It is present in around 13–20% of the population [5, 19].

The fabello-fibular ligament (FFL) (Fig.6) runs from the fabella to the styloid process of the fibular head (it attaches laterally related to the popliteofibular ligament). It is worth emphasising that the ligament may still be present in the absence of the fabella and attach to the lateral condyle of the femur.

FFL was found in 24–80% of specimens in cadaver studies and in 48% of examined knees in papers using MR diagnostics [20, 21].

The study by Minow et al. [22] proved that a bony well-calcified fabella correlates with thicker FFL variations. Moreover, the presence of a thinner FFL variation was statistically significantly correlated with the occurrence of a well-developed arcuate ligament. In turn, the arcuate ligament may be absent in the presence of FFL thicker than 5 mm.

**POPLITEO-FIBULAR LIGAMENT**

The popliteo-fibular ligament (PFL) (Fig.7) is part of the posterolateral ligamentous complex of the knee.

PFL runs from the tendon of the popliteus muscle (proximally to the myotendinous junction) to the fibular head (posteriorly to the attachment of the fibular collateral ligament) [23].

The literature describes two types of PFL: type I – with one layer and type II – with two layers.
Type II is divided into three subtypes:

— II a – the superficial layer is located anteriorly to the deep layer
— II b – the superficial layer and deep layer lie parallel to each other
— II c – the superficial layer is located posteriorly to the deep layer.

In cadaver studies PFL type I was identified in 69.2% and type II – in 30.8% of specimens (of which type II a 9%, II b 12.8%, II c 9%) [24].

In MR images PFL is identified in slightly more than 50% of examinations and best seen in the frontal and sagittal sections.

**ANTERIOR CRUCIATE LIGAMENT**

The anterior cruciate ligament (ACL) (Fig.8) runs between the posteromedial part of the lateral condyle of the femur and the anterior intercondylar area of the tibia.

There are two bundles of ACL: the anteromedial bundle is tight in knee flexion and the posterolateral bundle remains tight in knee extension. Both the bundles attach independently to the femur and tibia.

The anterior cruciate ligament is best seen in the sagittal section. The attachments to the femur and tibia are clearly visible in the frontal section although the attachment to the femur is best seen in the cross section.

ACL bundles differ in signal intensity in individual sequences. The anteromedial bundle is hypointense in all sequences. In turn, the posterolateral bundle shows intermediate signal intensity in T1 weighted sequences and is moderately hyperintense in PD weighted, T2 weighted sequences with fat saturation and STIR.

There are several deviations from the above-described normal anterior cruciate ligament, which are typically associated with meniscal structure variations. Min et al. reported a case of coalescence between ACL and the lateral part of the discoid medial meniscus [25]. The literature also describes a case of ACL attachment to the anterior horn of the normal medial meniscus – a variation co-occurring in 5.5% of knees with the discoid lateral meniscus [26].

An ACL comprising three separate bundles has been described in several arthroscopic and cadaveric studies where an additional intermediate (IM) bundle has been identified [27-
ACL may also be hypoplastic, absent, replaced by a fibrous band or fatty degenerated [30].

Agenesis of ACL is typically associated with other lower limb anomalies such as, among others, retained meniscus, complete congenital absence of menisci, concomitant absence of PCL, shortening of the femur, fibular hemimelia, Humphrey’s ligament hypertrophy, tibial hypoplasia [31].

POSTERIOR CRUCIATE LIGAMENT

The posterior cruciate ligament (PCL) (Fig.9) runs from the posterolateral part of the medial condyle of the femur to the posterior intercondylar area of the tibia.

Similar to ACL, PCL also has two bundles: the anterolateral bundle and the posteromedial bundle. Each of them has a different degree of tightness depending on the degree of knee flexion [32]. In MR images the ligament has a hypointense signal and is clearly visible in the sagittal section while its attachments are best seen in the frontal and cross sections. In short TE sequences PCL may have intermediate signal intensity. PCL bundles may be visible as two separate structures, thus forming a double PCL [33], which should be differentiated from a “double PCL sign”. The double PCL sign consists in the occurrence of a linear hypointense structure parallel to PCL, secondarily to a bucket handle tear of the medial meniscus. A false “double PCL” may also result from the presence of such anatomical structures as menisco-meniscal and menisco-femoral ligaments. Posterior oblique fibres of PCL were identified, which can be misinterpreted as pMFemL if their distal attachments are not properly identified [6].

Deviations from the above-described normal PCL are rare.

On very rare occasions, centrally displaced tears of both menisci can produce a triple PCL sign [34]. These should not be confused with a true double-bundle PCL. This is where the PCL comprises two clearly separate bundles that both take origin from the posterior tibial plateau and insert side-by-side on the medial femoral condyle [33, 35]. Hypoplasia or agenesis of PCL are typically associated with lower extremity length abnormalities [30].
SUMMARY

Anatomical variations are quite commonly encountered on MRI and may be present in as many as 25% of all patients. Progressive improvements in spatial resolution in MRI of the knee mean that smaller anatomical details, and therefore, normal anatomical variations, are more frequently identified. These variants provide an extra challenge to accurate interpretation. Sound knowledge of both normal and variation anatomy is required to avoid misdiagnoses and overdiagnoses.

Conflict of interest: The authors have no conflicts of interest to declare.

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**Figure 1.** Oblique menisco-meniscal ligament (OMML). **A.** Cross section in PD weighted sequence with fat suppression. Arrows indicate the ligament originating from the anterior horn and running to the posterior horn of the opposite meniscus. **B** sagittal section in PD weighted sequence with fat suppression.

**Figure 2.** Anterior (transverse) intermeniscal ligament. **A** cross section and **B** frontal section in PD weighted sequence with fat saturation. Arrows indicate the ligament originating from the anterior part of the convex edge of the lateral meniscus and running to the anterior horn of the medial meniscus. **C.** Sagittal section in PD weighted TSE sequence.

**Figure 3.** Menisco-fibular ligament (MFL). **A, B.** Sagittal sections in PD weighted TSE sequence. Arrows indicate the ligament running between one-third of the posterior lateral meniscus and the head of the fibula (anteriorly to the tendon of the popliteus muscle).

**Figure 4.** Wrisberg’s menisco-femoral ligament MfemL. **A.** Frontal plane in PD weighted
TSE sequence with fat saturation; **B.** Sagittal plane in PD weighted TSE sequence. The arrow indicates Wrisberg’s ligament running posteriorly to PCL (black arrowhead) and attached to the medial condyle of the femur (Type I) e frontal plane in T1 weighted TSE sequence.

**Figure 5.** Arcuate ligament in frontal plane in PD weighted TSE sequence.

**Figure 6.** Fabello-fibular ligament (FFL). **A.** In sagittal plane and **B.** In frontal plane in PD weighted TSE sequence with fat saturation. Arrows indicate the ligament running from the fabella to the styloid process of the fibular head.

**Figure 7.** Popliteo-fibular ligament (PFL) in sagittal plane in PD weighted TSE sequence with fat saturation.

**Figure 8.** Anterior cruciate ligament (ACL). **A.** In sagittal plane in PD weighted TSE sequence and **B.** In transverse plane in PD weighted TSE sequence with fat saturation. Arrows indicate the ligament running between the posteromedial part of the lateral condyle of the femur and the anterior intercondylar area of the tibia.

**Figure 9.** Posterior cruciate ligament (PCL). **A.** In sagittal plane in PD weighted TSE sequence. Arrows indicate the ligament running from the posterolateral part of the medial condyle of the femur to the posterior intercondylar area of the tibia. **B.** “Double PCL sign”, secondarily to a bucket handle tear of the medial meniscus in sagittal plane in PD weighted TSE sequence. **C.** A double PCL - PCL visible as two separate bundles in coronal plane in PD weighted TSE sequence. **D.** A double PCL - PCL visible as two separate bundles in axial plane in PD weighted TSE sequence.