Case report

Magnetic resonance imaging of the posterior cruciate ligament in flexion☆

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Background: Posterior cruciate ligament (PCL) injuries of the knee are common and sometimes difficult to diagnose. Magnetic resonance imaging (MRI), performed using standard orthogonal plane views, is the investigation of choice. It can be particularly difficult to differentiate acute partial and complete tears and identify elongation of chronic healed tears. The aim of the paper is to describe a new method of positioning the patient with the knee flexed at 90°, allowing the PCL to be visualised in a position of greatest length and tension which may assist in differentiating and identifying these injuries.

Methods: Four symptomatic patients with suspected PCL injuries, two acute and two chronic, were MRI scanned using a routine protocol with the knee in extension before performing oblique sagittal fast spin-echo (FSE) proton-density (PD) sequences with the knee positioned in 90° of flexion. The appearance of the PCLs were then qualitatively assessed.

Results: MRI scanning with the knee in flexion identified more extensive PCL injury than standard imaging. In the two patients with acute injuries, partial tears on the standard orthogonal plane views were found to be complete ruptures. In the two patients with chronic injuries, elongation of the PCL not identifiable on the standard orthogonal plane views was apparent.

Conclusion: MRI scanning of the PCL with the knee flexed at 90° may help in differentiating partial and complete ruptures of the PCL and identifying elongation of the PCL in chronic injuries.

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1. Introduction

Posterior cruciate ligament (PCL) injuries represent between one and 44% of all knee injuries [1]. PCL tears are sometimes difficult to diagnose due to the limitations of the clinical history and examination [2–4]. Magnetic resonance imaging (MRI) scanning is the investigation of choice to assist in the diagnosis of PCL injuries. Standard orthogonal plane views, both sagittal and coronal, are commonly used [5]. Routine MRI assessment is performed with the knee in extension. In the extended position, the PCL is lax and subject to partial volume artefact due to its oblique course. As a result, it can be particularly difficult to differentiate acute partial and complete tears and identify elongation of chronic healed tears [6]. The addition of an oblique coronal T2-weighted sequence (PCL view) can overcome the partial volume artefact, by visualising the entire width of the PCL along a parallel axis [5].

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In this paper we describe a new method of positioning the patient with the knee flexed. This allows the PCL to be visualised in a position of greatest length and tension, which may assist in differentiating acute partial and complete tears and identifying elongation of chronic healed tears.

2. Methodology

Scans were performed on a 1.5 tesla unit (Signa HDxt, General Electric). All patients were scanned twice, firstly with the knee in extension using our routine imaging protocol, followed immediately with the knee in flexion using our new knee flexion protocol.

Our routine knee protocol involves scanning patients supine with the knee in a dedicated GE eight channel high definition extremity knee coil. An oblique sagittal fast spin-echo (FSE) proton-density (PD) sequence (repetition time (TR)/echo time (TE): 2820–3900/20.82–24.45) is planned from a three-plane fast gradient-echo (FGRE) localizer sequence. The 13–14 cm field of view includes the medial femoral condyle and fibula head (matrix 448 × 256) orientated perpendicular to a line tangential to the posterior surfaces of the femoral condyles (Figure 1A & B). The echo train length (ETL) is eight and number of excitations (NEX) two, with an average scan time of three minutes and 51 s. The resultant images show the PCL in its classical bent morphology over two or three slices (Figure 2A).

To image the PCL in the knee flexion view, the patient is positioned in a lateral decubitus position with the affected side down (Figure 3). A GE general purpose flex coil is secured around the affected knee in 90° flexion. The affected knee is kept as close to the middle of the MRI bore as possible with the other leg extended and kept away from the affected knee as far as patient size

Figure 1. Planning for routine sagittal sequences with the knee in extension utilising axial (A) and coronal planes (B). Planning for the sagittal PCL sequence with the knee in flexion utilising axial (C) and coronal planes (D).
and comfort will allow. The oblique sagittal PCL sequence obtained with the knee in flexion is a FSE PD sequence (TR/TE: 2300–3200/19.65–34.92), planned from a three-plane FGRE localizer sequence. The 13–14 cm field of view (FOV) coverage extends from the mid-medial femoral condyle to mid-lateral femoral condyle. Sixteen, 3.5 mm slices with a 0.3 mm gap were aligned to the PCL in the coronal and axial planes (Figure 1C & D). The ETL was eight to 10 and with two to three NEX and an average scan time of two minutes and 33 s. The resultant images show the PCL in an elongated, straight line, over two or three slices (Figure 2B).

3. Results

We imaged four patients with suspected PCL injuries. Two patients had suspected acute injuries and two patients had suspected chronic injuries.

The patients with acutely injured PCLs (patients 1 and 2) (Figures 4 and 5) were symptomatic with clinical instability and, in the case of patient 2, pain. On MRI scanning with the knee in an extended position, the PCLs appeared partially continuous with increased signal intensity in the midsubstance of the PCL, making it difficult to differentiate between partial thickness and complete tearing. MRI scanning in the flexed knee position revealed complete tears of the PCLs in both cases.

The patients with chronically injured PCLs (patients 3 and 4), were imaged due to ongoing symptoms with patient 3 suspected to have re-injured the PCL (Figures 6 and 7). On MRI scanning with the knees in an extended position the PCLs appeared ‘scarred’ with normal low-signal along the entire course of the PCL with abnormal morphology. The PCL of patient 3 demonstrated some proximal thickening and distal attenuation of the ligament. The PCL of patient 4 appeared homogeneously thickened. MRI scanning in a flexed knee position in the case of patient 3 revealed almost complete division of the PCL and associated redundancy with visible elongation. In patient 4 the PCL appeared intact but redundant with visible elongation.

**Patient 1** — 18-year-old male who fell onto flexed knee playing sport. Clinical instability with suspected PCL injury (Figure 4).

**Patient 2** — 18-year-old male with symptomatic instability and pain (Figure 5).

**Patient 3** — 31-year-old male two years following PCL injury. Suspected re-injury clinically (Figure 6).

**Patient 4** — 31-year-old male. Suspected PCL injury after fall from bicycle (Figure 7).

4. Discussion

The PCL has a confluent rectangular origin from the facet on the posterior aspect of the tibia one to 1.5 cm distal to the joint line [3,7]. It courses antero-medially as an intra-articular but extra-synovial structure to its half-moon shaped insertion on the anterolateral medial femoral condyle [3,7]. It averages 13 mm in width and 32–28 mm in length [3,7]. There are two bundles. The anterolateral bundle is tight in flexion, while the posteromedial bundle is tight in extension [3]. The PCL is concave antero-inferiorly with the knee in an extended position and concave posteriorly with the knee in flexion [8]. Between 60 and 120° of knee flexion, the PCL is ‘out to length’ or straight, secondary to its attachments being maximally separated [8]. In the cadaver and loaded living knee the PCL is at its maximal length at 120° of knee flexion [8]. In the unloaded living knee the maximal length is at 90–100° of knee flexion [8,9]. However, the lengths of the anterior and posterior surfaces of the PCL change in a consistent albeit different pattern over the arc of flexion between

![Figure 2.](image-url)routine sagittal PD sequence showing a normal PCL in knee extension (A) and knee flexion (B).
extension and 120° of flexion [9]. As a result, deformation of one part of the PCL cannot be inferred from deformation of another part, nor can it be inferred from attachment separation in the unloaded knee.

PCL injuries are difficult to diagnose due to the limitations of the clinical history and examination [2–4]. They usually do not present with specific symptomatic complaints and are often asymptomatic [2,10]. Patients with PCL injuries most often report vague symptoms, such as unsteadiness or discomfort [10]. In the acute phase of injury the patient may complain of a mild to moderate effusion, pain in the back of the knee, pain with kneeling, and instability during rapid direction change [10]. Instability is more likely to be reported in cases of combined injuries [10]. In the subacute or chronic phase of injury the patient may experience vague anterior knee pain, pain with deceleration and descending stairs, and pain with running at full stride [10].

PCL injuries, particularly isolated injuries, are frequently missed on physical examination [1]. Clinical examination, particularly in the acute setting, can be difficult due to the presence of an effusion, concomitant injuries, and/or pain [10]. Several tests can be used to examine for posterior and posterolateral instability. They include but are not limited to the posterior drawer, posterior sag, quadriceps active, reverse pivot shift, and dial tests [2]. Despite their widespread use the physical examination tests have not been evaluated sufficiently enough to be confident in their ability to assess the integrity of the PCL [11].

The natural history of PCL injuries is unclear and the management of isolated PCL injuries is uncertain and controversial [12,13]. There is potential for intrinsic healing with continuity but with residual laxity and attenuation [13,14]. It was previously thought that isolated PCL injuries may be adequately managed non-operatively. Recent evidence, though, suggests that the non-operative management of isolated PCL injuries is associated with increased progression of osteoarthritis, affecting eight to 36% of patients, and decreased functional outcomes [14,15]. Although operative management has been shown to improve stability there is no evidence to indicate that operative management can prevent the development of osteoarthritis [15].

The challenge is to identify PCL injuries, especially isolated acute complete or near-complete partial tears and functionally deficient elongated chronic healed tears, which may benefit from operative intervention.

MRI scanning is the investigation of choice for imaging PCL tears. The standard series is obtained with the knee in extension and include T2-weighted or PD orthogonal sagittal and coronal sequences [5]. On these sequences the normal PCL appears as a well-defined continuous band of very low signal concave antero-inferiorly [16]. Complete PCL tears demonstrate fibre discontinuity with high-signal fluid traversing the torn fibres [16]. Partial thickness tears appear thickened with increased signal, without complete fibre discontinuity [16]. Chronic tears appear attenuated, absent or thickened or alternatively elongated with normal...
homogeneous low signal [6,16]. Although the sensitivity and specificity of MRI scanning in identifying PCL tears are 97–100%, differentiation of complete and partial tears is problematic with sensitivity for identifying partial tears only 67% [2,14,17]. In the authors’ clinical experience, accurate assessment of chronic PCL injuries, particularly elongation, is difficult when the PCL is bent or buckled.

The ‘PCL view’ (oblique coronal T2-weighted sequence) was developed to overcome the partial volume artefact of scanning in the sagittal plane by scanning in a plane parallel to the PCL. The use of the ‘PCL view’, may improve visualisation of the entire width of the PCL along its parallel axis and has been reported to reduce the number of false negative diagnoses, and to increase the specificity and accuracy of MRI scanning [5]. These findings however were not statistically significant [5].

Stress radiographs have been shown to be useful in diagnosing PCL injuries [2,14]. Some authors advocate MRI scanning the knee positioned in slight flexion, up to 30°, rather than full extension to more clearly visualise the anterior cruciate ligament (ACL) [18,19]. To our knowledge, imaging in flexion has not been suggested for the PCL. To improve visualisation of the PCL and to aid in differentiating acute partial and complete tears and identifying elongation of chronic healed tears, the authors advocate scanning the knee at 90° of flexion, the position in which the PCL is at its longest. As shown in the four cases described, this can assist in identifying injury to the PCL and help differentiate partial and complete tears, by distracting the ends of the tear. In the setting of chronic healed PCL tears, stretching the PCL to its full length will aid in identifying elongation, which in our experience is extremely difficult to identify with the knee in an extended position. The mean separation of the PCL attachments in the unloaded living knee at 90° of flexion is 43.5 mm [8]. The current best measure of elongation is comparing the separation of the PCL attachments to that of the PCL of the contralateral knee. The authors aim to establish normative data in a future study to define elongation.

There are limitations to using this MRI scanning protocol and the authors advocate only using it to visualise suspected PCL injuries, particularly partial or chronic injuries. Scanning with the knee in a flexed position requires the use of a general-purpose flex coil, not a high definition extremity knee coil, which results in poorer image quality for delineating other non-PCL injuries. MRI scanning of the knee in a flexed position also adds to scanning time which potentially adds to patient discomfort and cost. The protocol only images the knee at 90° of knee flexion which does not consider the differing patterns of lengthening of
the anterior and posterior surfaces of the PCL, and thus components of the PCL, through flexion. This can be overcome by MRI scanning the knee in an open-bore MRI scanner which allows the knee to be scanned through a large, uninterrupted range of flexion [9]. Open-bore MRI scanners though are usually of low strength and thus low resolution, limiting their utility in diagnosing PCL pathology and integrity, and have limited availability. Finally, there is currently no normative data defining elongation of the PCL in a flexed unloaded knee, something the authors wish to define in a follow-up study.

In conclusion, the authors have outlined a new MRI imaging protocol of the PCL that may assist in differentiating acute partial and complete tears and identifying elongation of chronic healed tears. A larger case series is required to identify the accuracy of the described protocol and establish normative data to define elongation.

References