Get a kick out of this: the spectrum of knee extensor mechanism injuries

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ABSTRACT
At the end of this article, the reader should be able to (1) recognise normal anatomy and anatomical variants of the extensor mechanism of the knee on various imaging modalities, including plain film, ultrasound and MRI; (2) diagnose a broad spectrum of EM injuries in adult and paediatric patients including patellar and quadriceps tendinopathy, Osgood–Schlatter disease, Sindig–Larsen–Johansson syndrome, chondromalia patellae and patellar fractures on various imaging modalities; and (3) appreciate the important role of imaging in the diagnosis of musculoskeletal injuries.

INTRODUCTION
The extensor mechanism (EM) of the knee comprises the quadriceps muscles and tendon, the patella, patellar tendon and supporting retinacula (figure 1). Injuries of the EM are common and may be due to acute trauma, overuse injuries or chronic degenerative disease, and imaging plays an important role in diagnosis. In addition to clinical evaluation, abnormalities of bone and soft tissues can be visualised with plain films and CT, and tendons can be assessed with ultrasound (US). MRI provides excellent evaluation of the knee and is often the imaging modality of choice in the characterisation of EM injuries.

ANATOMY OF THE EM OF THE KNEE
The EM of the knee comprises the quadriceps muscles and tendon, the patella, the patellar tendon and supporting retinacula. The quadriceps muscles include the rectus femoris and the vastus lateralis, vastus intermedius and vastus medialis. The origin of the rectus femoris is the anterior inferior iliac spine, and the vastus muscles originate from the femoral shaft. The quadriceps tendon inserts on the superior pole of the patella and usually has a trilaminar appearance on MR.1 The superficial lamina is composed of the rectus femoris, the intermediate lamina is composed of the vastus lateralis and medialis, and lastly the deep lamina is formed by the vastus intermedius.

The patella is the largest sesamoid bone in the body and articulates with the trochlear groove of the femur. It usually possesses a median ridge that divides the proximal patella into medial and lateral facets, and the medial facet is generally smaller. The patellar tendon is mainly composed of rectus femoris fibres that course over the patella and originates at the superior pole of the patella and inserts on the tibial tuberosity.

The medial retinaculum has three components: the superior component is composed of the vastus medialis and patellofemoral ligament, the midportion is composed of the medial collateral ligament fibres, and lastly the inferior component includes the patellotibial ligament and the medial patellomeniscal ligament. Similarly, the lateral retinaculum is composed of three parts: the superficial component includes the iliotibial tract and biceps femoris, the midportion is composed of the vastus lateralis, and the deep component is composed by the joint capsule.

Additional soft tissue structures include fat pads, namely the anterior suprapatellar (quadriceps) fat pad, the posterior suprapatellar (prefemoral) fat pad and the infrapatellar or Hoffa’s fat pad. The suprapatellar, prepatellar and prepatellar bursae are also important structures.

Anatomy of the EM is best characterised on MR (figure 1). Plain films and CT provide excellent bony detail and soft tissue characterisation to a lesser degree. Tendons can be quickly and efficiently visualised on US and normally have an echogenic fibrillar appearance with parallel superficial and deep surfaces.

IMAGING PITFALLS
A common artefact in MRI called the ‘magic angle’ phenomenon is unique to the musculoskeletal system, affecting tissues that are

Figure 1 Normal MRI anatomy of the extensor mechanism of the knee in a 34-year-old male. (A) Sagittal T1-weighted MR image: A, quadriceps tendon with normal striated appearance; B, patellar tendon; C, patella; D, femur, E, patellar cartilage; F, trochlear cartilage; G, Hoffa’s fat pad; H, tibial insertion of the patellar tendon. (B) Axial proton density fat-saturated MR image labelled as above in (A), and I, medial retinaculum; J, lateral retinaculum.
composed of well-ordered collagen fibres, such as hyaline cartilage, menisci and tendons. These tissues appear to behave in an anisotropic fashion when placed in a magnetic field and appear hyperintense when the fibres are oriented at a ‘magic angle’ of approximately 55° to the static field of the magnet. Thus, the artefact can be mistaken for the appearance of pathology (ie, tendinopathy) (figure 2). This artefact is most apparent at short echo times and can be reduced with an echo time of 37 ms or more (ie, T2-weighted sequences).

On US, tendons also display an anisotropic effect when the probe is not oriented perpendicular to the tendon at 90°. As a result, areas of low echogenicity can be mistaken for tendinopathy. To overcome this pitfall, the probe is angled through its full range, and if the previously low echogenicity area within the tendon becomes more echoic and eventually isoechoic to the rest of the tendon, then tendon disease can be excluded.

ANATOMICAL VARIANTS

Articular muscle of the knee (articularis genu m.)
This muscle supports the suprapatellar bursa and the superior joint capsule of the knee. It originates from the anterior aspect of the distal femur and extends inferomedially to insert near the suprapatellar bursa (figure 3). In a 1995 retrospective study, the articular muscle of the knee could be seen in 83% of clinical MRI studies of the knee. It should not be mistaken for a soft tissue mass.

Dorsal defect of the patella
Dorsal defect of the patella (DDP) is an anomaly of ossification and is of little clinical significance. The characteristic lesion is round and lytic with well-defined margins and located in the superolateral aspect of the patella adjacent to the subchondral bone (figure 4).

Bipartite patella
This anatomical variant is a result of failure of an accessory ossification centre to unite with the main body of the patella. As a result, the accessory ossification centre unites with the patella via a synchondrosis. The most common location for the secondary ossification centre is at the superolateral aspect of the patella and can be mistaken for a patellar fracture. It can be differentiated both by its position and the smooth, corticated margins along adjoining surfaces (figure 5).

PATHOLOGY

Patellar tendinopathy
Patellar tendinopathy or ‘jumper’s knee’ is a common overuse condition that classically occurs in young athletes who jump, kick and run, placing repeated stress on the patellofemoral joint. Patellar tendinopathy includes a spectrum of pathology from chronic degeneration to partial tearing. Lesions in patellar tendinopathy typically occur in the deep posterior portion of the proximal patellar tendon adjacent to the lower pole of the patella. On US, the normal fibrillar pattern of the patellar tendon is disrupted with decreased echogenicity and thickening near its proximal insertion (figure 6A). Increased flow on colour Doppler indicating neovascularisation can also help localise the site of injury (figure 6B). Typical findings on MRI include focal thickening of the proximal one-third of the patellar tendon with abnormal high signal intensity on T2-weighted images (figures 6C and 6D).
patient’s body weight with the knee in flexion. The injury is suggested on radiographs by a superiorly displaced patella and infrapatellar soft tissue swelling (figure 7A). On MR, the patellar tendon is completely torn from its patellar attachment and can appear buckled (figure 7B).

Osgood–Schlatter disease

Osgood–Schlatter disease (or tibial tubercle apophyseal injury) is a common cause of knee pain in adolescents. It is caused by repeated traction on the immature tibial tuberosity by the patellar tendon, which can cause inflammation, avulsion fractures and excess bone growth. Osgood–Schlatter disease is usually a clinical diagnosis, and imaging is used to rule out other pathologies. The diagnosis of Osgood–Schlatter disease can only be suggested on plain films if radiographic soft tissue swelling is present anterior to the tibial apophysis (figure 8), as fragmentation of the tibial apophysis can be a normal variant.

Sindig–Larsen–Johansson syndrome

This syndrome is caused by traction on the patellar tendon, causing inflammation at the insertion of the proximal tendon into the inferior pole of the patella. It usually appears in children after a period of rapid growth and can be distinguished from patellar tendinopathy by the presence of bone marrow oedema in the patella (figure 9), and by clinical presentation.

Figure 4  Dorsal defect of the patella in a 12-year-old male. Anteroposterior radiograph of the knee (A) and a reconstructed sagittal CT image (B) shows a well-defined, round and lytic lesion in the superolateral aspect of the patella adjacent to the subchondral bone (arrow). Axial gradient recalled echo MR image (C) demonstrates a defect in the superolateral aspect of the patella with intact overlying cartilage that is mildly thickened with increased signal (arrow).

Figure 5  Bipartite patella in a 42-year-old woman with lateral knee pain. Anteroposterior (A) and skyline (B) radiographs of the knee demonstrate an osseous fragment in the superolateral aspect of the patella with smooth, corticated margins (arrow). Axial proton density fat saturated (C) and sagittal T1-weighted (D) MR images demonstrate cartilage overlying both osseous parts of the patella.

Figure 6  Patellar tendinopathy in a 34-year-old male with anterior knee pain. (A) Longitudinal sonogram of the patellar tendon showing fusiform swelling of the proximal patellar tendon and a hypoechogenic area effacing the fibrillar appearance of the tendon (arrow). (B) Colour Doppler sonogram (in greyscale) of the patellar tendon demonstrating the same findings as in (A) with increased vascularity on Doppler (arrows). (C) Sagittal gradient recalled echo MR image demonstrating thickening of the proximal patellar tendon and internal high signal intensity (arrow). (D) Axial proton density fat saturated MR image showing high signal at the attachment of the patellar tendon to the patella (arrow).
Quadriceps tendinopathy occurs less frequently than patellar tendinopathy but demonstrates similar findings on imaging (figure 10). The most common site of injury is at the distal site of insertion on the patella. Tears of the quadriceps tendon usually occur in an older patient population, and a predisposing risk factor, such as diabetes, gout or rheumatoid arthritis, often exists. In the younger patient, acute tears can be due to forced muscle contraction or blunt trauma.

Quadriceps tendon rupture
Rupture of the quadriceps tendon is relatively infrequent and is more common in patients older than 40 years. It occurs less frequently than patellar tendinopathy but demonstrates similar findings on imaging (figure 10). The most common site of injury is at the distal site of insertion on the patella. Tears of the quadriceps tendon usually occur in an older patient population, and a predisposing risk factor, such as diabetes, gout or rheumatoid arthritis, often exists. In the younger patient, acute tears can be due to forced muscle contraction or blunt trauma.
usually occurs in the setting of underlying disease, including chronic renal failure, diabetes, rheumatoid arthritis, gout and obesity. Most ruptures of the quadriceps tendon occur during attempts to regain balance to avoid a fall. The quadriceps muscle rapidly contracts against the patient’s body weight (eccentric contraction) while the knee is in a semiflexed position, placing the quadriceps tendon under its greatest tensile stress. Findings on MR include complete rupture of the quadriceps tendon with a ‘wrinkled’ appearance of the patellar tendon, which no longer has a tensile force applied to it (fig 11).

**Patellar fractures**

Patellar fractures are usually sustained through blunt trauma or forced contraction and result in transverse or stellate fractures. They can be mistaken for bipartite patella (figure 5) but can be distinguished from this anatomical variant based on orientation and the presence of indistinct margins and non-corticated irregular fragments (figure 12). While plain films can detect the presence of fractures, they are better delineated with CT.

In paediatric patients, osteochondral sleeve fractures are the most common patellar fractures, although they are rare. A full circumference of cartilaginous tissue and often a bony fragment is avulsed from the lower pole of the patella due to rapid and forceful muscle contraction against a partially flexed knee. This occurs most often with jumping, and skateboarding is a common cause. On plain films, an abnormally superiorly displaced patella and/or a small bone fragment distal to the lower pole of the patella can provide a clue to
diagnosis. On MR, cartilaginous injury can be easily detected due to the contrast between hypointense cartilage and the hyperintense fracture line. It can also delineate the extent of cartilaginous injury in further detail and define the relationship of the fracture fragments to help in further management (figure 13).$

**Patellar dislocation/relocation**

Patellar dislocation most commonly results from a twisting motion and occurs in a lateral direction. The natural history for most patellar dislocations is for the patella to relocate prior to the patient’s presentation, thereby confusing the clinical picture. Lateral patellar dislocation/relocation results in demonstratable injury to both soft tissue (retinacular disruption) and bony structures. The medial patellar facet impacts against the lateral femoral condyle, which is seen on MRI images as bone marrow contusion or fracture, findings pathognomonic for patellar dislocation.$ A distinct triad of findings can be seen on MRI (figure 14), including subchondral oedema in the medial facet of the patella and in the anterolateral femoral condyle with a tear in the medial retinaculum. In children, patellar dislocation/relocation often results in an osteochondral fracture and can result in large intra-articular loose fragments.

**Chondromalacia patellae**

Chondromalacia patellae (also known as patellofemoral syndrome) is a common cause of anterior knee pain especially in athletes due to degradation of the patellar hyaline cartilage. It is difficult to diagnose clinically. The gold standard for chondral assessment is arthroscopy, and a widely used four-stage grading system of pathological change was developed by Shahriaree.$ However, MRI can accurately assess the condition of the articular cartilage for more severe grades of chondromalacia patellae (table 1, figure 15) and is a reliable diagnostic tool for investigation of anterior knee pain.$

**Prepatellar bursitis**

The prepatellar bursa is a synovial lined sac containing synovial fluid located anterior to the patella and below the skin. Prepatellar bursitis or ‘housemaid’s knee’ may result from a variety of causes, including acute trauma, chronic friction or repetitive minor injuries (such as repeated kneeling),
REFERENCES

CONCLUSION
In addition to clinical evaluation, a wide range of imaging modalities, including plain film, CT, US and MRI, play a major role in the diagnosis of a variety of EM injuries.

Competing interests None.
Provenance and peer review Not commissioned; externally peer reviewed.

Figure 16 Prepatellar bursitis. Sagittal T1-weighted (A), sagittal gradient recalled echo (B) and axial fast spin echo proton density fat saturated MR images (C) of prepatellar bursitis demonstrate a complex fluid collection anterior to the knee in the region of the prepatellar bursa (arrows). The patient’s knee is markedly enlarged, and thus falls outside the field of view.

inflammation, crystal deposition (as in gout or pseudogout) or infection (through direct inoculation or haematogeneous spread). Findings on MRI may include a complex fluid collection anterior to the knee in the region of the prepatellar bursa (figure 16), and the wall of the bursa may be thickened and irregular.

Provenance and peer review Not commissioned; externally peer reviewed.