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Role of X-Ray to Evaluate Suitable Knee Joint Projection

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1. Introduction

The knee joint is a modified hinge joint between the femur, tibia and patella. It is the largest synovial joint in the body and allows flexion and extension of the leg as well as some rotation in the flexed position.

Indication/Technique
X-rays of the knee joint are requested frequently, particularly at the Emergency Assistance department. They are used primarily to confirm/exclude a fracture, or to assess the level of osteoarthritis in the knee joints.

Technique
- To establish the presence of a fracture, as in each conventional X-ray, the knee should be imaged in at least two directions.
- A standard examination includes an anterior-posterior image and a lateral image. Additional directions may be added when indicated.

The most commonly used examinations are explained below.

AP/PA image
The front-to-back or anterior-posterior knee image can be made in both supine and standing positions. In supine position, the X-rays pass through the knee from anterior to posterior (= AP image). An alternative to the supine position is the standing AP image. The knee is fully extended and imaged in the craniocaudal direction under a 10° angle. Additionally, a standing posterior-anterior image (= PA image) may be opted for, also known as the Rosenberg method. In the
Rosenberg method, knees should be flexed at 45° .

Standing images have the advantage over supine images that by the additional load on the knee joint they more reliably detect reduced joint space caused by meniscus and cartilage disorders (see also the Pathology section).

Lateral image
Lateral images are made in the supine position with the knee flexed to 30°. The X-rays pass through the knee joint from medial to lateral.

In a good lateral image, the medial and lateral femoral condyles project over each other and the patellofemoral joint is projected free.

Where necessary, oblique images can be obtained by exorotation of the knee from the neutral supine position (= lateral oblique image) or endorotation (= medial oblique image).

In a trauma setting, an image using a horizontal x-ray beam may be preferred over the standard lateral image in order to establish lipohemarthrosis (see Pathology section). The knee is fully extended and the X-rays pass through the knee from lateral to medial.

Axial image
The axial image is also termed the sunrise image and provides information on the patellofemoral joint. Additionally, patellar pathology (fracture & subluxation/luxation in particular) can be identified.

There are several techniques to make an axial image of the patella. One commonly used technique is the inferosuperior projection. The patient is in the supine position and flexes the knee to 40-45° using knee support.

Tunnel view
In a tunnel view, the intercondylar fossa is projected free.
It is used primarily to identify a free body or osteochondral defect (see Pathology section).
There are various techniques to make a tunnel image. One commonly used technique is the axial projection. The patient is in the supine position and flexes the knee to 40-45° using knee support.
X-rays pass through the knee from anterior to posterior at a 90° angle to the lower leg.
Normal anatomy

AP/PA image
The knee joint is formed by the femorotibial joint (femur - tibia articulation) and the patellofemoral joint (patella - femur articulation). The femorotibial joint is subdivided into the medial compartment and the lateral compartment. Despite the fact that the three above articulations are regularly described as separate joints, they share a common articular capsule.

The femoral condyles and tibial plateau are visible on an AP/PA image . The lucent spaces at the level of the medial & lateral compartments of the femorotibial joint are the same in a normal knee. This space is indicative for the joint space. An asymmetric joint space may suggest meniscus disorders and/or cartilage loss (note: cartilage is not visible on X-ray) and/or ligament laxity.

The medial & lateral tibial plateau are separated by a minor elevation; the tibialintercondylar eminence.

Measurement of AP/PA image:
Tibiofemoral alignment: on an AP/PA image, draw a vertical line along the lateral femoral condyle. Be alert for a lateral tibial plateau fracture if the line is more than 5 mm lateral of the lateral tibial plateau .

Lateral Image
The lateral image produces a better image of the patellofemoral joint than the AP image. In addition to bone, we can also assess soft tissue. The knee has three fat pads:

Infrapatellar fat pad, also termed Hoffa's fat pad.
Posterior suprapatellar fat pad (= prefemoral fat).
Anterior suprapatellar fat pad.

The posterior and anterior suprapatellar fat pads are separated by the suprapatellar recess. The suprapatellar recess is also termed the suprapatellar bursa and is connected to the femorotibial joint. In joint effusion, the recess may be distended, this is explained in more detail in the Pathology section. A normal knee has little fluid in the suprapatellar recess (anterioposterior thickness <5 mm).

Importantly, it is more difficult to assess joint effusion as knee flexion increases . Explanatory note: under flexion > 30°, the patella moves downward and the suprapatellar recess and surrounding soft tissues may be compressed/deformed. Consequently, small amounts of fluid stay unnoticed in the suprapatellar recess.

Additionally, the contours of the quadriceps tendon and the patellar tendon are visible on a lateral image . They have a denser (= whiter) aspect than the fat. Remember, fat has a more hypodense aspect (= blacker) because fat absorbs fewer X-rays than muscles/tendons. See class X-ray/CT technique for more information on X-ray densities.

On a normal knee image, the femoral condyles are superimposed, but seeing the lateral condyle is smaller than the medial, a good lateral image will show that the front of the medial condyle projects before the front of the lateral condyle. By minor asymmetries in the femoral condyles, it may be possible to distinguish between medial and lateral on a lateral image.

Tip:
The lateral femoral condyle has a small superficial notch / lateral femoral notch (= transition of range of movement of femorotibial & patellofemoral joint). Note: the medial femoral condyle also has a femoral notch, however it is located more anteriorly and is often not easily seen.
Directly proximal to the posterior side of the medial femoral condyle is a bony elevation; the adductor tubercle. This is where the adductor magnus muscle inserts.

Patellar measurements in lateral image:
The length of the tibial tubercle - patellar lower pole is about the same as the length of the patella, with a variation of 20%. The length of the patellar tendon length and that of the patella . Ideally, the measurement is performed with the knee flexed at 30°. In a normal knee, the ratio is between 0.9 - 1.4 (mean value = 1). If the ratio is < 0.9, the patella lies low if the ratio is > 1.3, the patella lies high . It should be noted here that another proposal has been made in the literature for the normal value, a ratio between 0.75- 1.7.

In the more recently developed modified ratio, the same measurement is performed, but the patellar tendon is measured up to the lower pole of the articulating portion of the patella . The patellar length includes the articulating portion of the patella. The mean normal value ratio is 1.3 and a ratio > 2.2 is considered diagnostic for patella Hight.

Axial Image
An axial (sunrise) image provides information on the patella and the patellofemoral joint. During flexion/extension, the patella slides in the trochlea and is located in the middle of the trochlea. The patellofemoral joint has a medial facet and a lateral facet, where the lateral facet is longer than the medial facet. Rule of thumb: the longest facet is the lateral side.
The contours are smooth everywhere and the joint space is symmetric at the medial and lateral sides.

Tunnel view
In a tunnel view, the intercondylar fossa is projected free. In a normal knee, there are no osteochondral defects or intra-articular bodies. The medial joint compartment has a slightly smaller joint space on the tunnel view than the lateral joint compartment. This is a normal finding. Explanatory note: the cartilage is slightly thinner on the contact point of the medial femoral condyle and the medial tibial plateau when the knee is flexed at 40-45°.

Pathology
Fracture
fracture general
tibial plateau fracture
patellar fracture
Avulsion fractures
intercondylar eminence fracture
Segond fracture
chronic: Osgood-Schlatter disease
Patellar instability
Osteochondritisdissecans/ osteochondral lesion
Osteoarthritis

Fracture General
Non-dislocated fractures (dislocation = displacement) may be very subtle.
A fracture is frequently associated with joint effusion. The suprapatellar recess will fill with fluid/blood and the suprapatellar fat pads will expand.
Be aware that hydrops may also occur in e.g. infection/inflammation and degenerative changes (clinical information is therefore essential!)
In a trauma setting, a supine lateral image is recommended as this visualizes the fat-blood level; a lipohemarthrosis. Lipohemarthrosis is strongly associated with intra-articular fracture. It may occur also in a marked bony contusion or ligamentary lesion. In lipohemarthrosis, fat and blood are released into the joint from the bone marrow, creating a fat-blood level.

Tibial Plateau Fracture
A tibial plateau fracture is a common knee fracture. Subtle fractures may be missed in a knee X-ray. When in doubt, a CT scan should be made (e.g. for lipohemarthrosis without obvious fracture on knee X-ray).
The Schatzker classification is commonly used by surgeons/orthopedists and classifies tibial plateau fractures into 6 subtypes :
Type I: wedge-shaped fracture of lateral tibial plateau, with < 4 mm depression* or dislocation
Type II: split + compression fracture of lateral tibial plateau with > 4 mm depression (= type I with depression)
Type III: pure depression fracture of lateral tibial plateau
Type IV: medial tibial plateau fracture with split or compression component (poorest prognosis!)
Type V: Fracture of medial & lateral tibial plateau
Type VI: transversal fracture through the metadiaphysis (involvement of medial/lateral tibial plateau is variable)
* depression is measured as the vertical distance between the lowest point of the intact medial tibial plateau and the lowest point of the lateral tibial plateau fragment.

Patellar fracture
Most patellar fractures are easily recognized on lateral images.

When a patellar fracture is suspected, an axial (sunrise) image should always be made. A vertical patellar fracture can be missed on the AP/PA image and the lateral image .

Be aware of bipartite patella as a normal variation. A fracture has an irregular cortex interruption (vs. smooth sclerotic contours in a bipartite patella) and will not be present on old images.

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Intercondylar Eminence Fracture

The anterior cruciate ligament inserts on the medial tubercle (medial tibial spine) of the intercondylar eminence.

The intercondylar eminence has not yet fully ossified in children. Following excessive stress, an avulsion fracture may develop on the anterior cruciate ligament . Think of e.g. forced hyperextension of the knee. An intercondylar eminence fracture may occur in the elderly also, particularly in the presence of osteoporosis.

Concomitant meniscus and ligamentary damage may be present. However, this occurs more frequently in adults after high-energy trauma.

Segond Fracture
A segond fracture is an avulsion fracture on the outer side of the lateral tibial plateau and may develop following internal rotation in combination with varus stress . Debate continues on which structures are exactly involved in this type of avulsion fracture. It was originally held that an avulsion of the middle third part of the lateral joint capsule occurs. Others now believe it is a more complex avulsion that may also involve the iliotibial ligament and a portion of the lateral collateral ligament.
A Segond fracture is highly associated with rupture of the anterior cruciate ligament.

Osgood-Schlatter Disease
Repetitive microtrauma and traction of the patellar tendon at the level of the tibial tubercle may lead to Osgood-Schlatter disease. It is considered a chronic avulsion fracture of the proximal tibia and develops predominantly at age 10 - 14 years (boys > girls). Particularly jump & kick sports appear to increase the risk of Osgood-Schlatter disease.

The clinical rationale and local pain symptoms are usually sufficient for diagnosis. A knee X-ray may appear entirely normal. The classical radiologic picture of Osgood-Schlatter disease is fragmentation of the tibial tubercle and local soft tissue swelling. There may also be obliteration of the caudal portion of Hoffa's fat pad (secondary to infrapatellar bursitis). Fragmentation of the tibial tubercle without soft tissue swelling may also occur as a normal variation (multiple ossification centers); patient symptoms determine presence/absence of Osgood-Schlatter disease.

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Patellar Instability
The patellofemoral joint is stabilized by the extensor muscles, the bone (trochlea) and ligaments (medial patellofemoral retinaculum/ligament). The patella may luxate towards lateral, frequently the result of a twisted leg; knee in flexion + internal rotation of the femur + fixated foot with a valgus component.

A number of predisposing factors to patellofemoral instability:
Patella alta (patellar tendon too long) and patella baja (patella tendon too short)
Abnormal shape of trochlea; trochlear dysplasia
Relatively weak vastusmedialis muscle
Ligamentary laxity (including ehlers-danlos and marfan syndrome)

Chronic instability of the patellofemoral joint may lead to progressive cartilage damage and eventually severe osteoarthritis.

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OsteochondritisDissecans/ Osteochondral Lesion
Osteochondritisdissecans (OCD) is an osteochondral disorder that is observed in children/teenagers with joint pain, swelling and/or locked joints.

The exact etiology has not been elucidated. It is likely a multifactorial process consisting of genetic factors, growth abnormalities and chronic subchondral stress.

At adult age (= mature skeleton) the term osteochondral lesion is used rather than OCD.

The disorder encompasses a spectrum starting at subchondral bone edema to subchondral fracture/fragmentation and eventually detachment of the osteochondral fragment .

The literature describes various laparoscopic and non-laparoscopic classifications (not addressed here). Irrespective what classification is used, MRI must be used to find out whether the OCD/osteochondral lesion is stable. Intact cartilage suggests stability; a cartilage defect suggests instability. Cystic changes near the interface at adult age suggest instability, but are specific at a young age.

An OCD may develop in various joints (including ankle and elbow) but is most common in the knee joint. The classical location for OCD in the knee is the lateral side of the medial femoral condyle. Rule of thumb: LAME, Lateral Aspect of the Medial femoral (Epi)condyle.

The tunnel view image in particular provides good visualization of the osteochondraldefects and free bodies .

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