

CMEARTICLE

Clinics in diagnostic imaging (163)

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Fig. 1 Lateral radiograph of the left knee.

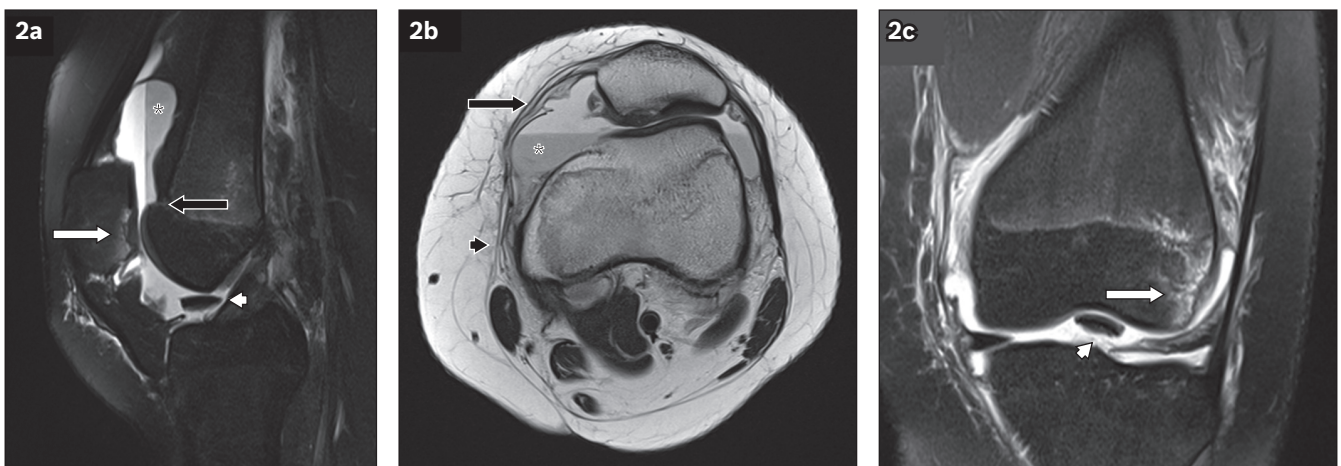


Fig. 2 (a) Sagittal fat-suppressed T2-W, (b) axial T2-W and (c) coronal fat-suppressed PD-W MR images of the left knee.

CASE PRESENTATION

A 14-year-old girl presented with pain and swelling of the left knee after accidentally twisting her knee when walking on level ground. She was subsequently unable to bear weight on her left

knee. Physical examination revealed a large knee effusion and limited range of motion. What does the radiograph (Fig. 1) and subsequent magnetic resonance (MR) images (Figs. 2a–c) of the left knee show? What is the diagnosis?

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IMAGE INTERPRETATION

The radiograph shows a defect (arrow, Fig. 1) at the inferior articular surface of the patella and a suprapatellar effusion (*). The sagittal fat-suppressed T2-weighted MR image (Fig. 2a) confirms the presence of a displaced osteochondral fragment in the intercondylar notch (arrowhead), which originated from the inferomedial aspect of the patellar articular surface and is associated with underlying bone marrow oedema (white arrow). A step-like transition from the distal femoral metaphysis to the trochlea is also noted (black arrow). The axial T2-weighted MR image (Fig. 2b) demonstrates lateral patellar subluxation and a shallow trochlear groove. The medial patellofemoral ligament (MPFL) appears attenuated and wavy (arrow) with avulsion of its femoral attachment (arrowhead). Haemarthrosis with a fluid-fluid level (*, Figs. 2a & b) is also visualised. Coronal fat-suppressed proton density (PD)-weighted MR image (Fig. 2c) shows marrow oedema in the lateral femoral condyle (arrow). Seen together with the findings in the inferomedial aspect of the patella in Fig. 2a, this represents 'kissing' bone contusions. The displaced osteochondral fragment is again demonstrated (arrowhead).

DIAGNOSIS

Transient lateral patellar dislocation with trochlear dysplasia.

CLINICAL COURSE

The patient underwent open reduction and internal fixation of the patellar osteochondral fracture, plication of the medial patellar retinaculum and lateral release one week after the injury. She recovered well after surgery.

DISCUSSION

The patella articulates with the femoral trochlea to form the patellofemoral joint. The patella has a tendency to dislocate laterally due to the divergent direction of pull of the quadriceps and patellar tendons (forming the Q angle, which is approximately 15°), compounded by the valgus configuration of the knee in the normal state.⁽¹⁻³⁾ Active and passive mechanisms help to stabilise the patella during knee flexion. The most important active stabiliser is the vastus medialis obliquus, the inferior portion of the vastus medialis muscle, which neutralises the action of the vastus lateralis.^(3,4) Passive stabilisers include the medial ligaments (of which the medial patellar retinaculum and the MPFL are the most important) and a sufficiently deep femoral trochlea.^(2,3,5,6) Anatomical variations in these areas may lead to patellar instability and a predisposition to dislocation. These variations can be accurately identified and quantified on imaging.

In cases of patella alta (when the patella is in a high position), there is reduced contact between the patella and trochlea during early knee flexion.^(3,5,7) Using the Insall-Salvati method, patella alta is present when the length of the patellar tendon divided by the maximal diagonal length of the patella on a lateral knee radiograph produces a ratio of more than 1.2 (normal ratio: 1.0) (Fig. 3).^(2,4) The modified Insall-Salvati method uses the length of the articular surface of the patella instead of its maximal

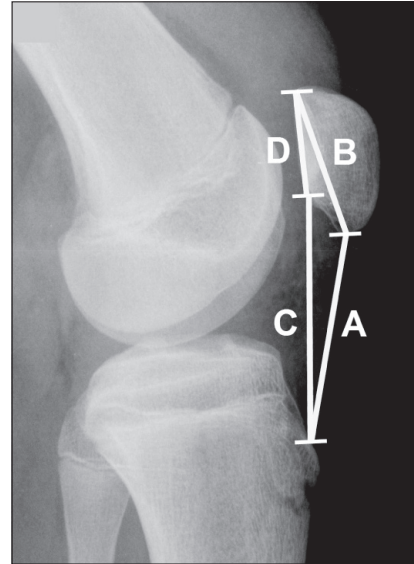


Fig. 3 Lateral knee radiograph shows patella alta in a 14-year-old boy. The Insall-Salvati ratio, or the length of the patellar tendon (line A) divided by the maximal diagonal length of the patella (line B), is 1.4. In the modified Insall-Salvati method, the distance between the inferior articular surface of the patella and the patellar tendon insertion (line C) is divided by the length of the patellar articular surface (line D), giving a ratio of 2.4.

diagonal length, which is less sensitive to variations in patellar morphology.^(2,4) In the modified method, patella alta is defined as having a ratio of more than 2.0 (Fig. 3).⁽²⁾ These indices may also be used on midsagittal computed tomography (CT) and MR imaging of full knee extension.^(1,5,8,9)

Femoral trochlear dysplasia occurs when a shallow trochlear groove reduces engagement of the patella during early knee flexion.⁽⁵⁾ Köhlitz et al reported it as the most important contributing factor in patellar instability.⁽⁹⁾ On true lateral radiographs, in which the posterior borders of the femoral condyles overlap or have a gap of 2 mm or less, the 'crossing sign' (seen in up to 96% of dysplasia cases) is present when the deepest part of the trochlear groove crosses the anterior aspect of the femoral condyles (Fig. 4).^(5,7,10) On axial CT and MR imaging at the apex of the intercondylar notch, the lateral trochlear inclination is measured by drawing two lines: (a) along the subchondral bone of the lateral trochlear facet; and (b) along the posterior aspects of the femoral condyles, i.e. the posterior condylar axis (Fig. 5a).^(5,11) An angle of less than 11° indicates trochlear dysplasia.⁽⁵⁾ On an axial image 3 cm above the tibiofemoral joint cleft, a ratio of the length of the medial trochlear facet to that of the lateral trochlear facet (trochlear facet asymmetry) of less than 0.40 indicates dysplasia (Fig. 5b). On the same image, femoral depth can be measured by subtracting the distance between the deepest point of the trochlear sulcus and the posterior condylar axis from the mean anteroposterior distance of the medial and lateral femoral condyles (Fig. 5c); trochlear dysplasia is present when femoral depth is 3 mm or less. These measurements have been reported to be 93%–100% sensitive and 87%–96% specific on MR imaging.^(5,10) On midsagittal MR imaging, a nipple-like anterior prominence at the superior end of the trochlea has also been reported by Pfirrmann et al to be a highly specific sign (i.e. 91%) (Fig. 6).⁽¹⁰⁾

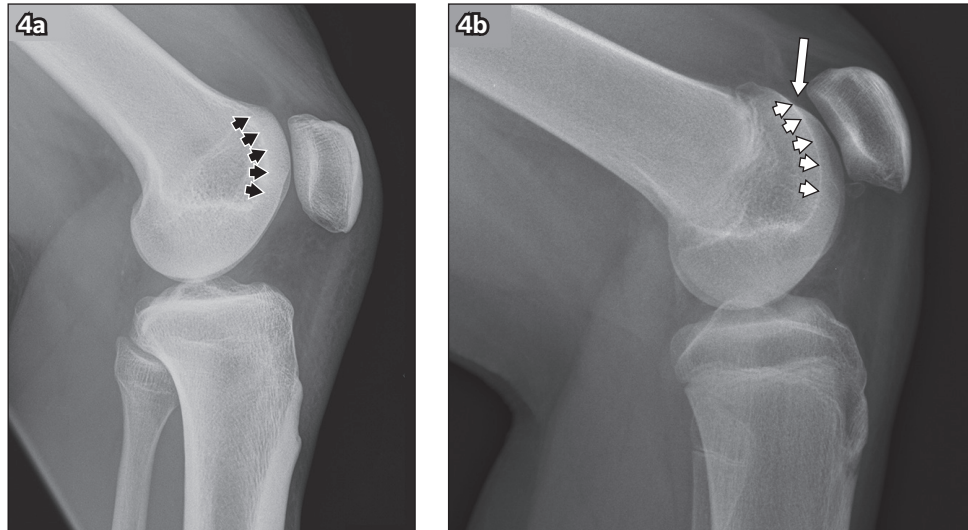


Fig. 4 (a) A normal lateral knee radiograph of a 19-year-old man shows that the femoral trochlear groove (black arrowheads) does not cross the femoral condyles. (b) Lateral knee radiograph of a 15-year-old boy shows the 'crossing sign', which occurs when the deepest part of the femoral trochlear groove (white arrowheads) crosses the anterior aspect of the femoral condyles (arrow) and is an indicator of femoral trochlear dysplasia.

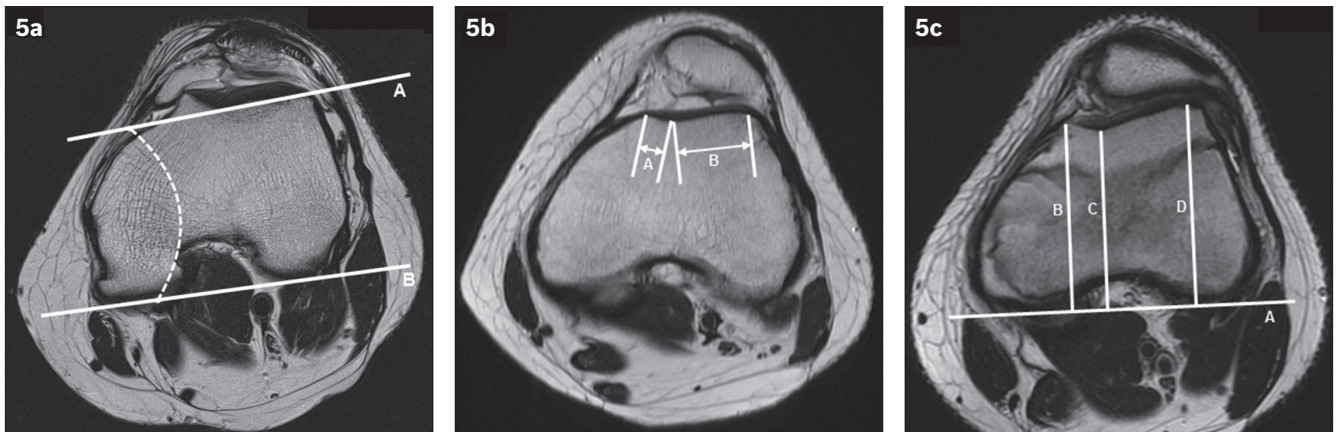


Fig. 5 Axial MR images show methods of assessing femoral trochlear dysplasia. (a) Lateral trochlear inclination in a 23-year-old man: at the apex of the intercondylar notch, the angle (dashed line) between line A, along the subchondral bone of the lateral trochlear facet, and line B, along the posterior aspects of the femoral condyles (posterior condylar axis), is 4°, indicating trochlear dysplasia. (b) Trochlear facet asymmetry in a 19-year-old woman: at 3 cm above the tibiofemoral joint cleft, the ratio of the length of the medial trochlear facet (line A) to that of the lateral trochlear facet (line B) is 0.32, indicating trochlear dysplasia. (c) Femoral depth in a 13-year-old boy: at 3 cm above the tibiofemoral joint cleft, the distance C between the deepest point of the trochlear sulcus and the posterior condylar axis (line A) is subtracted from the mean anteroposterior distance of the medial and lateral femoral condyles (lines B and D) $[(B + D)/2 - C]$. The femoral depth measured 3 mm in this case, indicating trochlear dysplasia.



Fig. 6 Midsagittal PD-W MR image in a 23-year-old man shows a nipple-like anterior prominence (arrow) at the superior end of the femoral trochlea, which has been reported to be a highly specific sign of trochlear dysplasia.

An excessive lateral position of the tibial tuberosity can also lead to instability by increasing the lateral pull on the patella. This can be detected on CT and MR imaging by measuring the tibial tuberosity-trochlear groove (TT-TG) distance,⁽⁸⁾ which is the horizontal distance between the deepest point of the trochlear sulcus and the tibial tuberosity on two superimposed axial images (Figs. 7a–c).⁽⁵⁾ A borderline measurement is between 15 mm and 20 mm; when the TT-TG distance exceeds 20 mm, it is nearly always associated with patellar instability.^(5,7)

Lateral patellar dislocation, which most commonly affects adolescent females, usually occurs when the aforementioned predisposing factors are present.^(1,5,12) It most often results from a twisting injury with knee flexion, as the femur rotates internally on a fixed tibia.^(1,5,13) As the patella frequently relocates spontaneously, the diagnosis may be clinically unsuspected or

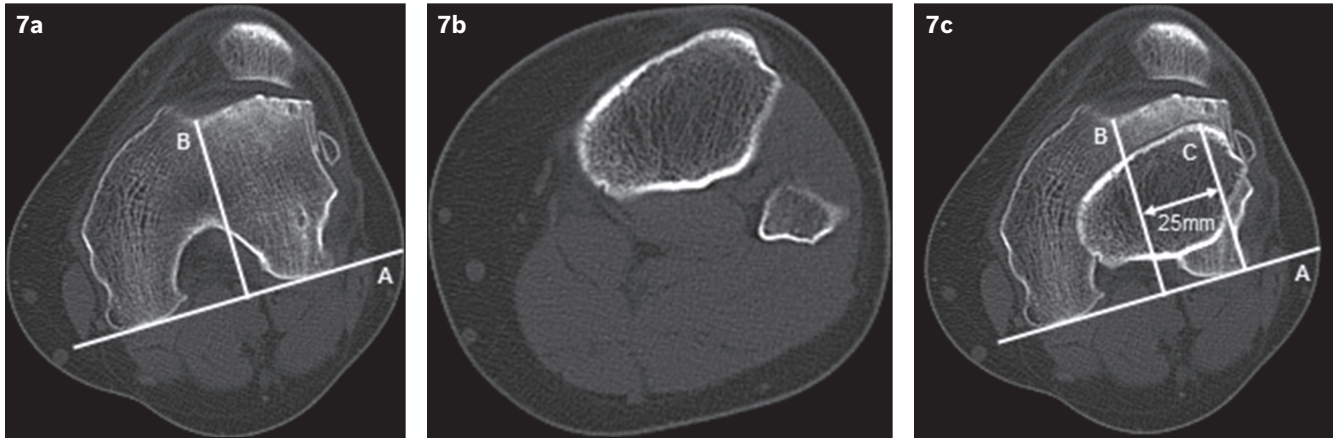


Fig. 7 Axial CT images of a 29-year-old man with recurrent patellar dislocation show tibial tuberosity-trochlear groove (TT-TG) distance. (a) Line B is drawn from the deepest point of the trochlear sulcus, perpendicular to the posterior condylar axis (line A). An axial image of the tibial tuberosity (b) is superimposed on the first image to form image (c). Line C is drawn from the tibial tuberosity, perpendicular to line A. The distance between lines B and C (TT-TG distance, double-headed arrow) is measured (25 mm in this case).

misdiagnosed in up to 73% of patients; hence, imaging plays a very important role in diagnosis.^(1,2,6)

Characteristic patterns of osseous injury are seen on MR imaging. As the patella relocates, the inferomedial patella impacts upon the anterolateral aspect of the lateral femoral condyle, leading to bone contusions. These are visualised as focal areas of high T2-weighted and low T1-weighted signal intensity (i.e. the classic 'kissing' contusion pattern) (white arrows in Figs. 2a & c; white and black arrows in Fig. 8).^(1,4,14) Femoral bone contusions are usually more anterior and superior than the contusions in pivot shift injuries.^(1,4,6) They may be associated with chondral or osteochondral lesions and range from mild articular cartilage irregularity to large displaced osteochondral fractures (arrowhead, Fig. 2a). A concave impaction deformity at the inferomedial patella may also be present in up to 44% of patients; this is analogous to the Hill-Sachs lesion of the humeral head in anterior glenohumeral joint dislocation.⁽²⁾ Avulsed chondral or osteochondral fragments may be seen as intra-articular loose bodies in up to 33% of patients (arrowheads, Figs. 2a & c).^(1,5) MR imaging is particularly helpful to locate purely chondral loose bodies that are radiolucent on radiography.⁽¹⁾

The MPFL and medial retinaculum may be injured in up to 70%–100% of patients.^(1,5) The MPFL is normally seen on axial and sagittal T2-weighted sequences as a well-defined, low-signal-intensity band extending from between the adductor tubercle and the medial femoral epicondyle towards the medial patella (Fig. 9a).^(5,6) The medial retinaculum is seen just distal to the MPFL and may not be separable.^(5,14) Complete tears of the MPFL result in discontinuity with retraction or a wavy appearance of its fibres with surrounding oedema (Fig. 9b), while partial tears lead to fibre irregularity, thickening or partial discontinuity with intrasubstance and/or surrounding oedema (Fig. 9c).^(5,14) Most MPFL injuries occur at or close to its femoral attachment, where it is weakest.^(1,4,6) Superficial to the MPFL, there may also be oedema around the vastus medialis obliquus muscle, uplifting of the muscle from the medial femoral condyle and the possible stripping of its distal attachment to the adductor tubercle (Fig. 10).^(2,4,5) These are best seen on coronal and axial fluid-sensitive images.⁽⁵⁾

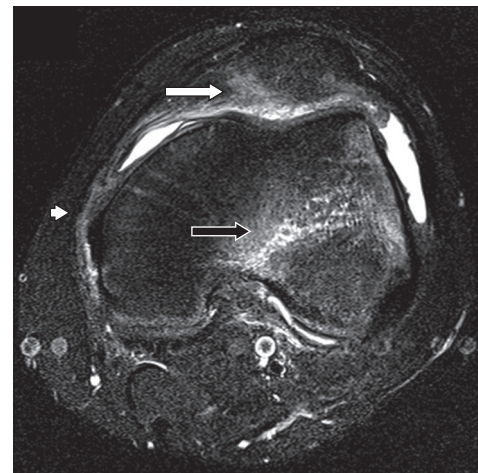


Fig. 8 Axial fat-suppressed T2-W MR image in a 15-year-old boy shows the characteristic 'kissing' bone contusions at the inferomedial patella (white arrow) and lateral femoral condyle (black arrow). Note also the avulsion of the medial patellofemoral ligament from its femoral attachment (arrowhead).

A joint effusion is often seen if imaging is performed early.⁽¹⁾ There may be a fluid-fluid level in a haemarthrosis due to sedimentation of blood components (*, Figs. 2a & b) or a fat-blood interface if an osteochondral injury causes a lipohaemarthrosis.^(1,5) However, in recurrent dislocations with chronic instability, an effusion may not be present as there are no new injuries in the already lax medial stabilisers.^(1,5,6) Persistent lateral subluxation or tilt of the patella are also frequently observed despite relocation, due to medial retinacular injury and joint effusion.⁽¹⁾

Patellar instability is also associated with oedema in the superolateral portion of Hoffa's (infrapatellar) fat pad.^(2,8,15) This may be due to impingement of fat between the patellar tendon or lateral patellar facet and the lateral femoral condyle.⁽¹⁵⁾ The oedema is best seen as high signal on the far lateral sagittal images of a fluid-sensitive sequence (Fig. 11).⁽⁸⁾ Chronic impingement may lead to hypertrophy of the fat pad, which may extend laterally beneath the lateral patellar retinaculum or cause anterior bowing of the patellar tendon.⁽⁸⁾ Chronic instability may lead to ligamentous ossification of the medial patella due to repetitive

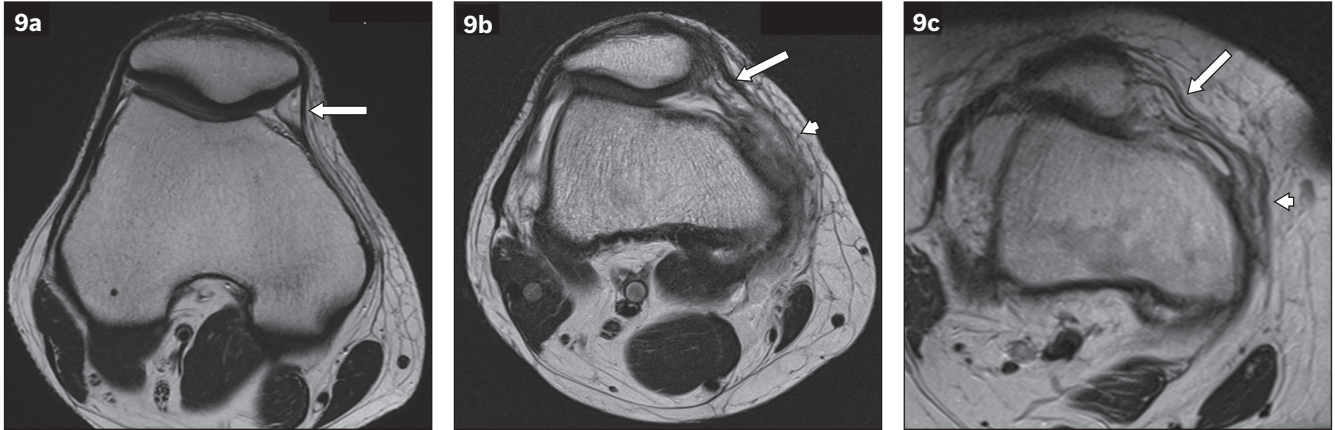


Fig. 9 Axial T2-W MR images of three patients. (a) Normal medial patellofemoral ligament (MPFL) in a 19-year-old man: a well-defined, low-signal-intensity band (arrow) extends from between the adductor tubercle and the medial femoral epicondyle towards the medial patella. (b) Complete MPFL tear in a 22-year-old man: the MPFL (arrow) shows complete discontinuity of its fibres near its femoral attachment (arrowhead), with extensive surrounding oedema. (c) Partial MPFL tear in an 18-year-old woman: the MPFL (arrow) shows thickening and irregularity of its fibres at its femoral attachment (arrowhead), with intrasubstance and surrounding oedema.



Fig. 10 Coronal fat-suppressed PD-W MR image in a 22-year-old man shows oedema (arrow) around the inferior portion of the vastus medialis obliquus muscle.

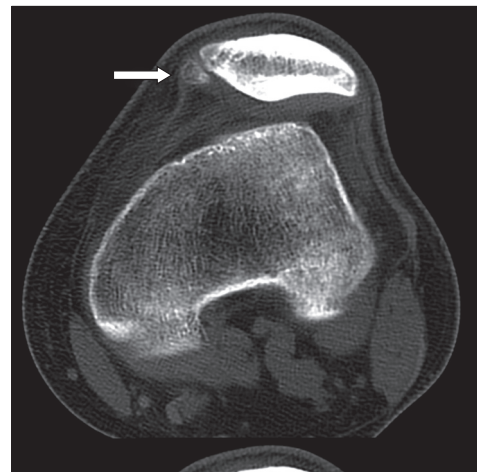


Fig. 12 Axial CT image in a 20-year-old man shows ligamentous ossification of the medial patella (arrow).

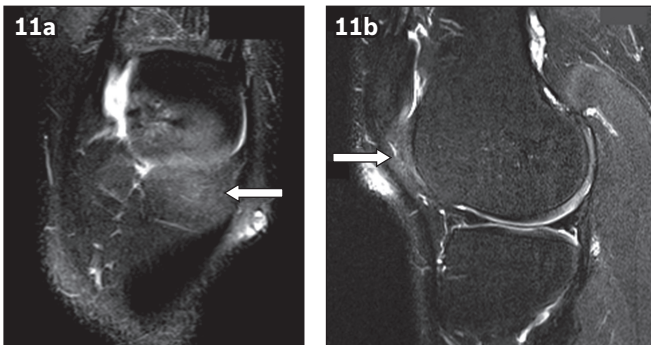


Fig. 11 (a) Coronal fat-suppressed PD-W and (b) sagittal fat-suppressed T2-W MR images in a 23-year-old man show oedema in the superolateral portion of Hoffa's (infrapatellar) fat pad (arrows), in keeping with impingement.

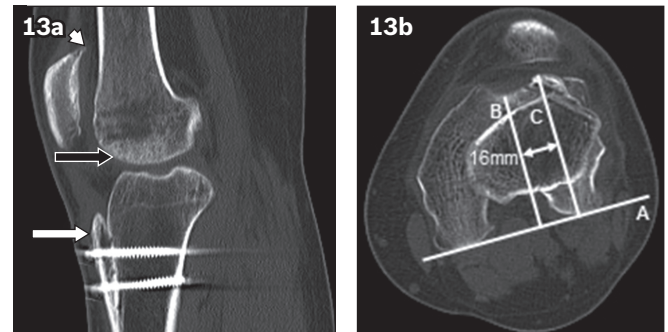


Fig. 13 (a) Sagittal CT image post-tuberosity transfer in a 29-year-old man (patient in Fig. 7) shows screw fixation of the tibial tuberosity (white arrow) to the proximal tibia in its corrected position. Changes due to osteoarthritis with patellar osteophyte formation (arrowhead), and subchondral sclerosis and cysts (black arrow) are also apparent in the lateral femoral trochlear facet. (b) Superimposed axial CT images show a reduced tibial tuberosity-trochlear groove distance of 16 mm, from the preoperative 25 mm. Lines B and C were drawn perpendicularly from the posterior condylar axis (line A) to the deepest point of the trochlear sulcus and the medialised tibial tuberosity, respectively.

stress to the MPFL (Fig. 12),⁽⁵⁾ chondromalacia patellae and, eventually, patellofemoral osteoarthritis (Fig. 13a).^(5,8,10)

First-time patellar dislocations are usually managed conservatively with rest, ice, compression, elevation (RICE) and immobilisation with a brace in extension for 3–6 weeks.^(1,3,5) Physical therapy consisting of quadriceps strengthening (focusing

on the vastus medialis obliquus) and hamstring stretching is also performed.^(1,3) Indications for surgery in the acute setting include

the presence of osteochondral fragments or loose bodies, which require surgical reattachment or resection, and femoral avulsion of the medial stabilisers, which may require surgery to fully restore the patella to its normal position.^(1,5) Surgery is also indicated in recurrent patellar instability, which may occur in up to 50% of cases managed conservatively.^(3,5,7,12) The choice of surgical procedure depends on the underlying anatomical anomaly and its severity. The most common surgical procedure performed is a combination of medial capsular plication, which involves suturing the tear in the medial stabilisers, and release of the lateral patellar retinaculum.⁽⁵⁾ This can often be performed arthroscopically.⁽⁵⁾ Reconstruction of the MPFL with an autograft (e.g. gracilis tendon) or an allograft (e.g. semimembranosus tendon) is increasingly performed in lieu of medial plication.^(1,5,7) In patients with a TT-TG distance of more than 20 mm, transfer of the tibial tuberosity to a more medial position can be performed to reduce the lateral force on the patella (Fig. 13).⁽¹⁾ In severe trochlear dysplasia, where alternative surgical options are inadequate, surgical reconstruction of the trochlea can be performed with trochlear

osteotomy, in which a bone graft is used to elevate the lateral trochlear facet, or trochleoplasty; this creates a deeper trochlear surface by removing the subchondral bone and compressing the overlying cartilage into the resultant defect.⁽⁵⁾

As lateral patellar dislocation is often clinically unsuspected, an understanding of its characteristic imaging features (particularly on MR imaging) is important in making the diagnosis. Imaging also allows for accurate identification of potential sites of injury and anatomical variants that predispose an individual to lateral patellar dislocation, which may affect the timing and choice of surgical management.

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ABSTRACT A 14-year-old girl presented with left knee pain and swelling after an injury. Magnetic resonance (MR) imaging showed a transient lateral patellar dislocation with patellar osteochondral fracture, medial patellofemoral ligament tear and underlying femoral trochlear dysplasia. Open reduction and internal fixation of the osteochondral fracture, plication of the medial patellar retinaculum and lateral release were performed. As lateral patellar dislocation is often clinically unsuspected, an understanding of its characteristic imaging features is important in making the diagnosis. Knowledge of the various predisposing factors for patellar instability may also influence the choice of surgical management. We also discuss signs of acute injury and chronic instability observed on MR imaging, and the imaging features of anatomical variants that predispose an individual to lateral patellar dislocation. Treatment options and postsurgical imaging appearances are also briefly described.

Keywords: femoral trochlear dysplasia, lateral patellar dislocation, medial patellofemoral ligament tear, patellar instability

SINGAPORE MEDICAL COUNCIL CATEGORY 3B CME PROGRAMME (Code SMJ 201510B)

Question 1. Regarding lateral patellar dislocation:

- (a) It is most commonly encountered in middle-aged men.
- (b) Anatomical variants can lead to patellar instability and predispose an individual to lateral dislocation.
- (c) The most common mechanism of injury is a direct blow to the medial aspect of the knee.
- (d) The diagnosis can usually be confidently made without the use of imaging.

True	False
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Question 2. Regarding predisposing factors for patellar instability:

- (a) On lateral knee radiographs, patella alta is present when the Insall-Salvati ratio is more than 1.2.
- (b) On axial computed tomography (CT) and magnetic resonance (MR) imaging, a lateral trochlear inclination of more than 11° indicates femoral trochlear dysplasia.
- (c) On axial CT and MR imaging, femoral depth of 3 mm or less indicates femoral trochlear dysplasia.
- (d) Tibial tuberosity-trochlear groove (TT-TG) distance is abnormal if it is more than 20 mm.

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Question 3. Regarding imaging features of associated injuries:

- (a) 'Kissing' contusions are often seen in the medial patella and medial femoral condyle.
- (b) The medial patellofemoral ligament (MPFL) may be injured in up to 70%–100% of patients.
- (c) MR imaging is useful in detecting purely chondral loose bodies which are radiolucent on radiography.
- (d) Chondromalacia patellae and patellofemoral osteoarthritis may be seen in chronic patellar instability.

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Question 4. Regarding management of patellar dislocation and instability:

- (a) Lateral patellar dislocation often requires open surgical reduction.
- (b) The presence of osteochondral fragments or loose bodies is an indication for surgery.
- (c) Surgical procedures for recurrent patellar instability include medial capsular plication and release of the lateral patellar retinaculum.
- (d) The MPFL can be reconstructed with the gracilis or semimembranosus tendon.

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Question 5. Are the following statements true or false?

- (a) Most MPFL injuries occur at the patellar attachment of the MPFL.
- (b) If a lipohaemarthrosis is seen on imaging, an osteochondral injury should be suspected.
- (c) A joint effusion may not occur after a recurrent dislocation in cases of chronic patellar instability.
- (d) Oedema in Hoffa's (infrapatellar) fat pad is identified by low signal on a fluid-sensitive MR sequence.

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Deadline for submission: (October 2015 SMJ 3B CME programme): 12 noon, 27 November 2015.