Dynamic multi-detector CT in the assessment of patellar instability: how can I do it, what should I measure and why

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Learning objectives

To illustrate the clinical indications for performing a dynamic multi-detector CT (MDCT) examination of the knee, its technical principles, post-processing of data, measurements achievable, possible diagnoses and their therapeutic outcomes.

Background

Patellar instability is a widespread cause of pain and functional limitation in young patients, particularly athletic women. Plain film, even at different grades of knee flexion, as well as dynamic ultrasonography or static MR examination of the knee, in some cases are not capable of demonstrating all the different causes of patello-femoral instability. Dynamic MDCT can give a substantial incremental value to the examination of patello-femoral instability.

Findings and procedure details

In this exhibit are described:

- Clinical assessment of patellar instability
- Dynamic MDCT acquisition protocol: field of view, slice thickness, image reconstruction algorithms
- Patient collaboration: lower limbs in extension and 20° flexion, each at rest and under contraction of quadriceps femorismuscle
- Post-processing of data: single images superimposition, multi-planar (MPR) and volume rendered (VR) reconstructions
- Measurements obtainable: trochlear groove-tibial tuberosity (TG-TT) distance, type of patella (according to Wiberg’s classification), depth and angle of the trochlear groove, femoro-patellar congruence (Merchant) angle, femoro-patellar tilt angle, Laurin angle, patellar tendon-patella (Insall-Salvati) ratio
- Influence of knee position and muscle contraction on measurements
- Ruling out differential diagnoses
- Advising the clinician on possible surgical strategies

Clinical assessment of patellar instability
Patellar instability is a disabling condition predominantly affecting young patients [1, 2] and including patellar dislocation, patellar subluxation and symptomatic instability in general[3]. Certain anatomical or functional factors, such as trochlear dysplasia, patellar morphology, tibial tuberosity location[4, 5], soft tissues disruption (in particular a rupture of the medial retinaculum or medial patellar-femoral ligament), hypotrophy of the vastus medialis oblique and generalized ligamentous laxity, have been associated with primary patellar dislocation or recurrent secondary instability[6-11].

Several clinical tests are used to diagnose and assess patellar instability [12], the most common of which are:

Apprehension test

patient supine, knee relaxed, 30° flexion

the examiner uses one hand to push the patella laterally

a positive sign is when the maneuver reproduces the patient's pain or causes verbal expression of anxiety and/or involuntary quadriceps muscle contraction

Patellar positioning

patient initially supine, then retested in sitting position with knee initially relaxed in full extension

the examiner observes for eventual patellar tilt, lateralized position of patella, patella baja (excessively distal to the normal), patella alta (excessively proximal to the normal) while the knee is actively moved from full extension to full flexion

Q-angle

patient supine

a line is drawn from the anterior superior iliac spine, to the center of patella

a second line is then drawn from the center of patella to the tibial tubercle

the angle comprised between these lines is the Q-angle (normal value from 10° to 15° for men and from 15° to 20° for women) [13]

an increased Q-angle may enhance the laterally directed force of the extensor mechanism, predisposing the patella to mal-positioning and instability
Clinical examination is an essential diagnostic tool which, associated to radiological assessment, can frequently assist to choose among differential diagnoses and direct the decision-making process.

**Dynamic MDCT acquisition protocol**

The patient is examined supine, with knees positioned in the center of the gantry, feet affixed and toes pointing upwards in order to minimize leg movement throughout scanning. Basing a CT scout on the coronal and sagittal planes, both knees are included in the field of view (FOV) in order to allow a comparative evaluation of the inferior limbs. The scan interval always includes the myo-tendinous junction of the quadriceps femoris tendon cranially, and the distal insertion of patellar tendon on the tibial tuberosity caudally. The CT scanner to employ preferably is a 16 rows multi-detector CT (MDCT) or superior. The unit employed in our institution is a 64 slices LightSpeed VCT (GE Healthcare, Wis, USA). Images are obtained through a spiral acquisition. No intravenous iodinated contrast administration is required.

Acquisition parameters:

- pitch 1
- tube rotation 0.6 s⁻¹
- FOV 40 mm²
- slice thickness 1.25 mm
- acquisition kernel standard
- reconstruction slice thickness 0.6 mm
- reconstruction kernel bone
- total median dose length product (DLP) 2895.88 mGy/cm

**Patient collaboration**

Knees are initially scanned with the inferior limbs in full extension and muscle relaxation (Fig. 1, Fig. 3). Then the patient is asked to contract the quadriceps femoris muscle and a second scan is performed (Fig. 2). At this point a dedicated wedge-shaped foam pad is inserted below patient's knees in order to obtain a 20° flexion of the inferior limbs (Fig. 4). After acquiring a second CT scout in the coronal and sagittal planes, both knees are scanned first at rest and subsequently under muscular contraction.
Post-processing of data

A superimposition of the axial slices passing through the tibial tuberosity, at the point of its greatest prominence, and the trochlear groove, at its maximum depth is obtained for the measurement of the trocklear groove-tibial tuberosity (TG-TT) distance. A sagittal multi-planar reconstruction (MPR) passing through the middle of patella is employed for the assessment of the Insall-Salvati ratio. All remaining measurements are obtained on axial images.

Measurements obtainable

_Trochlear groove-tibial tuberosity (TG-TT) distance_

The trocklear groove-tibial tuberosity (TG-TT) distance is a measurement of the lateral pull on patella. When the tibial tuberosity is in an excessively lateral position, the patella is shifted laterally during knee flexion[14, 15]. The TG-TT distance is measured by superimposing the axial images passing through the apex of the intercondylar notch and the tibial tubercle, respectively, on MDCT scans obtained with the inferior limbs in full extension and without contraction of the quadriceps femoris muscle (Fig. 5). When the distance comprised between the tibial tuberosity and the deepest point of the trocklear groove (measured parallel to the posterior condylar axis) is greater than 20 mm, it is considered abnormal and always associated with patellar instability[14, 15].

_Type of patella_

The assessment of patellar morphology, according to commonly used Wiberg's classification [16, 17], may be another key point to address the clinician:

- type I: patellar facets are concave, symmetrical and of equal size (ideal configuration)
- type II: the medial facet (eventually flat or slightly convex) is rather smaller than the lateral one, this latter being concave (the most common patellar anatomy)
- type III: the medial facet (convex) is markedly smaller than the lateral one.

_Trochlear depth_

The trocklear depth is measured as the distance between the deepest point of the trocklear groove and a line traced tangential to the anterior margins of the medial and lateral femoral condyles, taken perpendicularly to it (Fig. 6). A trocklear depth of less than 3 mm is considered abnormal [18].
Trochlear groove angle

The angle of the trochlear groove is formed by the intersection of the lines connecting the highest points of the femoral condyles to the lowest point of the trochlear groove (Fig. 7). Normal values are 125°-145° [19].

Femoro-patellar congruence angle

The femoro-patellar congruence or Merchant angle is a measurement of the lateral subluxation of patella. It is comprised between a line bisecting the sulcus angle and a second line joining the apex of trochlear groove with the apex of patella (Fig. 8). A normal congruence angle is -8°±6°. Positive values are associated with recurrent lateral dislocation [20].

Patellar tilt angle

The patellar tilt angle is formed by a line paralleling the lateral facet of patella and a second line tangential to the posterior aspects of lateral and medial femoral condyles (Fig. 9).

The normal angle is greater than 8°. An abnormal patellar tilt angle may be associated with lateral pressure syndrome [21].

Laurin angle

It is the angle between the lines drawn along the lateral patellar facet and the anterior margins of femoral trochlea (Fig. 10). It should be open laterally, normal values being comprised between 8° and 13°. When it assumes negative values (open medially), it indicates lateral subluxation of patella (Fig. 11) [22].

Patellar tendon-patella (Insall-Salvati) ratio

The Insall-Salvati ratio is useful to evaluate, in full extension, the height of patella. It is calculated by dividing the length of patellar tendon (from the apex of patella to its insertion on the tibial tuberosity) by the longest supero-inferior diameter of patella (Fig. 12). An Insall-Salvati ratio greater than 1.50 is consistent with patella alta [15]. A ratio less than 0.74 indicates patella baja [23].

Influence of knee position and muscle contraction on measurements

The additional value of MDCT with respect to conventional axial radiographic projections of the knees at 30° flexion, consists in allowing the assessment of patello-femoral joint in the axial plane, with the inferior limbs in extension and in early degrees of flexion [24]. A CT scan performed with the knees in at least 20° flexion allows to evaluate the behavior
of patella when it engages in the femoral trochlea, identifying the most serious cases in which the patella is dislocated in flexion.

However, patellar instability is a dynamic phenomenon, due in part to functional abnormalities of quadriceps femoris muscle. Thus, a CT examination obtained during muscle contraction increases the sensitivity of this modality in demonstrating a lateral deviation of patella, already observed in static conditions and accentuated by muscle contraction (Fig. 2), as well as in revealing an eventual patellar misalignment not evident at rest conditions (Fig. 1). CT scan performed under muscle contraction can identify those patients in whom the action of quadriceps femoris does not exacerbate a poor patellar alignment and for which the lysis of lateral retinaculum, when executed, would cause the onset of post-operative medial subluxation.

**Ruling out differential diagnoses**

The most common symptom associated to patellar instability is anterior knee pain. However, this kind of pain may be determined by several pathologies. The most common causes in young athletes are trauma, osteochondrosis, patellar insertional peritendinitis or tendinosis and synovial impingement. Less common sources of patellar pain are osteochondritis dissecans or tumors. It is always important to rule out eventual underlying hip pathologies such as osteochondrosis or infections. A careful physical examination and an appropriate MDCT scan in extension and 20° flexion of the knees, each at rest and under contraction of quadriceps femoris muscle, can point to the correct diagnosis of patellar instability in the majority of cases and rule out the differential diagnoses [25].

**Advising the clinician on possible surgical strategies**

Non-operative treatment techniques include physical therapy, focusing on strengthening the gluteal or vastus medialis oblique muscles, and patellar taping or bracing. Acute medial-sided repair of patella may be indicated when there is an osteochondral fracture fragment or a retinacular injury. Recent literature does not support the use of an isolated lateral release for the treatment of patellar instability. The measurements provided by an MDCT scan of the knee, such as TG-TT distance and the type of patella, are of great help to the clinician in determining the correct therapeutic procedure and, possibly, the most appropriate type of surgery.

A patient with recurrent instability, with or without trochlear dysplasia, who has a normal TG-TT distance and a normal patellar height, may be a candidate for a reconstruction of the medial patello-femoral ligament with an autograft or allograft. Differently, distal realignment procedures are used in patients with an increased TG-TT distance or patella alta. The degree of anteriorization, distalization, and/or medialization of tibial tuberosity during surgery mainly depends on associated arthrosis of the lateral patellar facet or the presence of patella alta. An associated medial or proximal patellar osteochondrosis is a contraindication to distal realignment because the tissues are already degenerated [26].
Images for this section:

Fig. 1: CT scan in full extension at the rest. These images demonstrate an external patellar tilt in both knees.

Fig. 2: In the same patient, CT scan in full extension with quadriceps femoris muscle contraction. Muscle contraction increases the external.
Fig. 3: CT scan in full extension at the rest. External patellar tilt in both knees.

Fig. 4: In the same patient, CT scan in 20° flexion shows a reduction of the external patellar tilt.
**Fig. 5:** TG-TT. Border-line values: 13 mm to the right and 15 mm to the left. Pathologic TG-TT: # 20 mm.
Fig. 6: Trochlear depth. Normal value > 3mm.
Fig. 7: Trochlear groove angle. Normal values: 125°-145°.
Fig. 8: Femoro-patellar congruence angle. This congruence angle is 21°. Normal values: -8°±6°.
Fig. 9: Patellar tilt angle. The normal angle is greater than 8°.

Fig. 10: Laurin angle. It should be open laterally, so this measurement is normal.
Fig. 11: Laurin angle. It is pathological Laurin angle. When it assumes negative values (open medially) it indicates lateral subluxation of patella.
Fig. 12: Insall-Salvati ratio. This is a normal value. An Insall-Salvati ratio greater than 1.50 is consistent with patella alta. A ratio less than 0.74 indicates patella baja.
Conclusion

Dynamic MDCT of the knee is a fast, non-invasive technique, requiring little collaboration from the patient, through which radiologists can rule out almost all causes of patellar instability, functional or structural, advising the clinician about possible surgical strategies.

Personal information

References


