Plain radiography in femoroacetabular impingement syndrome

Rentgensko slikanje pri utesnitvenem sindromu kolka

Matic Ciglič,[1] Klemen Stražar[2]

[1] Department of Traumatology, University Medical Centre Ljubljana, Zaloška 2, 1000 Ljubljana

[2] Orthopaedic Clinic, University Medical Centre Ljubljana, Zaloška 9, 1000 Ljubljana

Korespondenca/ Correspondence:
e: matic.ciglic@gmail.com

Ključne besede:
kolk; utesnitveni sindrom; rentgensko slikanje; radiološki parametri; artroza

Key words:
hip; impingement syndrome; radiography; radiographic parameters; osteoarthritis

Citirajte kot/Cite as:
Zdrav Vestn 2014; 83: 475–83

Prispelo: 25. apr. 2013,
Sprejeto: 29. maj 2014

Izvleček

Namen preglednega članka je natančno opisati tehniko zajemanja rentgenskih slik in pojasniti obdelavo le-teh pri diagnosticiranju utesnitvenega sindroma kolka. Orisani so radiološki parametri utesnitve kolčnega sklepa in njihov pomen pri odločanju o načinu zdravljenja. Podane so tudi osnovne informacije o etiologiji, epidemiologiji in kliničnih značilnostih utesnitvenega sindroma kolka in o njegovem zdravljenju. Opisane so smernice, kdaj je kirurško ukrepanje še pravočasno.

Abstract:

The aim of this article is to describe in detail the technique how to obtain radiographs with all the necessary information about hip pathology suggesting FAI. Radiographic factors of FAI and their significance are presented. Basic information about etiology, epidemiology and clinical presentation of FAI, together with current concept of its treatment, are provided as well. The problems regarding the timing of surgical intervention are also presented.

Introduction

Femoroacetabular impingement (FAI) is a relatively new concept which addresses the cases of osteoarthritis (OA) of the hip joint that were once considered idiopathic or primary.[1] Its clinical and radiographic characteristics were first described in details by R. Ganz and his coworkers.[1] There are two main types of FAI, pincer or acetabular type and CAM or femoral type.[1-4] By definition, pincer FAI is caused by focal (cephalad or true acetabular retroversion) or global (coxa profunda or protrusio acetabuli) overcoverage of the acetabulum.[1] In contrast to pincer, CAM FAI is caused by either loss of sphericity of the femoral head or by diminished antero-lateral offset of the head-neck junction.[1] Less frequently, femoral type of FAI results from femoral retroversion or femoral varus.[3,5] Improper relationship between the femoral head and the acetabulum may cause chronic abutment at the anterolateral acetabular rim. The damage patterns differ in cases of predominant type of deformity, with pincer causing primary labrum lesion and CAM causing first outside-in abrasion or delamination of the acetabular cartilage.[6] Central parts of the acetabulum and the femoral head are typically involved later in advanced stages of the disease.[2,3]

Radiographic signs of FAI are present in high percentages of patients with hip complaints, with isolated pincer type reported in 18 %, isolated CAM type in 17 % and combined type of FAI in 65 %.[7] Interestingly, in patient with acetabular dysplasia, where the acetabulum is too shallow or deformed, concomitant CAM deformity of the femoral head was noted in a significant number of cases.[8] It is particularly important for the investigator to be familiar with imaging techniques and with all parameters of FAI leading to timely diagnosis and early, properly performed surgery that provides best possible result and prevents or slows down the progression of the disease into an end stage OA.[22]

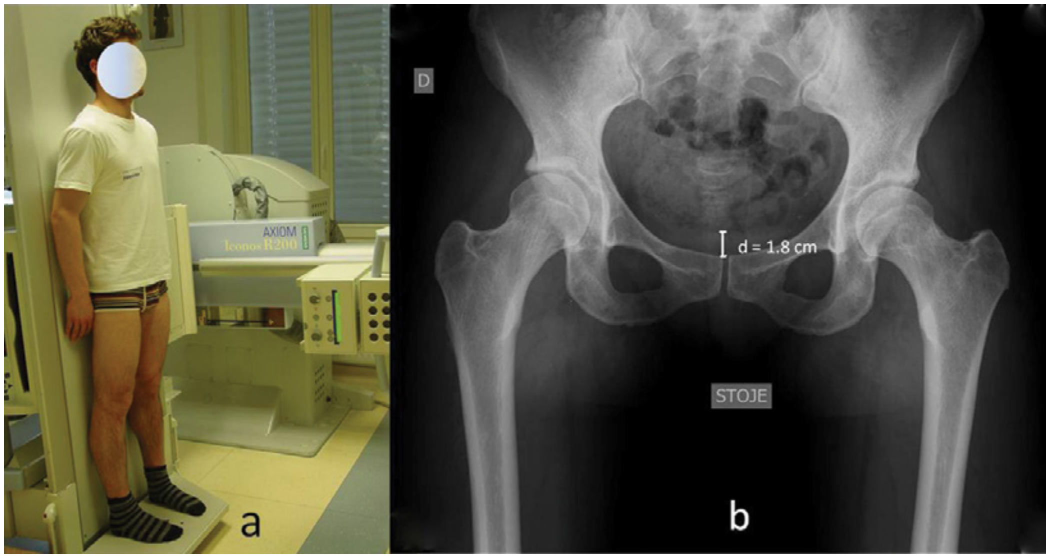


Figure 1: Weight bearing AP pelvic radiograph
a) Technique – Feet are oriented 15° inward (15° internal rotation of the hips) in order to maximize the length of the femoral neck. The X-ray tube to film distance should be 120 cm and the tube oriented perpendicular to the frontal axis of the patient. Crosshair of the beam should be centered on the point midway between the superior border of the pubic symphysis and a line drawn connecting the anterior superior iliac spines.
b) Radiograph – To guarantee neutral pelvic tilt, the distance between the tip of the coccyx and the pubic symphysis (d) should be between 1 to 3 cm. To control the rotation of the pelvis, iliac wings, obturator foramina and radiographic teardrops should be symmetrical in appearance.

Etiology, epidemiology and clinical presentation of FAI

The etiology of the condition is still not completely known, but it was suggested that childhood diseases (e.g. slipped femoral capital epyphisis, Mb Perthes) and their sequelae, metabolic or inflammatory factors, genetics and physical stress, posttraumatic or iatrogenic deformities are all associated with an increased incidence of FAI.[2-4]

The prevalence of radiographic signs of any type of FAI in asymptomatic population is shown to be more than twice as common in men as in women (13.95 % and 5.56 % respectively).[9,10] On the other perspective, 90 % of patients with labral lesions have bony abnormalities of the hip joint.[11]

Patients with FAI may be asymptomatic for a long period or may complain of some degree of hip joint stiffness but become painful in the presence of soft tissue damage, particularly at the acetabular chondrolabral junction.[12] A traumatic episode prior to the onset of symptoms is reported in only a quarter of patients with symptomatic FAI, insidious onset in a half of them, and acute onset without known traumatic event in the rest.[12] Pain, as the most frequent complaint, is in the majority of cases located in the groin (in 81 % of cases) but may be present over the greater trochanter (in 61 %), could radiate deep into the posterior buttock (in 52 %) or less frequently toward sacroiliac joints (in 23 %).[12] Besides pain, patients may also experience joint stiffness, weakness of the involved limb, non-audible clicking or snapping in the groin and feeling of instability or giving way.[12]. Physicians report on diminished range of motion of the involved hip, especially in flexion and internal rotation, positive impingement test (painful interior rotation and adduction in 90° of hip flexion), and in case of labrum lesion, painful manipulation of the involved hip in fully flexed position.[12] Positive FABER (flexion, abduction, external rotation) test is often a sign of advanced stages of the disease with more cartilage involved.[12] Anterior FAI results in reactive hip pain typically related to activities that require repetitive movements of the hip into flexed position. Less common, in the setting of acetabular or femoral anteversion, patients suffer from posterior FAI,

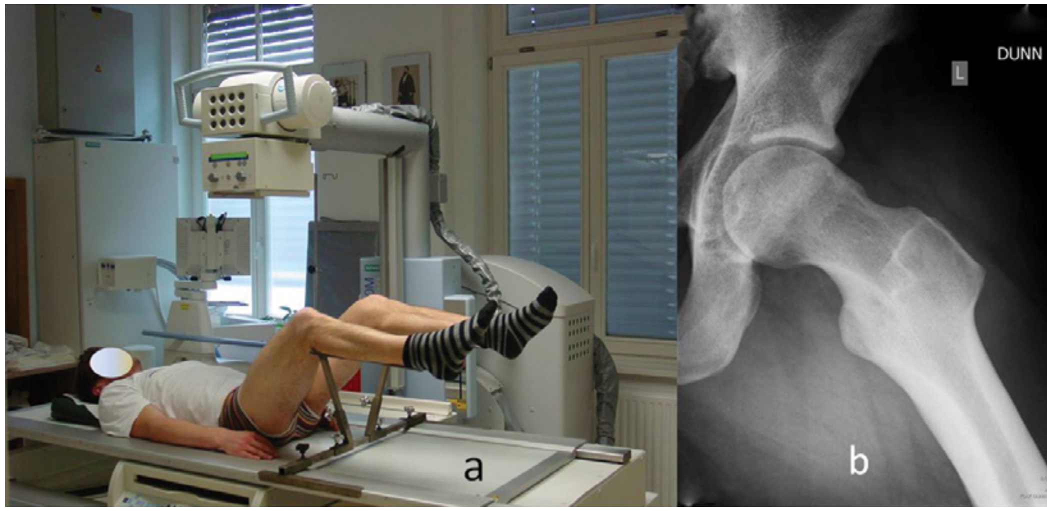


Figure 2: 45° Dunn view
a) Technique – The patient is laying supine on the x-ray table. The subjected hip is flexed to 45° and abducted 20° with neutral rotation. The beam is directed towards the point midway between the anterior superior iliac spine and the pubic symphysis. The tube-to-film distance should be approximately 120 cm.
b) Radiograph – CAM deformity with a pronounced bump at the femoral head-neck junction is present.

experiencing pain with extension and external rotation.[4,5] Bodily habits also play a role in producing symptoms in hips with FAI, as seen in those patients involved in sports that require repetitive extreme movements, e.g. in ballet dancers, gymnasts, hockey players and in many other sports.[13]

Radiographic imaging technique

To provide all necessary data for proper diagnosis and treatment from plain radiographs, patient with clinically suspected FAI should have three projections performed: 1 – weight bearing anteroposterior (AP) pelvic projection; 2 – axial projection according to Dunn; and, 3 – standing false profile by Lequesne of the involved hip.[14]

Weight bearing AP pelvic radiograph involves both hips and is made with the patient standing straight (Fig. 1).[14,15] Compared to the lying AP pelvic radiographs, a weight bearing AP view is the preferred one for evaluating joint space width. It appears to be more appropriate as acetabular version is more correctly visualized.[44]

Among the variety of axial views most of them are likely to miss asphericity of the femoral head.[16] Superposition of the greater trochanter over the head-neck junction is best avoided by Dunn view (Fig. 2).[16] It was shown that the angle alpha, which is the most reliable radiographic factor to demonstrate the degree of femoral head asphericity, is most profound on Dunn view with 45° hip flexion.[16] Alternatively to 45°, the hip can be in 90° flexion (90° Dunn view).[16]

False profile (FP) by Lequesne is a view of choice in assessing the hip for presence of OA, especially in cases of insidious OA (Fig. 3). It is also used to asses anterior femoral head coverage by the acetabulum.[17]

Signs indicating pincer type of FAI

To diagnose global over-coverage, one should look for the presence of coxa profunda or protrusio acetabuli, but in cases of focal over-coverage, cross-over sign (COS), posterior wall sign (PWS) and a prominent ishial spine are usually positive.[14,18] Centre--edge (CE) angle of Wiberg, and acetabular index (AI) also indicate acetabular coverage.[19-21] Anterior centre-edge (ACE) angle is measured on a FP radiograph, determining anterior coverage.[22]

Coxa profunda is present when on an AP pelvic radiograph fossa acetabuli touches or overlaps the ilioischial line and protrusio acetabuli is present when on the same view

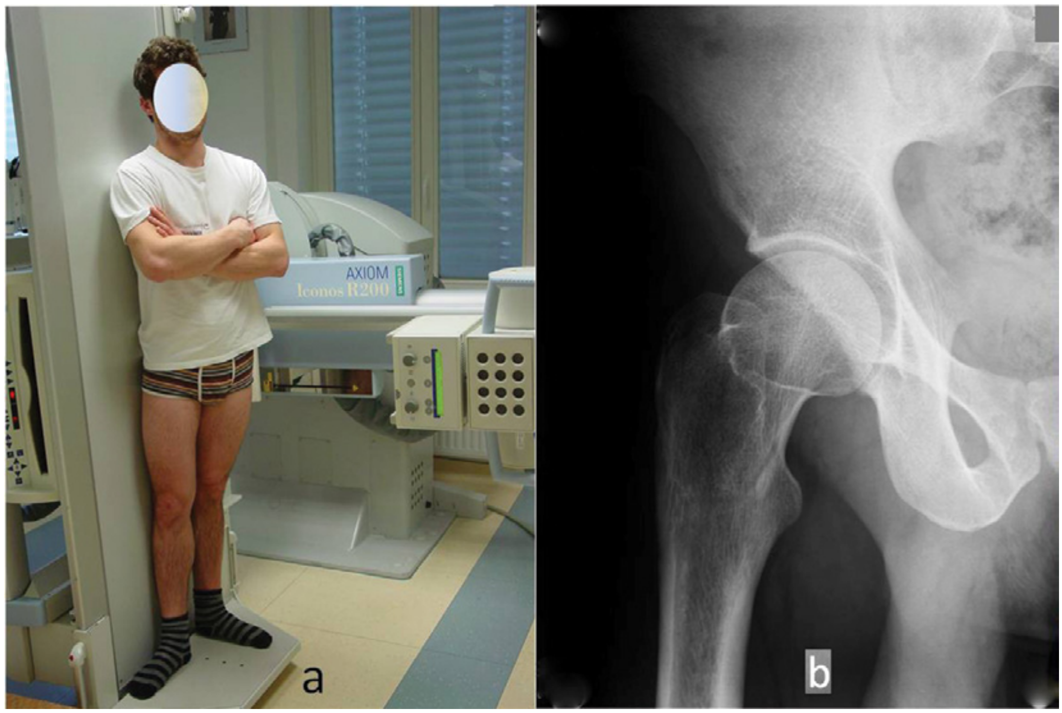


Figure 3: False profile view by Lequesne
a) The patient is standing with the affected hip against the cassette and the pelvis rotated 65° in relation to the wall stand. The foot on the same side as the affected hip should be positioned parallel to the cassette. The central beam is centered on the medial part of the contralateral groin, with a tube-to-film distance of approximately 110 cm.
b) Radiograph

femoral head lies medially to the ilioischial line (Fig. 4).[14]

LCE angle of Wiberg is measured on an AP pelvic radiograph and should be in range from 25° to 39° (Fig. 5a). Less than 20° defines structural instability due to acetabular dysplasia (under-coverage), 20°–24° indicate borderline acetabular dysplasia and 40° or more indicates acetabular over-coverage.[19,20] The LCE angle can also help to assess the amount of correction performed during surgery in cases of acetabular decompression, pelvic osteotomy or shelf procedures.[23]

The same technique, but on FP view, is used to assess **ACE angle**. Less than 20° indicates structural instability (Fig. 5b).[22]

Acetabular index (AI) defines acetabular inclination, with 0° to 10° considered as normal range, hips with an increased inclination are at risk for instability, whereas hips with a negative inclination are at risk for pincer impingement (Fig. 5a).[14,21]

COS is a reliable sign to predict the presence of acetabular retroversion (Fig. 6).[18] In normal anteverted sockets, a line representing the anterior rim of the acetabular mouth runs medially and distally, diverging from the posterior rim, which runs more vertically. But in the retroverted condition, the anterior rim will be lateral to the similar point for the posterior rim at the most proximal part of the acetabular mouth. As these lines progress distally, the anterior line crosses the posterior one, giving a figure 8, called cross-over sign.[13] **Prominent ishial spine** projecting into the pelvis together with COS further indicates the existence of acetabular retroversion (Fig. 6).[24] Posterior wall of a normal acetabulum descends through the center point of the femoral head or lateral to it. In the retroverted situation, the descent of this line is usually medial to the center of the head indicating positive **posterior wall sign** (Fig. 6).[13]

Signs indicating CAM type FAI

The first parameter used to describe CAM deformity was the **angle alpha** by Nötzli (Fig. 7).[25] At first, 50° was considered

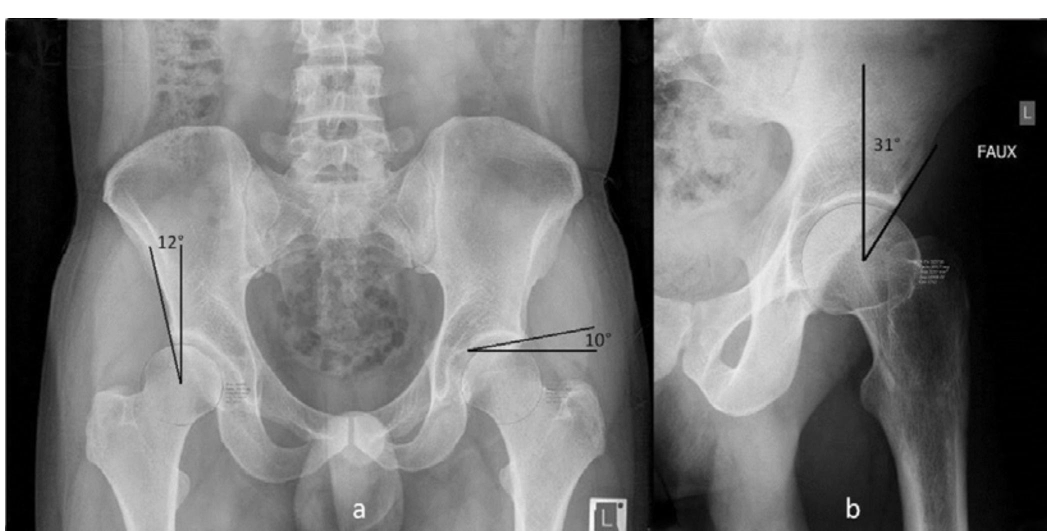
Figure 4: Bilateral acetabular protrusion in a 19-year-old female: the femoral heads are crossing ilioischial lines (gray dotted)

as pathological value,[25] but increasing the alpha angle threshold value from 50° to 60° resulted in a substantial gain in specificity, with a moderate loss in sensitivity.[26] The highest alpha angles are found in the anterosuperior area of the femoral head-neck junction[26-28] and are in correlation with a decreased range of motion and the degree of chondrolabral damage.[29] Although alpha angle was originally a parameter assessed from MRI, it could be measured on any radiographic projection, with Dunn view being most appropriate to show asphericity of the anterosuperior area of the head-neck junction.[30]

Because of the influence of rotation in the hip joint on the size of alpha angle, a new parameter was developed, called **triangular index (TI).**[31] TI is measured on the same projection as alpha angle, but it remains relatively unaltered between 20° of internal rotation and 20° of external rotation, which makes it especially useful in studying historical radiographs.[31]

Anterior offset (AOS) and **anterior offset ratio (AOSR)** are alternative radiographic parameters indicating CAM FAI.[14,32,33] A line is drawn on the lateral radiograph of the hip through the axis of the neck, not necessarily through the center of the femoral head. Another line is drawn parallel to the first one along the anterior cortex of the neck, and the third line is drawn parallel to the first two along the most anterior outer part of the head. AOS is determined as the distance between the second and the third described line.[14,32,33] Then AOSR is calculated dividing AOS with the diameter of the head.[14,33] AOS is considered pathological if less than 8 mm whereas AOSR is considered pathological if less than 0.18.[14,32,33] In femoral varus condition, there is a relati-

Figure 5: Acetabular coverage
a) LCE angle of Wiberg (right hip). One line is drawn from the center of the femoral head to the lateral margin of the acetabular sourcil, the second line is drawn vertical from the center of the femoral head. LCE angle 12° = acetabular under-coverage.
AI (left hip) is defined as an angle between the horizontal line connecting the bases of acetabular teardrops and a line connecting medial and lateral borders of the acetabular sourcil.
b) ACE angle is measured on false profile view between a vertical line through the center of the femoral head and a line connecting the center of the femoral head to the most anterior point of the acetabular sourcil.



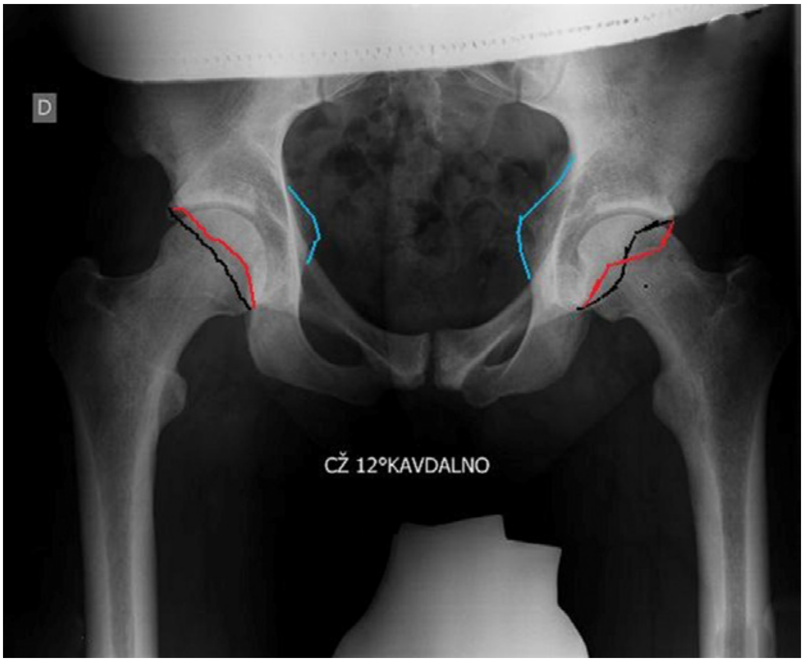
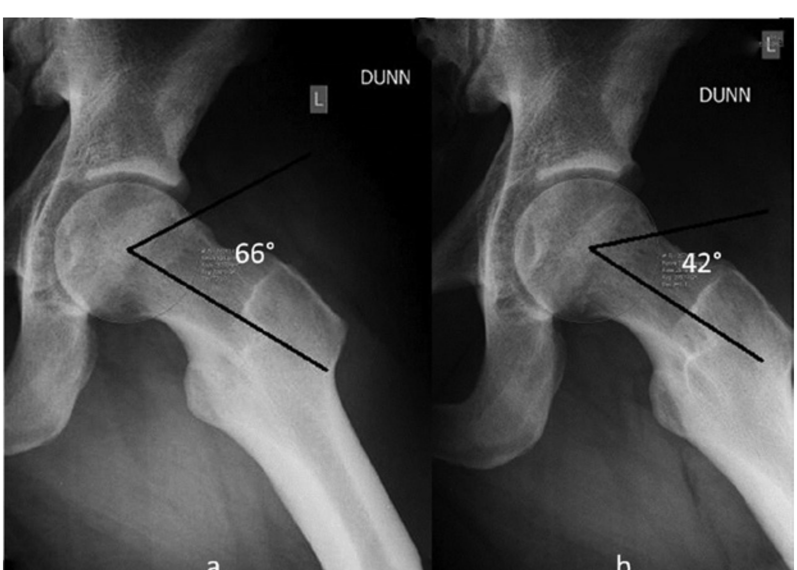


Figure 6: Signs of acetabular retroversion: positive cross-over sign of the left acetabulum (anterior wall – red line crosses posterior wall – black line) and prominent ishial spine (blue line). Note: there is no retroversion of the right acetabulum (anterior wall – red line, passes medially to posterior wall – black line)

Figure 7: Alpha angle is formed between the axis of the femoral neck and a line connecting the center of the femoral head to the point where the contour of the femoral neck first exceeds the radius of the cartilage-covered femoral head. The axis of the femoral neck is defined as a line passing through the head center and the center of the neck at its narrowest point.
a) pathological alpha angle on Dunn view
b) normal alpha angle on Dunn view after arthroscopic osteochondroplasty (the same hip)



ve shortening of the femoral neck. Thus, the prominence of the greater trochanter from a reduced neck-shaft angle can result in extra-articular, lateral impingement of the greater trochanter against the anterior inferior iliac spine and soft tissues. Furthermore, it can amplify intra-articular, lateral impingement of a superolateral CAM and/or rim impingement lesion.[1] It is measured by means of **caput collum diaphyseal angle (CCD).**[34]

Radiographic changes secondary to FAI

Herniation pits are fibrocystic changes, identified on AP radiographs at the site of the hip impingement, most often at the anterosuperior area of the femoral head – neck, surrounded by a narrow margin of sclerotic bone and usually more than 3 mm in diameter. These are nonspecific findings, but should raise suspicion and lead the investigator into searching for the presence of other radiological signs of FAI.[15]

Delamination cysts are subchondral cysts (geodes) seen on radiographs under the lateral edge of the sourcil and are highly suspicious for acetabular cartilage delamination.[35]

Calcification of the anterosuperior labrum is also an indirect sign of chronic irritation of the labrum suggesting secondary degeneration and probable concomitant chondrolabral separation.

Recently described radiographic parameters of FAI

ß angle has been described to indicate possible CAM deformation.[36] It may be obtained from additional radiographs taken with the patient in sitting position. **Anterior rim angle (ARA), anterior wall angle (AWA)** and **anterior margin ratio (AMR)** are new parameters, which have been suggested to provide a more comprehensive description of possible focal anterior acetabular over-coverage due to acetabular retroversion.[37] They can be obtained from AP radiographs and may be of great value in determining whether the rim resection was

Figure 8: Triangular index: radius ($r = 13.20$ mm) of the femoral head and the height ($h = 14.49$ mm) of the head-neck contour are measured. Then a line is drawn perpendicular to r at r½, with r parallel to the longitudinal axis of the femoral neck. Thus, radius R of the femoral head-neck contour can be calculated with the help of Pythagorean law as: $R^2 = (r½)^2 + h^2$. TI is calculated as TI = R-r. When this difference exceeds 2 mm on AP or lateral radiographs at 120 % magnification, then TI is considered positive and bump malformation is present. Calculation: TI = (14.49–13.20 mm) = 1.29 mm (non-pathologic)

adequate. To our knowledge, none of the above mentioned and recently described parameters have been clinically validated nor widely used in orthopedic practice.

In the end, given the secondary derangement that CAM and pincer deformity can cause to the labrum and cartilage, MRI remains the gold standard in the investigation of FAI as it provides further information to the clinician for prognostication and patient counseling.[19] MRI should be made with a high resolution machine, in best case by using gadolinium contrast medium injected into the joint to provide valuable information.[2]

Osteoarthritis: Before planning actions, particularly surgical interventions, in patients with diagnosed FAI, every hip should be checked for signs that predispose hips to OA and of course for the presence of OA itself. It was found that not every hip is equally prone to progress to OA.[38] To find hips that are more likely to progress to OA, medial proximal femoral angle (MPFA) was suggested to be measured.[38] This is the angle subtended by the anatomical axis of the femur and a line connecting the center of the femoral head and the tip of the greater trochanter. A reduction of 1° of MPFA increases the odds of the OA progressing by 20.6 times; similarly, OA is 10.2 times more likely to progress in a hip with a positive PWS.[38]

When OA is found to be present it is graded according to Tönnis as grade 1 to 3.[19] Advanced hip OA is present when joint space width is less than 3 mm superolateral, less than 2 mm apical or less than 2 mm superomedial.[39,40]

Timing the surgical procedure

The combination of clinical and radiological signs as an indication for surgery is still to be determined in future research.[41] History and physical examination contribute considerably to the interpretation of the radiographs and in no case should surgical treatment be based or recommended on radiographic findings alone, which may be prone to subjective interpretation.[21,26] In most cases the indications for surgery include pain, unyielding to conservative treatment, multiple indicative examination findings, positive radiographic findings by use of various modalities (radiography, CT scan, MRI, MR arthrography) and positive diagnostic intra-articular injections.[41,45] Worse prognosis after surgery is expected in cases with advanced articular cartilage degeneration, older age and more severe and continuous preoperative pain.[43] The failure rate of surgery for FAI is 12 % for non-arthritic hips, 33 % for hips with mild joint space narrowing (still > 50 % of the preserved contralateral hip or > 2 mm of joint space measured on AP supine radiograph) and 82 % for hips with advanced OA (< 50 % of preserved contralateral hip or < 2 mm of joint space measured on AP supine radiograph).[43] Unfavorable prognosis is also expected if Tönnis II grade.[19] or more osteorthrtitic changes are observed on radiographs.[43] Joint-preserving surgery should be undertaken with caution in patients with advanced secondary OA since they lack in improvement of Harris hip score at any time postoperatively.[3,42] Based on this, FAI correction in cases with milder degree of OA might be considered for younger patients with primarily intermitent, mechanical pain of shorter duration. Patients with advanced OA are better served with continued conservative care and later hip artroplasty.[43]

Conclusion

FAI is still a new concept of hip pathology and as such, it still lacks a gold standard evaluation method that would be sensitive and specific enough to make a reliable diagnosis. Deceision about treatment should be based on a combination of data collected from patient´s history, clinical examination and diagnostic imaging methods. If plain radiography is used to determine bony abnormalities, MR artrography still remains the gold standard in the evaluation of chondral and soft tissue damage. Either way, this review article should serve radiologists and orthopedic surgeons in diagnosing the FAI condition and also in assessing treatment outcomes.

Literature

1. Ganz R, Parvizi J, Beck M, Leunig M, Nötzli H, Siebenrock KA. Femoroacetabular impingement: a cause of osteoarthritis of the hip. Clin Orthop 2003; 417: 112–20.
2. Leunig M, Beaulé PE, Ganz R. The concept of femoroacetabular impingement: current status and future perspectives. Clin Orthop Relat Res 2009; 467: 616–22.
3. Ganz R, Leunig M, Leunig-Ganz K, Harris WH. The etiology of osteoarthritis of the hip: an integrated mechanical concept. Clin Orthop Relat Res 2008; 466: 264–72.
4. Kaplan KM, Shah MR, Youm T. Femoroacetabular impingement- diagnosis and treatment. Bull NYU Hosp Jt Dis 2010; 68: 70–5.
5. Bedi A, Dolan M, Leunig M, Kelly BT. Static and dynamic mechanical causes of hip pain. Arthroscopy 2011; 27: 235–51.
6. Beck M, Kalhor M, Leunig M, Ganz R. Hip morphology influences the pattern of damage to the acetabular cartilage: femoroacetabular impingement as a cause of early osteoarthritis. J Bone Joint Surg Br 2005; 87-B: 1012–8
7. Ochoa LM, Dawson L, Patzkowski JC, Hsu JR. Radiographic prevalence of femoroacetabular impingement in a young population with hip complaints is high. Clin Orthop Relat Res 2010; 468: 2710–4.
8. Sankar WN, Neubuerger CO, Moseley CF. Femoral head sphericity in untreated developmental dislocation of the hip. J Pediatr Orthop 2010; 30: 558–61.
9. Jung KA, Restrepo C, Hellman M, AbdelSalam H, Morrison W, Parvizi J. The prevalence of cam-type femoroacetabular deformity in asymptomatic adults. J Bone Joint Surg Br 2011; 93: 1303–7.
10. Lung R, O'Brien J, Grebenyuk J, Forster BB, De Vera M, Kopec J, et al. The prevalence of radiographic femoroacetabular impingement in younger individuals undergoing total hip replacement for osteoarthritis. Clin Rheumatol 2012; 31: 1239–42.
11. Wenger DE, Kendell KR, Miner MR, Trousdale RT. Acetabular labral tears rarely occur in the absence of bony abnormalities. Clin Orthop Relat Res 2004; 426: 145–150.
12. Philippon MJ, Maxwell RB, Johnston TL, Schenker M, Briggs KK. Clinical presentation of femoroacetabular impingement. Knee Surg Sports Traumatol Arthrosc 2007; 15: 1041–7.
13. Reynolds D, Lucas J, Klaue K. Retroversion of the acetabulum. A cause of hip pain. J Bone Joint Surg Br 1999; 81: 281–8.
14. Clohisy JC, Carlisle JC, Beaulé PE, Kim YJ, Trousdale RT, Sierra RJ, et al. A systematic approach to the plain radiographic evaluation of the young adult hip. J Bone Joint Surg Am 2008; 90 Suppl 4: 47–66.
15. Laborie LB, Lehmann TG, Engesæter IØ, Eastwood DM, Engesæter LB, Rosendahl K. Prevalence of radiographic findings thought to be associated with femoroacetabular impingement in a population-based cohort of 2081 healthy young adults. Radiology 2011; 260: 494–502.
16. Meyer DC, Beck M, Ellis T, Ganz R, Leunig M. Comparison of six radiographic projections to assess femoral head/neck asphericity. Clin Orthop Relat Res 2006; 445: 181–5.
17. Lequesne MG, Laredo JD. The faux profil (oblique view) of the hip in the standing position. Contribution to the evaluation of osteoarthritis of the adult hip. Ann Rheum Dis 1998; 57: 676–81.
18. Jamali AA, Mladenov K, Meyer DC, Martinez A, Beck M, Ganz R, Leunig M. Anteroposterior pelvic radiographs to assess acetabular retroversion: high validity of the »cross-over-sign«. J Orthop Res 2007; 25: 758–65.
19. Tönnis D. Normal values of the hip joint for the evaluation of X-rays in children and adults. Clin Orthop Relat Res 1976; 119: 39–47.
20. Barton C, Salineros MJ, Rakhra KS, Beaulé PE. Validity of the alpha angle measurement on plain radiographs in the evaluation of cam-type femoroacetabular impingement. Clin Orthop Relat Res 2011; 469: 464–9
21. Clohisy JC, Carlisle JC, Trousdale R, Kim YJ, Beaule PE, Morgan P, et al. Radiographic evaluation of the hip has limited reliability. Clin Orthop Relat Res 2009; 467: 666–75.
22. Ganz R, Parvizi J, Beck M, Leunig M, Nötzli H, Siebenrock KA. Femoroacetabular impingement: a cause for osteoarthritis of the hip. Clin Orthop Relat Res 2003; 417: 112–20.
23. Kutty S, Schneider P, Faris P, Kiefer G, Frizzell B, Park R, et al. Reliability and predictability of the centre-edge angle in the assessment of pincer femoroacetabular impingement. Int Orthop 2012; 36: 505–10.
24. Kalberer F, Sierra RJ, Madan SS, Ganz R, Leunig M. Ischial spine projection into the pelvis – a new sign for acetabular retroversion. Clin Orthop Rel Res 2008; 466: 677–83.

25. Nötzli HP, Wyss TF, Stoecklin CH, Schmid MR, Treiber K, Hodler J. The contour of the femoral head-neck junction as a predictor for the risk of anterior impingement. J Bone Joint Surg Br 2002; 84: 556–60.
26. Sutter R, Dietrich TJ, Zingg PO, Pfirrmann CW. How useful is the alpha angle for discriminating between symptomatic patients with cam-type femoroacetabular impingement and asymptomatic volunteers? Radiology 2012; 264: 514–21.
27. Dudda M, Albers C, Mamisch TC, Werlen S, Beck M. Do normal radiographs exclude asphericity of the femoral head-neck junction? Clin Orthop Relat Res 2009 ; 467: 651–9.
28. Hack K, Di Primio G, Rakhra K, Beaulé PE. Prevalence of cam-type femoroacetabular impingement morphology in asymptomatic volunteers. J Bone Joint Surg Am 2010 ; 92: 2436–44.
29. Johnston TL, Schenker ML, Briggs KK, Philippon MJ. Relationship between offset angle alpha and hip chondral injury in femoroacetabular impingement. Arthroscopy 2008; 24: 669–75.
30. Meyer DC, Beck M, Ellis T, Ganz R, Leunig M. Comparison of six radiographic projections to assess femoral head/neck asphericity. Clin Orthop Relat Res 2006; 445: 181–5.
31. Gosvig KK, Jacobsen S, Palm H, Sonne-Holm S, Magnusson E. A new radiological index for assessing asphericity of the femoral head in cam impingement. J Bone Joint Surg Br 2007; 89: 1309–16.
32. Eijer H, Leunig M, Mohamed MN, Ganz R. Cross--table lateral radiographs for screening of anterior femoral head-neck offset in patients with femoroacetabular impingement. Hip international 2001; 11: 37–41.
33. Tannast M, Siebenrock KA, Anderson SE. Femoroacetabular impingement: radiographic diagnosis–what the radiologist should know. Am J Roentgenol 2007 ; 188: 1540–52.
34. Putz R, Pabst R. Sobotta – Atlas of human anatomy, Vol. 2 Thorax, Abdomen, Pelvis, Lower Limb. 13th Engl. Ed. 2001: 277.
35. Gdalevitch M, Smith K, TanzerM. Delamination cysts: a predictor factor of acetabular cartilage delamination in hips with labral tear. Clin Orthop Rel Res 2009; 467: 985–91.
36. Brunner A, Hamers AT, Fitze M, Herzog RF. The plain beta-angle measured on radiographs in the assessment of femoroacetabular impingement. J Bone Joint Surg Br 2010 Sep; 92: 1203–8.
37. Gross CE, Salata MJ, Manno K, Yelavarthi V, Barker JU, Williams J, et al. New radiographic parameters to describe anterior acetabular rim trimming during hip arthroscopy. Arthroscopy 2012; 28: 1404–9.
38. Bardakos NV, Villar RN. Predictors of progression of osteoarthritis in femoroacetabular impingement: a radiological study with a minimum of ten years follow-up. J Bone Joint Surg Br 2009; 91: 162–9.
39. Lequesne M, Malghem J, Dion E. The normal hip joint space: variations in width, shape, and architecture on 223 pelvic radiographs. Ann Rheum Dis 2004 ; 63: 1145–51.
40. Gosvig KK, Jacobsen S, Sonne-Holm S, Palm H, Troelsen A. Prevalence of malformations of the hip joint and their relationship to sex, groin pain, and risk of osteoarthritis: a population-based survey. J Bone Joint Surg Am 2010 May; 92: 1162–9.
41. Ayeni OR, Wong I, Chien T, Musahl V, Kelly BT, Bhandari M. Surgical indications for arthroscopic management of femoroacetabular impingement. Arthroscopy 2012; 28: 1170–9.
42. Clohisy JC, St John LC, Schutz AL. Surgical treatment of femoroacetabular impingement: a systematic review of the literature. Clin Orthop Relat Res 2010; 468: 555–64.
43. Larson CM, Giveans MR, Taylor M. Does arthroscopic FAI correction improve function with radiographic arthritis? Clin Orthop Relat Res 2011; 469: 1667–76.
44. Polkowski GG, Nunley RM, Ruh EL, Williams BM, Barrack RL. Does standing affect acetabular component inclination and version after THA? Clin Orthop Relat Res 2012; 470: 2988–94
45. Ayeni OR, Naudie D, Crouch S, Adili A, Pindiprolu B, Chien T et al. Surgical Indications for treatment for femoroacetabular impingement with surgical hip dislocation. Knee Surg Sports Traumatol Arthrosc 2013; 21: 1676–1683