

Update on pediatric hip imaging

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Abstract

Hip disorders are common in children. Prompt diagnosis and treatment are important because of the potential complications. Symptoms are frequently nonspecific (hip pain, limp, irritability), and clinical examination can be difficult and unreliable, especially in smaller children. Therefore, imaging can be valuable. Imaging modalities available for evaluation of the hip include radiography (RX), ultrasound (US), Computed Tomography (CT), Magnetic Resonance Imaging (MRI) and bone scintigraphy.

Radiography and ultrasound remain the initial imaging modalities of choice. Increasingly, MRI is obtained for assessing the pediatric hip, although the long imaging time and need for sedation may limit its use in daily clinical practice. Because of the exposure to ionizing radiation, the use of CT and bone scintigraphy in children is limited to selected cases.

Pediatric hip pathology varies depending on patient age. This article provides an overview of the common hip pathologies in children, including congenital and developmental pathologies, trauma, infectious processes, inflammatory disease and neoplasm. The age of the child, history and clinical examination are essential to narrow down the differential diagnosis and subsequent selection of the appropriate imaging modality.

Keywords: Hip, pediatric, imaging, pain

Introduction

Hip disorders are highly prevalent in children. Accurate diagnosis and treatment are important because of the potential complications, which may lead to long term morbidity such as degenerative joint disease in adult life. Diseases of the hip in children can cause nonspecific symptoms such as groin pain, limping, or pain radiating into the thigh and/or knee. Clinical examination can be difficult in children, especially in smaller children, and may be unreliable. The age of the child and the duration of the symptoms are important to make a differential diagnosis. In children with symptoms less than 5 days, without fever or elevated inflammatory markers, a wait-and-see policy is recommended. Otherwise, as the diagnosis is often not clear, imaging can be of value. Imaging findings should be interpreted together with clinical history, physical examination and laboratory findings to prompt an accurate diagnosis.

The hip of the child is not a "miniature adult hip". In hips that are not yet mature, the structures which later will result in the neck, head and greater trochanter, still partially exist of cartilage that progressively ossifies. By the age of 12, the greater trochanter and the femoral head are completely ossified. The growth plate of the femoral head is common to the greater trochanter and remains active, only closing after puberty. The blood perfusion of the femoral head in children depends solely on an arterial anastomotic network in the posterior region of the femoral neck. There is no flow to the femoral head due to the presence of a growth plate. There is growth in the transition area from the head to the femoral neck (growth cartilage), responsible for normal growth of the femoral head and neck lengthening, growth cartilage in the greater trochanter, and the triradiate growth cartilage of the acetabulum that grows in depth and width so as to maintain its sphericity concave and lodge the femoral head. Lesion or trauma of this regions may predispose to severe anomalies in the development of the femoral head or deformities of the acetabulum.

In this article we provide an overview of the common hip pathologies in children, including congenital and developmental pathologies, trauma, infectious processes, inflammatory causes and neoplasia (benign or malign) (Table 1).

Imaging modalities

The imaging modalities available for evaluation of the hip are conventional radiography (CR), ultrasound (US), Computed Tomography (CT), Magnetic Resonance Imaging (MRI) and bone scintigraphy.

Conventional Radiography

Conventional Radiography (CR) remains the first choice imaging modality. Because the appearance of a child's hips varies with age, consideration should be given to obtain anteroposterior and frog-leg view (hips externally rotated and flexed) images of the entire pelvis rather than views of a single hip [Gough-Palmer]. This allows easy comparison with a 'normal' hip. Gonad shielding during girls pelvic x-ray is no longer indicated. However in boys it is controversial and depends on the skill and effort of radiographers [Karami, Frantzen].

Ultrasound

Ultrasonography (US) is also imaging modality of choice, especially for identifying hip joint effusion, for guiding fluid aspiration and for assessment of the unossified structures. US has low cost, does not involve ionizing radiation, is readily available, and allows dynamic evaluation. Disadvantage is its highly operator dependence.

Computed tomography

Computed tomography (CT) has limited indications for the assessment of the pediatric hip because of the exposure to ionizing radiation. CT may be indicated for preoperative assessment of developmental dysplasia of the hip (DDH), Legg-Calvé-Perthes or slipped capital femoral epiphysis (SCFE), evaluation of tumor matrix or cortical invasion, and guidance for biopsy or ablation.

Magnetic Resonance Imaging

Magnetic Resonance Imaging (MRI) is increasingly obtained. MRI is excellent for detecting early disease and can depict not only bone marrow edema (BME), but also soft tissue inflammation and joint effusion/bursitis, as it had very good soft tissue contrast resolution. The cartilage can be assessed as well. Disadvantages are the relatively higher cost, the accessibility and the need for sedation in younger children.

Bone scintigraphy

Bone scintigraphy can evaluate a large area, but is often non-specific and has exposure to ionizing radiation. It may be indicated for evaluation of osteomyelitis, Legg-Calvé-Perthes, osteoid osteoma, stress fractures or metastatic disease when MRI is contra-indicated.

Table 1: Common disease of the pediatric hip

Congenital/developmental	Developmental dysplasia of the hip Legg-calvé-Perthes disease Coxa vara Neuromuscular hip dysplasia
Traumatic	Slipped capital femoral epiphysis (stress) Fracture Apophyseal injury Stress reactions at the ischiopubic synchondrosis
Infectious	Septic Arthritis Osteomyelitis/CRMO
Inflammatory	Transient Synovitis Juvenile Idiopathic Arthritis

Neoplastic

Benign
Malignant

A. Congenital/developmental

A.1. Developmental dysplasia of the hip

Developmental dysplasia of the hip (DDH) is a relatively common disorder that involves abnormal development of the femoral head and acetabulum. It is more common in girls, in Caucasians, after breech deliveries and with a positive family history. The incidence ranges from 1.5 to 20 per 1000 births. It consists of a spectrum of abnormalities from birth to early infancy ranging from a stable hip with mild dysplasia to complete hip dislocation [bracken]. Early detection is mandatory to prevent labral tears and cartilage lesions at young age and development of premature degenerative hip disease. Different screening strategies have been described, including clinical examination alone, and selective - in patients with associated risk factors or abnormal clinical examinations - or universal ultrasound screening [ortiz]. Physical examination classically involves the Barlow and Ortolani maneuvers [giannakopoulou]. Ultrasonography (US) is still the imaging modality of choice for infants below the age of four-five months [bracken1-2]. In children older than five-six months, conventional radiography (CR) is indicated as progressing ossification of the femoral head prevents adequate evaluation with ultrasound [Gill, starr]. The American College of Radiology recommends that for a standard ultrasound examination two orthogonal planes should be performed: a coronal view in the standard plane at rest and a transverse view of the flexed hip with and without stress, and Graf α and β angles are measured [American institute]. The modified Graf grading classification (4 types – Table 2) is based on the α angle and degree of acetabular roof coverage [graf, starr]. To determine the position and stability of the femoral head, dynamic stress imaging could be performed, similar to the clinical Barlow examination. When monitoring is performed in the Pavlik harness, the infant is left in the harness and only static images are obtained [el ferzli]. Color Doppler imaging may be used to evaluate perfusion to the proximal femoral epiphysis, although there is little published on this topic [Barnewallt].

Table 2: Modified Graf Classification Scale [graf]

Graf Type	Description	α and β Angle
Type 1	Normal, mature hip with more than 50% acetabular roof coverage	α angle $\geq 60^\circ$, β angle $< 55^\circ$
Type 2a	Physiologic immaturity at younger than 3 mo	α angle 50–59°
Type 2b	Immature at age 3 mo or older	α angle 50–59°
Type 2c	Extremely deficient bony acetabulum; femoral head is concentric but not stable	α angle 43–49°, β angle $< 77^\circ$
Type 2d	Femoral head is grossly subluxed and labrum is everted, increasing β angle	α angle difficult to measure but is approximately 43–49°; β angle $>77^\circ$
Type 3	Dislocated femoral head with shallow acetabulum	α angle $< 43^\circ$
Type 4	Dislocated femoral head with severely shallow,	

For radiographic evaluation, an anteroposterior radiograph of the hips in neutral position is obtained. Familiarity with the normal growth and development is essential. A frog-leg lateral view is sometimes used to determine whether a subluxed hip reduces. Several lines and angles are used to diagnose and further characterize DDH: the Hilgenreiner, Perkins and Shenton line, and the acetabular and center-edge angle. In DDH, there is delayed ossification of the femoral head and an abnormally shallow acetabulum, predisposing to subluxation and dislocation [Donnelly, beltran]. Additionally, late complications, such as osteoarthritis and avascular necrosis, can be assessed too [starr 2, Donnelly, beltren].

CT with three-dimensional images may be used for preoperative planning or postoperative evaluation of reduction when MRI is contra-indicated or not available [murray]; reduced-dose CT-protocols should be used.

Both imaging modalities have excellent sensitivity and specificity for the evaluation of hip reduction, but CT has the disadvantage of radiation exposure, however, it has shorter imaging time and therefore needs less sedation [chin]. For the MRI protocol, axial and coronal Short-tau Inversion Recovery (STIR) or T2-weighted sequences with or without corresponding T1-weighted sequences can be obtained [starr, McNally], some studies even suggest that an axial STIR sequence alone may be sufficient [conroy, laor]. However, if there is concern for avascular necrosis of the femoral head, gadolinium – sequences are used to evaluate for femoral head enhancement abnormalities [Jaramillo, Tiderius]. MRI depicts the unossified acetabular epiphysis in the ilium and underlying labrum, therefore showing greater and more accurate acetabular coverage than seen on radiography alone [Kim]. Recent orthopedic articles have described the utility of both bony and cartilaginous acetabular indexes on MRI in the evaluation of DDH [Li, pirpiris]. After successful reduction, the femoral head should be concentrically located in the acetabulum [ray].

Jacob: 3D US?

A.2. Legg-Calvé-Perthes disease

Perthes or Legg-Calve-Perthes (LCP) disease is an idiopathic avascular necrosis (AN) of the proximal femoral epiphysis in children [gill]. It occurs more commonly in boys, typically between the age of 4 – 8 years, but may range from 2 years of age until adolescence. Bilateral involvement may occur in 10-20%, but usually it is seen unilaterally [gill]. The pathogenesis of Perthes disease is not completely understood and possibly related to a transient disturbance of the blood supply via the lateral epiphyseal vessels, resulting in ischemia and infarction, or trauma [Gill,de smet]. Although approximately 60-70% of children with LCP heal spontaneously without functional impairment, late onset in children older than 8 year, and nonspherical femoral head at skeletal maturity are associated with a higher incidence of premature osteoarthritis before the fifth decade of life. Children may present with limping and hip pain, aggravating by exercise and often irradiating to the knee, or may refuse to walk (younger children) [de smet, kocher].

Radiography is the imaging modality of choice, and may show fragmentation and flattening of the sclerotic capital epiphysis, features best appreciated on the frog-leg lateral view. During the course of the disease, metaphyseal widening and cysts may occur as well as femoral head enlargement.

Radiographic changes vary based on the stage of the disease and are summarized in Figure 1 [Vanhoenacker,Gill]. Multiple radiographic classification systems are described, of which the most common are the Catterall classification and the Herring classification, of which the latter is most accurate in predicting long-term prognosis (figure 2) [herring, vanhoenacker]. US is unlikely to pick up LCP, although a joint effusion can be seen.

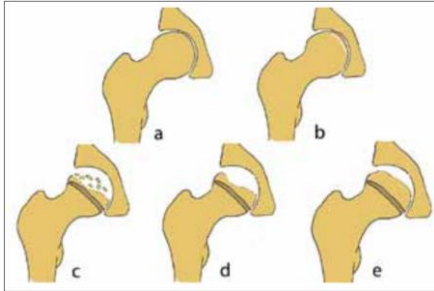


Figure 1: Schematic drawing of the radiographic changes based on the stage of the disease [gill, vanhoenacker].

(a) Stage I, no visible radiographic abnormalities. (b) Stage II, early: subchondral crescent line. (c) Stage II, late: collapse, decreased height and fragmentation of the epiphysis. (d) Stage III, regeneration phase with beginning reossification and remodeling. (e) Stage IV, complete healing.

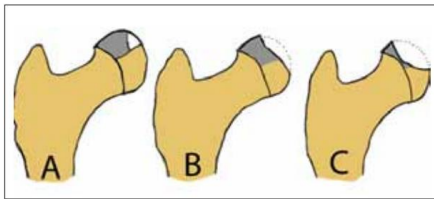


Figure 2: Herring classification, based on the degree of collapse of the lateral epiphyseal pillar [herring, vanhoenacker].

Stage A: Normal contour of the lateral pillar, indicating a good prognosis. Stage B: Decrease of height of the lateral pillar of less than 50%. The prognosis is usually good in patient of less than 6 years old, the prognosis is variable in the older age group. Stage C: Decrease of height of the lateral pillar of more than 50%, indicating a bad prognosis.

If the X-ray is normal and persistent symptoms trigger further imaging, MRI can be performed. MRI may show proximal femoral abnormalities before radiography, and can also assess revascularization, healing and complications [Dillman]. On T1-weighted images, the proximal femoral ossification center will show decreased signal intensity. The signal on T2-weighted images is variable. Areas of high signal correspond to bone marrow edema, whereas areas of low signal on T1 and T2 sequences suggest advanced necrosis. Curvilinear subchondral T2 hyperintensity corresponds to subchondral fractures (“crescent sign”). A mild joint effusion and synovitis are often present. The overlying articular cartilage may appear thickened. It is important to obtain sagittal images as well, as the disease process often begins anteriorly, which may be missed on coronal and axial images [gill]. Hypoperfusion, seen as absent or asymmetrically decreased enhancement may be one of the earliest indicators [gill]. On follow-up MRI, reappearance of enhancement of the femoral head epiphysis can be seen, due to revascularization. Early reperfusion of the lateral pillar is associated with a better prognosis [gill]. In the reparative phase, epiphyseal fragments

may demonstrate different signal characteristics, owing to different stages of healing. In the late stage, femoral head height is restored as these fragments coalesce [gill]. After approximately 6 years, signal intensity returns to normal [cheng].

If MRI is contraindicated or not available, bone scintigraphy can be helpful, as scintigraphic changes precede radiographic findings. A focal area of decreased uptake is seen [hubbard]. The role of CT is limited.

A.3. Coxa vara

In coxa vara the angle between the femoral neck and shaft is decreased compared with age-matched normal hips, usually to less than 120° (Figure 3). The normal femoral neck-shaft angle ranges between 120° - 135° , and decreases from 150° in infants to 120° in adults [hubbard]. Coxa vara deformity results from a failure of medial growth of the physal plate, and can be unilateral or bilateral. It may be acquired (secondary to prior infection, trauma or avascular necrosis) or true (secondary to congenital abnormalities or developmental). Coxa vara can also be seen in association with syndromes such as osteogenesis imperfecta or fibrous dysplasia. Developmental coxa vara usually presents around the age of 2 with an abnormal gait or painless limp. This form may be bilateral in as many as one half of cases, and is thought to be secondary to abnormal cartilage proliferation in the medial physis that causes increased lateral growth, resulting in a more vertical than usual orientation of the physis [bos,serafin, zucker]. Treatment is surgical, although it frequently recurs after surgery as the growth disturbance progresses until complete skeletal maturation [desai, günter].

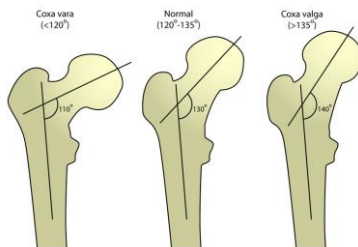


Figure 3: Femoral neck-shaft angle in normal hip, coxa valga and coxa vara.

Conventional radiography and MRI are the imaging modalities of choice. On CR, the femoral neck-shaft angle can be measured. Radiographic changes include a widened, irregular, vertically oriented physis. Due to abnormal stress in the physis, multiple small slips occur and small triangular corner fractures develop along the medial aspect of the physis, seen as metaphyseal bony fragments inferomedial to the physis. MRI can be useful in preoperative planning, and may show physal widening or bone marrow edema, and can assess potential impingement [zucker].

A.4. Neuromuscular hip dysplasia/ coxa valga

Children with either increased or decreased muscle tone are at risk for secondary hip dysplasia. Children who do not walk before the age of five have a 58% chance of hip dislocations, which are bilateral in 44% of the cases [scrutton1]. Hip dysplasia is also a common problem in children with cerebral palsy. The hip

is normal at birth, but the lack of physiologic stress results in coxa valga and increased anteversion of the femur. Secondly, posterolateral subluxation may occur due to muscle imbalance resulting in flexion and adduction contractures [chang]. Symptoms include sitting imbalance, walking difficulty, decubitus ulcers from abnormal positioning and pain [khalife]. The acetabulum becomes globally dysplastic, resulting in posterior deficiency. Hip dislocation can be prevented through radiographic screening and early treatment.

Conventional radiography is the imaging modality of choice, showing the valgus deformity, an abnormal shape and location of the femoral head and a dysplastic acetabulum [haglund]. Also, the acetabular index can be measured, as well as the migration percentage (MP), describing the degree of femoral head containment within the acetabulum, or the proportion of the ossified femoral head that lies lateral to the Perkins line [REIMERS]. In normal hips, up to 25% of the femoral head can be uncovered. Generally, in children with a MP >33%, a varus derotational osteotomy of the femur is indicated [terjesen, scrutton2]. Postoperatively, radiographic evaluation for signs of redislocation or avascular necrosis is indicated [khalife]. It is important to image the patient in the most neutral position possible, as femoral adduction/abduction gives a false respectively high/low MP.

CT and MRI are helpful preoperatively to evaluate the orientation and shape of the acetabulum, and for assessing the femoral anteversion and tibial torsion.

B. Traumatic

B.1. Slipped capital femoral epiphysis

Slipped capital femoral epiphysis (SCFE) is one of the most common hip disorders of adolescence, characterized by an idiopathic Salter Harris type 1 fracture through the proximal femoral physis, resulting in posteromedial displacement of the capital femoral epiphysis. It typically occurs in adolescents between the age of 11 – 15 years, more commonly in boys than in girls, and can be acute (symptoms <3 weeks) or chronic. Bilateral involvement may occur in 20-30 % of cases [gholve, zucker]. It is attributed to a variety of conditions, including obesity, metabolic disorders, endocrine disorders and radiation therapy. Estrogen seems to play a protective factor reinforcing the growth plate, which may explain why males are more affected than females [gholve]. Children present with chronic hip, groin or referred knee pain or may limp. Immediate treatment of SCFE is mandatory, consisting of non-weight-bearing therapy and single-screw fixation. Delayed diagnosis and therapy can lead to avascular necrosis (AN), gait abnormalities and premature osteoarthritis, femoroacetabular impingement and leg length discrepancy [Gholve,Tins 1]. AN occurs in 20-45% of cases [lubicky].

Conventional radiography remain the prime method of diagnosing SCFE. Views of both hips should be obtained, because of the high incidence of bilateral disease. Antero-posterior (AP) as well as frog-leg views are required, as the slip may only be evident on the frog-leg lateral view. Typical findings are widening and irregularity of the physis, but this can easily be overlooked on the AP view. The frog-leg view shows the posteromedial slippage of the femoral epiphysis. Klein's line should be drawn along the lateral femoral neck margin on an AP view, and along the superior margin on the frog-leg view. The line should intersect the lateral aspect of the femoral head in normal subjects, as in SCFE, this line fails to intersect the lateral aspect of the femoral head ("Trethowan's sign"). An increased density in the proximal metaphysis can be seen as well ("metaphyseal blanch sign") [Vanhoenacker book].

MRI can play a role in early diagnosis of clinically suspected cases with normal radiographic findings (“preslip SCFE”). In these cases, physeal widening can be seen, BME in the epiphysis or proximal metaphysis, and joint fluid. BME adjacent to the growth plate can be considered as an alarming sign [Tins2]. MRI is also the best imaging modality for detecting complications. MRI allows to examine the contralateral hip as well.

CT is rarely needed for diagnosis, but may be used preoperatively to measure the degree of femoral epiphyseal tilt and the precise relationship of femoral head to the metaphysis in three planes.

B.2. (Stress) fracture

Acetabular or pelvic ring fractures are less common in children than in adolescents or adults because of the greater elasticity of the pediatric pelvis, particularly if the triradiate cartilage is not yet fully ossified [Johnson, boutry]. Femoral neck fractures are also uncommon in children. These fractures result usually from high energy trauma, but pathological fractures resulting from underlying metabolic disease (osteogenesis imperfecta, osteopetrosis) or focal bony lesions/tumors (e.g. bone cysts) may occur [watts, torode]. Acetabular fractures are often associated with traumatic posterior hip dislocations [quick]. Watts proposed a classification system with recommendations for management of acetabular fractures in children (Table) [watts]. Torode and Zieg classified pediatric pelvic fractures in 4 groups, of which the first three groups are stable with good prognosis, and the fourth type is unstable (figure) [torode]. Pediatric femoral neck fractures are classified by Delbet into 4 groups, of which the first three groups have high risk for AVN, the fourth group has no increased risk for AVN (figure) [quick]. One should be aware of other more rare complications such as non-union, premature fusion of the growth plate, femoral head deformity, arthritic changes and leg length discrepancy [quick, vanhoenacker book].

CT is the preferred method for precise evaluation of the lesion extension and to identify unstable fractures, and also to evaluate associated trauma [quick, vanhoenacker]. For low energy trauma or femoral neck fractures, conventional radiography is usually sufficient [bali]. MRI is indicated in case of suspicion of labral damage or osteochondral fragment [watts, vanhoenacker].

Watts type	Lesion extent	Treatment
A	Small posterior wall fracture fragments due to hip dislocation	Conservative; MRI in case of suspicion of labral damage or osteochondral fragment
B	Undisplaced linear fracture and associated pelvic fractures	Conservative; MRI in case of suspicion of labral damage or osteochondral fragment
C	Linear fracture with unstable hip	Open reduction and internal fixation
D	Central fracture dislocation of the hip	No consensus because high risk AVN

Table : Watts classification system and recommendations for acetabular fractures [watts, vanhoenacker book].

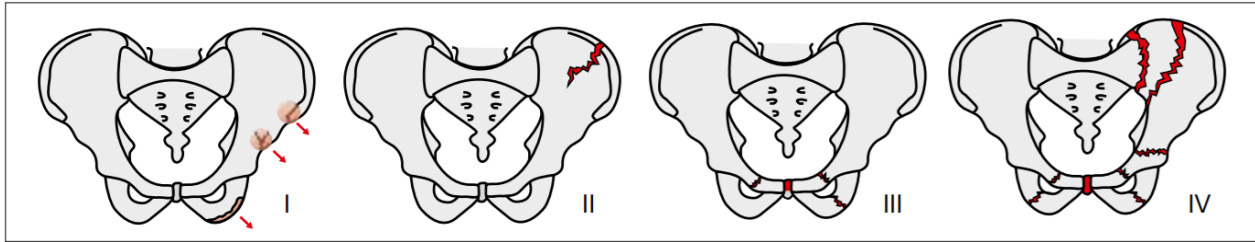


Figure : Torode-Zieg classification of pediatric pelvic fractures [torode]. Groups I-III are stable with good prognosis, type IV is unstable.

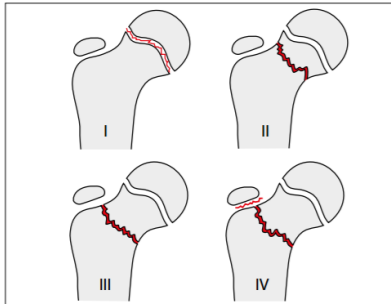


Figure : Delbet classification of pediatric femoral neck fractures [boutry, vanhoenacker]. Groups I-III have high risk for AVN, group IV has no increased risk for AVN.

Stress fractures of the pelvis are caused by abnormal stress on otherwise normal bone. They are relatively uncommon in children and adolescents, and occur mainly in high-level athletes training with repetitive loading activities [karantanas]. Radiographic findings are initially normal in most cases, and can detect typical findings such as periosteal reaction, endosteal cortical thickening and a lucent cortical fracture line by 2-14 weeks [Behrens, Campbell]. MRI and bone scintigraphy are approximately equally sensitive for early detection, but MRI is more specific and is therefore the preferred imaging method [Campbell, arendt]. MRI may show the fracture line, but in some cases only periosteal and bone marrow edema are seen, this is more appropriately called a stress reaction.

Finally, one must always keep in mind the possibility of non-accidental trauma, typically metaphyseal 'corner' lesions or fractures in a child not of walking age may be seen.

B.3. Apophyseal injury

Apophyseal avulsion injuries are Salter Harris type 1 fractures, unique to the growing skeleton. They are a frequent cause of hip pain in adolescents, boys more than girls, particularly those involved in sports. In the immature skeleton, the tendons are generally stronger than the apophyses, and forceful or repetitive traction from the attached muscles can result in an apophyseal avulsion fracture [rossi]. Avulsion fractures of the anterior superior iliac spine (ASIS) and anterior inferior iliac spine mostly occur in soccer players, injuries to the ischial tuberosity (IT) in gymnasts [rossi, vandervliet]. Other apophyses involved are the iliac crest, and the greater and lesser trochanters [kovacevic]. Clinically, sudden pain, exacerbated by activity, followed by restricted motion and weakness may occur [rossi]. Apophyseal

injuries are usually treated conservatively with rest. In case of avulsion fractures with displacement of more than 2cm, surgical fixation may be required [vandervliet].

Conventional radiography is usually diagnostic. Radiographs demonstrate displacement of the apophysis from its expected position or bone resorption in the early phase, followed by callus formation and bony reaction. Comparison with the contralateral side may help to distinguish a true avulsion fracture from a normal unfused apophysis. In case of suspected or subtle avulsion with negative radiographs, or in cases where the apophysis has not yet ossified, MRI is useful [stevens, vandervliet, mckinny]. MRI may show high T2 signal in the disrupted physis, as well as in the adjacent bone and soft tissues. T2-hyperintensity, periosteal stripping at the insertion of the tendons and even tendon tears can be seen as well [Meyers]. In the healing phase, fibrous healing may be seen as a focal hypointense bridging of the apophyseal growth plate, distinguishing it from a true non-union, where a persistent high signal intensity can be seen on fat-suppressed (FS) T2-weighted or STIR images between the displaced apophyseal fragment and the underlying bone [vandervliet]. However, comparison with the opposite side is useful as some degree of high T2 signal is expected in the actively growing apophysis. Excessive callus formation may cause impingement, in which case additional CT may be needed for precise evaluation of bony tunnel narrowing if surgical resection is considered [stevens, vanevenant].

In case of chronic repetitive microtrauma, no or little displacement of the physis may occur, and the physis appears widened and irregular on CR. MRI will show marked edema and enhancement in the physis, adjacent muscles and bone marrow, consistent with apophysitis. This is important to recognize, as it can be mistaken for malignancy [laor].

B.4. Stress reactions at the ischiopubic synchondrosis

The ischiopubic synchondrosis (IPS) is a cartilaginous joint that typically closes before or during early adult life. The ossification of the cartilage between the ischium and the pubis is highly variable, and IPS enlargement may be an incidental radiological finding [karantanas, oliveira]. When seen bilaterally and symmetrically, it causes usually no diagnostic problems. In case of asymmetrical closure of the synchondrosis, particularly in sportive children, it may cause confusion with a bone tumor or osteomyelitis. Ischiopubic synchondrosis asymmetry is much more common on the side of the weight-bearing non-dominant foot, with the differences in ossification thought to result from asymmetric mechanical forces [Herneth]. Clinically, there may be groin pain and restriction of movement. Treatment is conservative.

On conventional radiography, a tumour-like radiolucent area at the fusion zone with surrounding sclerosis may be seen. MRI findings are nonspecific and may be misleading, showing enlargement of the involved IPS, edema in the bone and adjacent soft tissues, and enhancement adjacent to the synchondrosis [herneth2]. On bone scintigraphy, increased uptake at the weight-bearing side may be seen.

Recognition of this normal variant is important when interpreting a pediatric pelvic radiograph. If seen asymptomatic without concerning history, it most likely represents a developmental variant. If symptomatic or with a concerning history, the interpretation warrants great care and other differential diagnosis should be considered [olivera, herneth2, kloiber].

C. Infectious

C.1. Septic arthritis

Septic arthritis is a joint infection that can occur by direct spread of contiguous osteomyelitis, hematogenous spread, or directly after penetrating trauma. It is a surgical emergency as it can have a rapidly deteriorating course with destruction of the joint. Septic arthritis in children is usually monoarticular; the hip is the most commonly affected joint in children under 10 years of age. Clinically, children are ill, with fever and severe joint pain. Unilaterally joint effusion is present in nearly all cases. Increased pressure within the joint may lead to ischemia or infarction of the femoral head epiphysis. Absence of fluid excludes septic arthritis. Treatment is surgical with urgent debridement and IV antibiotics [buchman].

Ultrasound is the first imaging modality of choice, both in detection of a joint effusion and guiding needle aspiration. When an effusion is present, the joint capsule becomes convex instead of concave, the anterior joint recess normally measures 2 to 5 mm from the outer margin of the capsule to the femoral neck cortex whereas the abnormal joint capsule should be at least 2 mm thicker than the contralateral normal side [grisson]. Effusion size and echotexture are not predictive of infection. A thickened synovium can also be seen. Increased flow at Doppler Ultrasound is more characteristic of a septic joint, but findings can be normal. Joint aspiration is both diagnostic and therapeutic, relieving intracapsular pressure, and is necessary to differentiate septic from transient synovitis [sarwar].

Conventional radiography may detect a large effusion and soft tissue swelling in the early stage, and in more advanced stages, may serve to exclude bone involvement, seen as cortical destruction, periosteal reaction, and subluxation [sarwar].

MRI may be helpful to evaluate the extent of the disease, and to detect concomitant osteomyelitis. MRI findings however are nonspecific, demonstrating joint effusion, synovial inflammation and enhancement after intravenous gadolinium administration, but no distinction between septic and transient synovitis can be made. The presence of periarticular BME and decreased perfusion of the femoral head after contrast administration favors septic arthritis [kwack]. More extensive bone marrow changes raise suspicion of osteomyelitis [rosenfeld].

Bone scintigraphy findings are nonspecific, showing increased periarticular uptake.

C.2. Osteomyelitis/CRMO

C.2.1. Osteomyelitis

Osteomyelitis of the hip is uncommon. It can occur at any age, generally in children 1-16 years old, and is usually caused by hematogenous spread of infection. Generally, the metaphysis is involved, transphyseal spread to the epiphysis and joint is rare but can occur in children younger than 18 months, or in older children with closed growth plates [schmit, blickman]. Patients present with hip pain and fever, passive range of motion is often preserved. Blood culture results are positive in fewer than half of cases. A subtype of osteomyelitis typically seen in children is Brodie's abscess, which is a subacute osteomyelitis with intraosseous abscess formation. Pain can be the only symptom, and fever and inflammatory

markers can be absent. Osteomyelitis is treated with IV antibiotics. Abscesses should be drained (imaging guided), and devitalized bone surgically debrided [klein, schmith].

The first imaging modality of choice is conventional radiography, but CR has limited sensitivity in early stages. Osseous destruction is evident only 10-14 days after the initial infection. In low-grade osteomyelitis, subtle bone resorption / a lytic lesion at a metaphysis may be seen, as in more advanced stages, extensive soft tissue edema, distortion of fat planes, lytic bone destruction and periosteal formation are seen [sarwar, khanna, blickman]. In case of Brodie's abscess, a sharp lytic lesion with or without sclerotic rim is seen in the metaphysis or in the epiphysis in young children.

MRI is indicated when symptoms are localized to the pelvis and radiographs are normal. MRI is more specific in detection of lesions, but is also effective in depicting complications such as soft tissue or intraosseous abscesses and necrotic bone [sarwar]. MRI shows bone marrow edema as T2 hyperintense signal in the metaphysis, with post contrast enhancement of bone marrow, abscess margins, periosteum and adjacent soft tissue collections [schmit].

Bone scintigraphy can be performed for detection of radiographically occult disease and for assessment of multifocal involvement, although more recently, whole body MRI is performed increasingly [von kale, villani].

C.2.2. Chronic recurrent multifocal osteomyelitis

Chronic recurrent multifocal osteomyelitis (CRMO) is an autoinflammatory disorder of children and young adults, that is characterized by nonbacterial osteomyelitis. It is seen more commonly in girls than boys, the peak age of incidence is around 10 years. Multiple sites of osteomyelitis are present concomitantly, typically in the metaphyses of long bones and the medial clavicles. Other common sites are the vertebral bodies, pelvis, ribs, and mandible. CRMO is often bilateral and multifocal at presentation [huber].

The imaging evaluation of CRMO should start with conventional radiography of the symptomatic sites. If CR is negative, but significant clinical symptoms are present, further evaluation with MRI should be considered to evaluate for marrow edema. When the diagnosis of CRMO is considered based on this findings, further evaluation of the whole body is suggested to identify multifocal lesions that may be clinically asymptomatic [khanna]. Bone scintigraphy can be used to for this whole-body evaluation, but recently, whole-body MRI is being increasingly used, as MRI has no ionizing radiation [khanna].

D. Inflammatory

D.1. Transient synovitis

Transient or toxic synovitis is the most common nontraumatic hip disorder in toddlers and children up to 10 years of age. Boys are more commonly affected. It is a self-limiting aseptic inflammation of the hip, with unknown cause, but often seen after a viral infection. Allergic and traumatic causes have been suggested as well. Generally, children are not sick, and may show limb, pain and limited motion of the

hip. Treatment is conservative, with rest and analgesics, and resolves usually in 3-10 days [zucker, miralles, do].

Imaging is not strictly necessary, but US might be the initial imaging study performed to demonstrate the presence of joint fluid, or to guide joint aspiration, which is the reference standard for differentiation with septic arthritis [sarwar, miralles]. Conventional radiography is not indicated, and only used to exclude other etiologies such as fracture, SCFE or AN. It may show atypical joint space widening, but are most often normal. MRI is not indicated, and may show joint effusion and synovial inflammation. MRI findings are non-specific and cannot differentiate with septic arthritis, although the presence of BME or osteomyelitis is suspicious and favors septic arthritis (cfr. 'Septic Arthritis') [sarwar, kwack].

D.2. Juvenile Idiopathic Arthritis

Juvenile Idiopathic Arthritis (JIA) is the most common form of arthritis in children and adolescents. JIA is an autoimmune, non-infective, inflammatory joint disease in children less than 16 years of age with arthritis that persists for more than 6 weeks [ravelli]. JIA recently is divided into 7 subtypes, according to the International League of Associations for Rheumatology (ILAR) classification [petty]. The large joints are mainly affected, with hip involvement in about 30-50% of cases, which is commonly bilateral. Clinically, morning stiffness is seen, improving with exercise, groin pain, or referred pain to the knee. Treatment is specialized in a pediatric rheumatology department, and includes physical therapy, anti-inflammatory agents, corticosteroids and even disease-modifying antirheumatic drugs (DMARD) or even aggressive therapy with anti-tumor necrosis factor (anti-TNF) agents [ravelli].

Conventional radiography the first imaging modality, although often normal in early stages, sometimes soft tissue swelling, joint effusion, peri-articular osteopenia can be seen. Later stages may show joint space narrowing, periosteal reaction, accelerated bone maturation, erosions and eventually ankylosis [buchmann, sheybani, williams].

Ultrasound can depict joint effusion, synovial thickening, and is excellent for guiding aspiration. Doppler ultrasound can evaluate hyperemia, which correlates with disease activity [sheybani].

Recently MRI is increasingly used as it can detect early changes long before radiographic changes become evident. MRI can show joint effusion, bone marrow and soft tissue edema, synovial proliferation, and cartilaginous and bony erosions [sheybani, eshed].

E. Neoplastic

Bone tumors or tumorlike lesions of the hip in children are rare. There is often a delay in diagnosis because symptoms are frequently nonspecific, some are detected incidentally or when a pathologic fracture occurs [zucker]. Most (more than 4/5) neoplastic lesions are benign, malignant tumors of the hip are very rare. The most common benign lesions of the hip are simple bone cyst, osteoid osteoma, eosinophilic granuloma, aneurysmal bone cyst, fibrous dysplasia and osteochondromas. The most frequently seen malignant tumors of the hip are Ewing sarcoma, osteosarcoma, lymphoma, leukemia or metastasis [Ruggieri, zucker].

Detailed discussion of these lesions is beyond the scope of this article.

Conclusion

Hip disorders are common in children. The age of the child, history, clinical examination and in some cases laboratory findings are essential to narrow down the differential diagnosis. Together with the appropriate imaging modality findings, the accurate diagnosis can be found.

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