Hip Disorders in Children

Hip disorders are both highly prevalent and diverse among pediatric patients. Causes include congenital, developmental, infectious, inflammatory, traumatic, and neoplastic processes (Table 1). Pertinent clinical history, such as patient age and habitus, combined with laboratory test results such as WBC count and erythrocyte sedimentation rate, helps narrow the differential diagnosis. However, the symptoms can be nonspecific (hip pain, irritability, limp), and clinical examination findings are often unreliable. Imaging plays a crucial role in differentiating benign from more serious disorders; directing appropriate management; and minimizing later complications, particularly osteoarthritis in adulthood.

Radiography is usually the initial imaging modality of choice. Anteroposterior and frog-leg (hips externally rotated and flexed) images of the entire pelvis should be obtained. Ultrasound is particularly useful for identifying joint fluid, guiding hip aspiration, and assessing the unossified structures of the infant and developing child. MRI has superior soft-tissue contrast resolution and is useful for detection of early disease, but often at the expense of imaging times and possible need for sedation. A limited-sequence MRI protocol can be used to overcome these limitations, especially in emergencies. Because of exposure to ionizing radiation, CT is often limited to preoperative anatomic planning. Similarly, bone scintigraphy is generally reserved for selected cases, such as those of patients with poorly localized symptoms. Together with clinical history, physical findings, and laboratory results, imaging findings facilitate prompt and accurate assessment of the abnormal pediatric hip.

Congenital Short Femur

Congenital short femur is a rare disorder characterized by shortening and anterolateral bowing of the femur with a valgus deformity of the knee. Hamstring shortening restricts...
straight leg raising, and lack of anterior cruciate ligaments causes knee instability. Associations include ipsilateral fibular hemimelia (longitudinal fibular deficiency) and foot deformities. Radiographs show the expected osseous anomalies (Fig. 3). Ultrasound or MRI can be used to assess cartilaginous and fibrous tissue and muscular and ligamentous involvement. Limb-lengthening surgery is a treatment option that has met with variable success.

**Meyer Dysplasia (Dysplasia Epiphysealis Capitis Femoris)**

Meyer dysplasia is a rare developmental disorder or variant of normal characterized by delayed and irregular ossification of the capital femoral epiphysis. Commonly bilateral, it occurs at a mean age of 2.5 years, more often in boys. The disorder is asymptomatic and requires no treatment; minimal loss of epiphyseal height is the only long-term sequela. Accurate diagnosis is essential, however, because Meyer dysplasia is easily mistaken for Legg-Calvé-Perthes disease (LCPD), potentially leading to unnecessary interventions. Combined with the absence of any clinical findings, the radiographic finding of a small, irregular, cracked, or cystic epiphysis is usually sufficient to make the diagnosis (Fig. 4). Pertinent negatives are the absence of condensation, subchondral fracture, subluxation, and collapse of the capital femoral epiphysis, all of which are typical findings in LCPD. The imaging appearance generally returns to normal after 2–4 years of observation. MRI is useful in selected cases. The lack of marrow signal abnormality differentiates Meyer dysplasia from LCPD.

**Proximal Femoral Focal Deficiency**

Proximal femoral focal deficiency is a rare congenital condition in which there is variable hypoplasia to complete aplasia of part or all of the proximal femur. Unilateral in 90% of cases, it occurs in 0.002% of live births and is clinically detected during infancy when limb shortening and malrotation are found. The Aitken classification system, ranging from type A (least severe) to type D (most severe), is most often used to grade the severity of disease based on the degree of involvement of the acetabulum, femoral epiphysis, and femoral diaphysis. Radiographs show the osseous defects (Fig. 5). Ultrasound and, particularly, MRI are useful for comprehensive assessment of the incompletely ossified femoral epiphysis and of soft-tissue, cartilaginous, and labral abnormalities. These modalities are also useful in preoperative planning (Fig. 6). Treatment approaches include amputation with prosthetic replacement and leg-lengthening reconstructive surgery.

**Developmental**

**Legg-Calvé-Perthes Disease**

LCPD is idiopathic osteonecrosis (osteochondrosis) of the immature capital femoral epiphysis. It occurs in as many as 0.016% of children 2–14 years old, with a peak incidence at 5–6 years old. Boys are 5 times as likely as girls to be affected, and 85–90% of cases are unilateral. Presenting symptoms include limp and pain in the hip, thigh, or knee. Other causes of avascular necrosis (such as sickle cell disease and corticosteroid therapy) must first be excluded before the diagnosis of LCPD is made. Radiographic grading systems (such as the Catterall classification) may be used for assessing the severity of disease, which ranges from limited epiphyseal involvement to complete sequestration or collapse and extension to the metaphyseal region (Figs. 7–9). Ultrasound findings are nonspecific, but LCPD should be considered if there is a persistent joint effusion. Bone scintigraphy shows radiographically occult disease and provides prognostic information. Early lateral column formation (type A Conway classification pathway) is associated with a good end result, whereas central activity at the base of the epiphysis or absent epiphyseal activity after 5 months (type B pathway) is predictive of a poor outcome. The scintigraphic patterns reflect differences in the potential for revascularization.

### TABLE 1: Hip Disorders in Children

<table>
<thead>
<tr>
<th>Type</th>
<th>Disorder</th>
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<tr>
<td>Congenital</td>
<td>Developmental dysplasia of the hip</td>
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<td>Congenital short femur</td>
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<td></td>
<td>Meyer dysplasia (dysplasia epiphysealis capitis femoris)</td>
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<td></td>
<td>Proximal femoral focal deficiency</td>
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<td></td>
<td>Legg-Calvé-Perthes disease</td>
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<td>Coxa valga</td>
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<td>Coxa vara</td>
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<td>Septic arthritisa</td>
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<td>Osteomyelitisb</td>
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<td>Juvenile rheumatoid arthritis</td>
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<td>Dermatomyositis</td>
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<td>Slipped capital femoral epiphysis</td>
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<td>Stress fracture</td>
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<td></td>
<td>Apophyseal injury</td>
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<td>Malignant</td>
<td>Unicameral bone cyst</td>
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<td></td>
<td>Aneurysmal bone cyst</td>
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<tr>
<td></td>
<td>Enchondroma, enchondromatosis</td>
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<td></td>
<td>Osteochondroma, multiple osteochondroma</td>
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<td></td>
<td>Osteoid osteoma</td>
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<td>Eosinophilic granuloma</td>
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<td>Fibrous dysplasia</td>
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<td>Ewing sarcomaa</td>
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<td>Lymphoma, leukemia</td>
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<td>Metastasisb</td>
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aTypically presents in young child (< 10 y).
bPresent in child of any age.
cTypically presents in older child or adolescent (age ≥ 10 y).
MRI also facilitates early detection, showing low T1 and high T2 signal intensity in the femoral epiphysis and no enhancement on dynamic gadolinium-enhanced subtraction images (Fig. 10). The utility of gadolinium in evaluating LCPD and the optimal protocol (e.g., routine vs dynamic contrast-enhanced imaging, subtraction sequences) remain a source of debate in the literature. As LCPD heals, the bone marrow exhibits increasingly normal signal intensity. Fibrous tissue repair is visualized as a semilunar, cup-shaped, low-intensity band on T1-weighted images. Furthermore, MRI provides excellent anatomic detail and may obviate arthrography in cases of associated hip subluxation. CT of LCPD shows early bone collapse, curvilinear zones of sclerosis, subtle changes in trabeculation, and intraosseous cysts of late LCPD. Use of CT, however, is tempered by relatively high radiation exposure. When LCPD is promptly detected, surgical containment of the femoral epiphysis improves prognosis, helping to prevent later osseous destruction and arthritis.

Coxa Valga
Coxa valga is an increase in the femoral neck-shaft angle relative to normal standards for age. This angle is measured between the mid axis of the femoral diaphysis and a line along the mid axis of the femoral epiphysis and neck on a true anteroposterior radiograph. The normal angle is approximately 150° in infants, increasing to 120° in adults. Patients with coxa valga commonly have underlying skeletal or neuromuscular disease (e.g., cerebral palsy). Adductor spasticity suppressing the hip abductors and extensors results in deformity. Signs and symptoms of coxa valga include impaired sitting balance and ambulation, pain, and decubitus ulcers from abnormal positioning.

In assessment of radiographs, it is important to remember that femoral anteversion and rotation may lead to the spurious projectional appearance of coxa valga. In advanced disease, there may be superolateral subluxation or dislocation of the femoral epiphysis and resultant acetabular dysplasia and osteoarthritis. CT and MRI are useful for assessing femoral and tibial torsion in patients about to undergo derotational osteotomy (Fig. 11). Patients also benefit from physical therapy, orthotic devices, and antispasmodic treatments (baclofen, botulinum toxin).

Coxa Varus
Coxa vara is defined as a decrease in the femoral neck-shaft angle compared with age-matched normal hips. It can be congenital, developmental, or acquired. Congenital coxa vara is usually caused by a limb bud insult and changes little after birth. The developmental (infantile) form, bilateral in as many as one half of cases, is thought to be secondary to abnormal cartilage proliferation in the medial physis that causes increased lateral growth. Children present when they are 2 years old with a waddling gait or painless limp. Acquired coxa vara may be associated with various skeletal abnormalities, including osteogenesis imperfecta and fibrous dysplasia. True coxa vara should be differentiated from apparent coxa vara, in which the femoral neck-shaft angle is preserved, but proximal femoral physeal growth is disturbed with resultant femoral neck shortening and relative trochanteric overgrowth. Causes of apparent coxa vara include trauma, infection, and avascular necrosis.

Radiographs show the decreased femoral neck-shaft angle (Fig. 11). Additional findings include a wide and irregular vertically oriented physis and a triangular metaphyseal bony fragment inferomedial to the physis. MRI is useful in preoperative anatomic planning. MR images show physeal changes (best with a 3D fat-suppressed spoiled gradient-recalled echo sequence), bone marrow edema (indicating abnormal stress), and the femoral epiphysis-neck complex, which is useful for assessing potential impingement. Treatment is usually surgical with varus subtrochanteric osteotomy, though the deformity frequently recurs because of skeletal immaturity.

Infectious
Toxic Synovitis
Toxic (transient) synovitis results from inflammation of the synovial lining that has no known cause. Allergic, traumatic, and viral causes have been suggested. Patients are generally 5–10 years old and present with a waxing and waning limp. Hip pain (usually minimal) or stiffness also may be reported. Toxic synovitis typically produces fewer acute symptoms than does its more serious mimic, septic arthritis.

Radiographs of infants and young children with toxic synovitis may show joint space widening on the affected side (Fig. 12A). In older children, radiographic findings are most often normal. Regardless, ultrasound is performed to determine whether a hip effusion is present. In the sagittal plane, a hip effusion appears as bulging of the joint space as it extends over the femoral neck. Although marked synovial thickening and debris within the joint fluid are more typical of septic arthritis, these features are nonspecific and can be seen in toxic synovitis (Fig. 12B). Similarly, neither scintigraphy nor MRI is reliable for excluding septic arthritis, although the presence of concurrent osteomyelitis raises suspicion. Ultimately, joint aspiration may be needed. Managed with only supportive measures, such as avoidance of weight bearing and antiinflammatory medication, toxic synovitis usually resolves in 3–10 days with no long-term consequences.

Septic Arthritis
Septic arthritis is infection of a joint. It can occur by direct spread of contiguous osteomyelitis, hematogenous dissemination from a remote site, or direct inoculation due to penetrating trauma. The hip is commonly affected in children younger than 10 years. Presenting symptoms of limp and hip pain overlap with toxic synovitis, though a child with septic hip appears acutely ill. Fever, lack of weight bearing, erythrocyte sedimentation rate greater than 40 mm/h, and WBC count greater than 12,000/mm3 are strong clinical predictors of an infected joint.

Imaging cannot be reliably used to differentiate septic arthritis and toxic synovitis. Radiographs may show bulging or asymmetric widening (> 2 mm) of the affected joint space (Fig. 13A). Ultrasound readily shows joint effusions (Fig. 13B), though effusion size and echotexture are not predictive of infection. Increased flow at power or color Doppler ultrasound is more characteristic of a septic joint, but Doppler findings can be normal. Bone scintigraphic findings are nonspecific, showing increased periarticular uptake in one or more parts of a three-phase examination. MRI shows large complex effusions, synovial thickening and enhancement, bone marrow edema, and bone erosions; however, these findings may also be seen in noninfectious inflammatory arthropathy. MRI is helpful for assessing an infectious process (such as myositis) adjacent to the infected hip joint (Figs. 13C and 13D). Joint aspiration is both diagnostic and therapeutic, relieving intracapsular pressure. Recognizing the limitations of imaging is essential because septic arthritis is a true emergency, requiring urgent surgical drainage and IV antibiotics to prevent osseous destruction and to preserve function.

Osteomyelitis
Osteomyelitis usually develops through hematogenous spread of transient, asymptomatic bacteremia. It occurs frequently in the pediat-
Hip Disorders in Children

Inflammatory
Juvenile Rheumatoid Arthritis

Juvenile rheumatoid arthritis (JRA) is a systemic disorder of unclear cause that predominantly affects the joints. It is a diagnosis of exclusion in children younger than 16 years who have arthritis persisting more than 6 weeks. JRA is the most common pediatric chronic arthropathy, as many as one new case per 5000 children being detected annually. Classic symptoms are morning stiffness with gradual resolution of pain on activity and painful or decreased range of motion at examination. Hip involvement occurs in 30–50% of patients, is commonly bilateral (but the hip rarely is the sole joint affected), and presents as groin pain or referred knee or thigh pain.

JRA once was classified into three major categories: pauciarticular (four or fewer joints involved after 6 months of illness), polyarticular (five or more joints), and systemic (formerly known as Still disease) with rash, intermittent fever, and variable arthritis. The term JRA has been replaced by the broader entity known as juvenile idiopathic arthritis, which differentiates rheumatoid factor–positive and –negative disease and includes the categories enthesitis-related arthritis, psoriatic arthritis, and undifferentiated arthritis. Further refinements to the classification system should be expected as more is understood about the pathogenesis of the various subtypes of disease.

The imaging evaluation begins with radiographs, which often have normal findings in early disease. Later findings include soft-tissue swelling, joint effusions, periarticular osteopenia, periostal reaction, epiphyseal remodeling, joint space narrowing, and erosions. Abnormally advanced skeletal maturation may also be present, as evidenced by premature physeal fusion, joint space narrowing, and length discrepancy (Fig. 15). Ultrasound is excellent for detecting joint effusions and synovial thickening and for guiding hip aspiration. The degree of hyperemia as detected with Doppler ultrasound correlates with disease activity. MRI with IV gadolinium administration is the best modality for assessment, effectively showing joint effusions, soft-tissue edema, proliferative synovium, lymphadenopathy, cartilaginous and bony erosions, and eventual meniscal hypoplasia due to synovial overgrowth. Patients with this chronic disease need follow-up with a pediatric rheumatologist for consideration of physical therapy, antiinflammatory agents, local intraarticual corticosteroid injections, and disease-modifying antirheumatic medications.

Dermatomyositis

Juvenile dermatomyositis is an inflammatory disorder of unknown cause affecting muscle and skin and having variable cardiopulmonary and gastrointestinal involvement. B lymphocyte– and T4 lymphocyte–mediated cell damage is hypothesized as the underlying pathogenesis. Children 2–15 years old are affected. Patients present with muscle weakness and enzyme elevation and a violaceous rash over the bony prominences of the knees and elbows. In contrast to the adult form of the disease, juvenile dermatomyositis is rarely associated with underlying malignancy.

Findings on radiographs early in the course of juvenile dermatomyositis may be normal or show soft-tissue swelling and subcutaneous edema with loss of normal tissue planes, especially around the proximal appendicular skeleton. Later radiographs show loss of muscle bulk and osteoporosis of the long bones and vertebrae. Most characteristic and conspicuous are dystrophic soft-tissue calcifications (subcutaneous, periarticular, and intramuscular), occurring in 25–50% of cases. Subcutaneous nodular or plaquelike calcification is most common, but large tumoral clumps or diffuse sheets of calcification may be seen. Ultrasound of affected muscles shows increased echogenicity, atrophy, and shadowing due to calcification. Flexor tenosynovitis and nodules may be seen. MRI in acute disease shows diffuse high T2 signal intensity within the involved muscles, often the adductors, in a nonuniform distribution (Fig. 16). In chronic disease, areas of low signal intensity are present in all sequences, corresponding to fibrosis and calcification, and foci of high T1 signal intensity may represent fatty change. Treated with corticosteroids and in more aggressive cases disease-modifying drugs such as methotrexate, juvenile dermatomyositis generally has a good long-term prognosis.

Traumatic
Slipped Capital Femoral Epiphysis

Slipped capital femoral epiphysis (SCFE) is a Salter-Harris type I fracture through the proximal femoral physis. The disorder is most often idiopathic, although a trauma history is reported in 50% of cases. It occurs most commonly among overweight African American male adolescents. As many as one third of cases are bilateral. Patients present with chronic hip or referred knee pain and limp.

Typical radiographic findings are widening, lucency, and irregularity of the physis on the affected side, all of which are often subtle. An additional sign is lack of intersection of the femoral epiphysis with a line drawn tangent to the lateral margin of the femoral neck (Klein line). Disuse muscular atrophy and osteopenia may be evident. The characteristic slippage (displacement) of the epiphysis, posterior in 99% of cases and medial in 75%, is best visualized on frogleg images (Figs. 17 and 18). MRI may be used to detect physeal or metaphyseal abnormalities in patients with clinically suspected SCFE but
normal radiographic findings. This scenario is referred to as preslip SCFE. The earliest finding is diffuse or globular physeal widening, which is visualized as an area of intermediate signal intensity surrounded by linear low signal intensity. Edema may be seen in the epiphysis or proximal metaphysis. MRI also is the best imaging modality for detecting complications of SCFE, such as chondrolysis and avascular necrosis. Prompt diagnosis and treatment, generally with surgical pinning, helps prevent these late sequelae and the development of premature osteoarthritis.

**Stress Fracture**

Stress fractures are caused by abnormal stress on otherwise normal bone. Previously uncommon in children, they are now seen regularly in high-level athletes training with repetitive loading activities. Occasionally, stress fractures may be seen in children with abnormal stress on abnormal bones (e.g., girls who are long-distance runners and have osteopenia due to abnormal menstruation). Only 3% of pediatric stress fractures occur in the femur. Patients present with hip, groin, or anterior thigh pain that worsens with activity and is characteristically reproduced with hopping on the affected side.

Radiographic findings are initially normal in 90% of cases. By 2–14 weeks after fracture onset, there is evidence of typical radiographic findings such as focal periosteal reaction, endosteal cortical thickening, and a lucent cortical fracture line (Fig. 19). Radionuclide bone scintigraphy and MRI are approximately equally sensitive for the detection of radiographically occult stress fractures, but MRI is more specific. Unless there is abnormal signal intensity in the cortex, typically a clear fracture line but sometimes one that is less discretely linear, the MRI findings of periosteal and marrow edema are more appropriately termed a stress reaction rather than a stress fracture. Fractures through the superior femoral neck (tension side) require surgical stabilization. Fractures of the inferior neck (compression side) can be managed conservatively with reduction in activity and weight bearing.

**Apophyseal Injury**

Apophyses are secondary growth centers that serve as tendinous attachment sites. During adolescence apophyses develop at the iliac crest, anterior superior and inferior iliac spines, greater and lesser trochanters, and ischium, where the abdominal oblique, sartorius, rectus femoris, gluteal, psoas, and hamstring tendons insert. Un ossified, these apophyses are prone to both acute avulsion fractures and chronic traction injury (apophysitis). Pediatric athletes (boys more than girls) involved in activities such as running, football, hockey, lacrosse, and dancing are at highest risk. Acute avulsion fractures elicit sudden-onset pain near the hip, whereas traction apophysitis causes a dull ache. In both conditions, the symptoms are exacerbated by activity.

On radiographs, acute apophyseal avulsion is diagnosed with confidence when there is displacement of the apophysis from its expected position and a clear fracture fragment (Figs. 20–22). Several days after the initial injury, only bone resorption may be evident. Chronic apophysitis manifests itself as callus and reactive bone formation, sometimes so exuberant that the findings may be mistaken for a tumor. If the radiographic findings are normal or a neoplasm is suspected, MRI may show marrow edema within the apophysis and donor bone. Comparison of the opposite side is useful, because some degree of high T2 signal intensity is normally expected in the actively growing apophysis. Apophysitis injuries are usually treated conservatively with rest, ice, physical therapy, and limitations on activity. Most children are able to return to full capacity in 4–8 weeks. Surgical fixation may be required for apophyseal avulsion fractures displaced more than 2 cm.

**Neoplastic**

**Benign**

Unicameral bone cyst—Unicameral, or simple, bone cysts (UBCs) are benign lesions that occur most often in the proximal metaphysis of long bones near the growth plate. Common in children and adolescents (boys more than girls), UBCs are usually detected incidentally or when a pathologic fracture occurs. Radiographs show an elongated lytic lesion (occasionally trabeculated) with distinct, circumscribed margins and a pathologic fracture occurs. Radiographs show an elongated lytic lesion (occasionally trabeculated) with distinct, circumscribed margins and located in the central metaphysis extending to the diaphysis (Fig. 23). The presence of a bony fragment at the dependent portion of the cyst, known as the fallen fragment sign, and secondary to pathologic fracture is considered essentially pathognomonic of UBC. CT is useful in atypical cases (e.g., multilocular) and to better assess the extent of the lesion. On MR images, UBCs characteristically are sharply defined with high T2 signal intensity and a thin rim of peripheral enhancement, consistent with a simple cyst. However, healing or recently fractured lesions may have a more heterogeneous signal pattern, at times with fluid-fluid levels or irregular enhancement. Approximately 25% of UBCs heal spontaneously. Treatment with curettage, bone grafting, or intralesional steroid injection is recommended for patients at high risk of pathologic fracture (e.g., due to significant cortical thinning). Recurrence is common in lesions located near the physis.

Aneurysmal bone cyst—Aneurysmal bone cysts (ABCs) are benign multicystic lesions consisting of blood-filled cavernous spaces separated by fibrous tissue. Most originate in the vertebrae, metaphyses of long bones, or pelvis. Some ABCs occur after trauma or in conjunction with underlying neoplasms, such as osteoblastoma and chondroblastoma. Approximately 70% of cases appear in patients younger than 20 years; the peak incidence is at 16 years. Because of the expansile nature of the lesion, presenting symptoms may include local pain and swelling or pathologic fracture.

Radiographs of ABCs show a multiloculated lytic lesion with no internal matrix. Approximately 85% of cysts have sharp, circumscribed margins (Fig. 24A). ABCs typically cause eccentric expansion of the underlying bone. The resultant cortical thinning may be so marked that the cortex appears completely absent. Rapidly growing ABCs may have aggressive features with periosteal reaction, simulating malignancy. On MR images, the lesions have low T1 signal intensity and high T2 signal intensity, with intervening low-signal-intensity thin septations corresponding to fibrous tissue (Fig. 24B). Fluid-fluid levels, best visualized on T2-weighted images, are a characteristic finding but are not diagnostic of ABC (Fig. 24C). Although the cyst wall and internal septations may become enhanced, the presence of solid enhancing tissue should raise concern for secondary ABC or an alternative diagnosis such as telangiectatic osteosarcoma (although rare in children). Therapeutic options include curettage and bone grafting, excision, sclerotherapy, and cryotherapy. Arterial embolization is sometimes performed before surgery or in select cases as primary treatment. After intervention, patients should be monitored for 5 years to detect any recurrence, most of which occur within 2 years.

Enchondromatosis—Enchondromas are common, usually solitary, benign bone tumors composed of hyaline cartilage. Approximately 25% are detected in children, typically in the 2nd decade of life. Patients with either solitary or multiple enchondromas may present with local pain and swelling or pathologic fracture. The long tubular bones, ribs, and spine may be...
affected, although hand and foot involvement is more common. Enchondromatosis, also known as Ollier disease and dyschondroplasia, is a rare nonhereditary disorder in which bony cartilage does not undergo ossification. In children with this condition, multiple lesions develop that are histologically similar but not identical to traditional enchondromas. The association of multiple enchondromas with soft-tissue or skin hemangiomas is termed Maffucci syndrome. Multiple enchondromas have a high risk of malignant transformation (usually to chondrosarcoma), which occurs in 20–30% of patients with Maffucci syndrome and 15–30% for those with Ollier disease.

On radiographs (or CT scans), enchondromas appear as circumscribed, expansile lytic lesions, typically measuring 1–2 cm; are located within the medullary portion of bone; and have a narrow zone of transition (Fig. 25). Calcification of the chondroid matrix (ring and arc calcification) is characteristic but seen in only one half of cases. Although some endosteal scalloping is to be expected, deep endosteal scalloping (>66% cortical thickness) should raise concern for malignant transformation. On MR images, enchondromas have low T1 signal intensity and high T2 signal intensity. If chondroid matrix is present, corresponding foci of internal low signal intensity may be seen within the lesion. Simple enchondromas require no specific treatment. If there is a pathologic fracture, curettage with bone grafting or excision is indicated. Because of the risk of malignant transformation, periodic surveillance is recommended for patients with enchondromatosis.

*Multiple osteochondromas*—Osteochondromas are osseous, cartilage-capped exostoses that arise from the outer surface of bone. They are the most common benign bone tumor of childhood and are usually detected by the age of 20 years. Previous radiation treatment is a risk factor. The long bones, particularly the distal femur, proximal tibia, and humerus, are most often affected. The presence of numerous osteochondromas occurs in association with an autosomal dominant disorder known as multiple hereditary exostoses, also called diaphyseal aclasis and multiple osteochondroma. Osteochondromas may cause symptoms secondary to local neurovascular impingement, reactive bursitis, or fracture. Continued growth or pain after skeletal maturity should raise suspicion of malignant transformation, which develops in 1% of solitary osteochondromas and in 3–5% of patients with multiple hereditary exostoses.

*Eosinophilic granuloma*—Eosinophilic granuloma (EG), formerly known as histiocytosis X, is strictly defined as a solitary-occurring lesion of Langerhans cell histiocytosis, although the terms are now largely synonymous. Histologically, EG is characterized by benign, nonneoplastic inflammatory proliferation with a predominance of Langerhans (antigen-presenting) cells. Langerhans cell histiocytosis has been reported incidence of 1 in 200,000 children and is approximately twice as frequent in boys. The skull, femur, pelvis, ribs, and vertebrae are most commonly affected. The condition may be asymptomatic or cause bone pain or pathologic fracture. Fever and peripheral blood eosinophilia are seen in 10% of cases.

The prospective imaging diagnosis of EG is challenging because the lesion can have any combination of aggressive and nonaggressive features. On radiographs, EG is typically lytic with no internal matrix (Fig. 28A). Lesions may be small or large, with a narrow or wide zone of transition. Periosteal reaction may or may not be present. Even permeative or moth-eaten bone destruction may be found. MRI is useful in assessing the extent of marrow involvement and the presence of a soft-tissue mass, which is less typical of EG (Figs. 28B and 28C). Because lesions can mimic infection or malignancy, biopsy may ultimately be necessary to make a definitive diagnosis, and this procedure has the added benefit of inciting healing. Solitary EG tends to stabilize or regress without intervention, although curettage, excision, steroid injection, and radiation are additional therapeutic options. Multifocal Langerhans cell histiocytosis has a poorer outlook, but the prognosis is more favorable when the disease is confined to bone without systemic involvement. A skeletal survey has traditionally been used to follow up on multifocal bone lesions, but whole-body MRI with STIR sequences has been increasingly used.

*Fibrous dysplasia*—Fibrous dysplasia is a common benign fibroosseous lesion of bone characterized by fibrous tissue and irregular woven bone. Usually detected before the age of 30 years, it is isolated to a single bone (monostotic) in 80% of cases. Any bone can be involved, including the large tubular bones (e.g., femur, tibia, humerus), jaw, skull, and ribs. The association of polyostotic fibrous dysplasia (involving multiple bones) with café-au-lait spots and precocious puberty is termed McCune-Albright syndrome. The condition may be asymptomatic or cause bone pain, swelling, deformity, and pathologic fracture.

On radiographs, the lesions of fibrous dysplasia are characteristically radiolucent with a ground-glass matrix. They are typically expansile and have a well-circumscribed border that is often sclerotic (Fig. 29A). A classic presentation is severe varus bowing deformity of the proximal femur, which is known as shepherd’s crook deformity (Fig. 29B). At MRI, fi-
brous dysplasia causes heterogeneous T1 hypointensity and T2 hyperintensity owing to variable calcification, septations, fat content, and cystic components. Surgery is not curative but may be performed if the patient has a fracture, marked deformity, or local impingement.

Malignant

Ewing sarcoma—Ewing sarcoma is a small, round, blue-cell tumor composed of primitive neuroectodermal cells. The second most common primary malignant bone tumor in children, it usually arises between the ages of 5 and 15 years and is more common in whites. Typical sites of involvement are the diaphyses (or metaphyses) of long bones and flat bones, particularly the pelvic bones and the clavicle. Metastasis to lung or bone is present in as many as 30% of patients at initial diagnosis.

Ewing sarcoma has a variable appearance on radiographs but is typically aggressive and mixed lytic and sclerotic and destroys the cortex (Fig. 30A). It causes an intense periosteal reaction, which is classically spiculated (hair on end) or lamellated (onion skin). On MR images the lesions have low T1 signal intensity and heterogeneously high T2 signal intensity. The lesions overall are hypointense or isointense to muscle and have an extensive soft-tissue component (Figs. 30B and 30C). Ewing sarcoma is treated with a combination of chemotherapy, surgery, and radiotherapy. The prognosis depends on the extent of disease at initial diagnosis.

Lymphoma and leukemia—Also tumors consisting of small, round, blue cells, lymphoma and leukemia are hematologic malignancies characterized by abnormal proliferation of lymphoid cells. Primary bone involvement is rare. Radiographically, lymphoma characteristically exhibits extensive moth-eaten bone destruction, which is centered at the diaphysis and has low T2 signal intensity on MR images (Fig. 31). It can appear identical to Ewing sarcoma, but the presence of multiple lesions or lack of a soft-tissue component should raise suspicion for this diagnosis. Leukemia is the most common malignancy of childhood. Skeletal involvement occurs in 50–90% of cases and manifests as permeative or focal bone destruction, local periostitis or sclerosis, or diffuse marrow infiltration, all of which are often best appreciated with MRI. It is important to consider lymphoma and leukemia as differential diagnoses of aggressive pediatric bone lesions because surgery is not indicated and the only treatment is chemotherapy or radiotherapy.

Metastasis—Bone metastasis is much less common in children than adults. Neuroblastoma, a tumor derived from the adrenal medulla or sympathetic chain, is the most common malignant neoplasm in children to metastasize to bone. The bone marrow is the most common site of metastasis in this disease: 50–60% of cases at presentation. Radiographs show poorly marginated lytic lesions with moth-eaten or permeative destruction, sclerosis and cortical destruction, and intense periosteal reaction (Fig. 32A). On CT scans, bony metastatic lesions from neuroblastoma are typically lytic. On MR images, neuroblastoma metastatic lesions (like those of many malignant tumors) are T1 hypointense, T2 hyperintense, and enhancing. MIBG scintigraphy is helpful for differentiating primary and metastatic disease from neuroblastoma (Fig. 32B). Treatment of metastasis depends on the primary tumor and the stage at diagnosis.

Conclusion

Pediatric patients with hip pain present a diagnostic challenge. The differential possibilities are vast, and yet the clinical findings in many entities overlap. Nevertheless, a timely and precise diagnosis is critical in ensuring early and effective treatment. Taken in context with the history, physical, and laboratory findings, a stepwise imaging approach including radiography, ultrasound, and MRI helps to pinpoint the correct diagnosis, avoid unnecessary interventions, direct appropriate management, and prevent later complications in adulthood.

Suggested Reading


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(Figures start on next page)
Hip Disorders in Children

Fig. 1—5-week-old girl with normal left hip and dysplastic right hip. Delivery was by cesarean section.
A, Sagittal ultrasound image of normal left hip shows normal acetabular angle measuring greater than 60° (white lines) and with 50% coverage (double-headed arrow) of femoral epiphysis (asterisk). Labrum has preserved triangular shape (single-headed arrow), and promontory is not blunted.
B, Axial ultrasound image of normal left hip shows femoral epiphysis (asterisk) well seated in normal acetabulum (arrows).
C, Sagittal ultrasound image of dysplastic right hip shows markedly shallow acetabulum that has alpha angle less than 50° (white lines) and does not cover dislocated femoral epiphysis (asterisk). Promontory is round (curved arrow), and cartilaginous labrum is thickened (straight arrow).
D, Axial ultrasound image of dysplastic right hip shows dislocated femoral epiphysis (asterisk) with only partial presence of acetabulum (arrow).

Fig. 2—4-month-old girl with developmental dysplasia of hip and family history of dysplasia of hip. Frontal radiograph of hips shows dislocated left femoral epiphysis (curved arrow) with shallow ipsilateral acetabulum (straight arrow). Left Shenton line (blue lines) is disrupted. It should normally be smooth and continuous between inferior border of superior pubic ramus and inferomedial border of femoral neck. Right acetabulum is also somewhat shallow.
Fig. 3—11-year-old girl with leg-length discrepancy due to congenital short femur. Frontal radiograph of leg-length study shows substantial shortening of right femur (arrow) with preservation of shape (hypoplasia). Femoral epiphysis has normal shape.

Fig. 4—2-year-old previously healthy boy with Meyer dysplasia (versus normal variant) and left hip bruise after fall from swing. 
A. Frontal radiograph of hips shows smaller and fragmented right femoral epiphysis (arrow) with no sclerosis or subchondral metaphyseal lucency. 
B. Frontal frogleg radiograph shows additional view of abnormal right femoral epiphysis (arrow).

Fig. 5—2-month-old female neonate with asymmetric thighs due to proximal femoral focal deficiency (Aitken class B). Frontal radiograph of pelvis shows hypoplastic proximal right femur, which is irregular with medial cortical thickening (straight arrow). Coxa vara is also present. Shallow ipsilateral acetabulum (curved arrow) and lateral position of proximal right femur (asterisk) indicate hip dislocation.
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Fig. 6—4-month-old female neonate with asymmetrically short left leg due to proximal femoral focal deficiency (Aitken class B).
A, Frontal radiograph of abnormal left leg shows foreshortened femur with minimal middiaphyseal beaking and mild lateral bowing (arrow).
B, Frontal radiograph shows normal right leg for comparison.
C, Sagittal ultrasound image of left hip shows femoral epiphysis (asterisk) and slightly dysplastic acetabulum with thickened labrum (single-headed arrow), shallow alpha angle (white lines), and uncovering of femoral epiphysis (double-headed arrow).

Fig. 7—7-year-old boy with left limp for 4 weeks due to Legg-Calvé-Perthes disease. Frontal frogleg radiograph shows mild asymmetry in size of left femoral epiphysis and linear oblique subchondral lucency (arrow) paralleling articular surface.
Fig. 8—6-year-old boy with bilateral hip pain due to bilateral Legg-Calvé-Perthes disease, more advanced on right. Frontal hip radiograph shows coxa plana (femoral epiphysis flattening), coxa magna (broadening of femoral epiphysis and neck) (double-headed arrow), and fragmentation and sclerosis of right femoral epiphysis (single-headed arrow). Right femoral epiphysis is contained by acetabulum. Margin of left femoral epiphysis ossification center is slightly irregular and has subchondral linear lucency (curved arrow).

Fig. 9—10-year-old boy with late appearance of Legg-Calvé-Perthes disease diagnosed early in childhood. Frontal radiograph of pelvis shows markedly enlarged right femoral epiphysis with mild acetabular remodeling (blue line), loss of femoral epiphyseal sphericity, and containment by acetabulum (white arrow). Coxa brevis (femoral neck shortening) (black arrow) and lesser trochanter overgrowth (asterisk) are present.
Fig. 10—5-year-old boy with bilateral hip pain due to Legg-Calvé-Perthes disease.
A, Frogleg radiograph shows only slight asymmetry of femoral epiphyses, left (arrow) smaller than right.
B, Coronal T1-weighted MR image shows subtly decreased signal intensity of left femoral epiphysis (arrow).
C, Coronal STIR MR image shows subtle patchy increased signal intensity in left femoral epiphysis (arrow) without joint effusion.
D, Gadolinium-enhanced subtraction MR image of left hip shows lack of enhancement in left femoral epiphysis (arrow).
E, Coronal 2-minute delayed contrast-enhanced T1-weighted MR image shows no enhancement in left femoral epiphysis (short arrow) compared with normal right femoral epiphysis (long arrow).
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Fig. 11—8-year-old girl with right coxa vara, left coxa valga, and limp. Frontal radiograph of hips shows decreased femoral neck-shaft angle (single-headed arrow) on right and increased angle on left. Uncovering of left femoral epiphysis by shallow ipsilateral acetabulum (double-headed arrow) is evident.

Fig. 12—5-year-old boy with left hip pain and low-grade fever due to toxic synovitis. History includes recent upper respiratory infection. He recovered fully with expectant management. 
A, Frontal radiograph of hips shows distention of gluteal fat planes (arrows) on left. Findings are suggestive of hip effusion. 
B, Sagittal color Doppler ultrasound image of left hip shows anechoic left hip effusion (asterisk) with synovial thickening (arrow) indicative of synovitis.
Fig. 13—4-year-old girl with high fever, leukocytosis, and limp due to septic arthritis.

A, Frontal radiograph of hips shows only asymmetric widening of right hip joint space (asterisk).

B, Ultrasound images of both hips show small right hip effusion (calipers) with internal debris and thickening of synovium (arrow), indicating synovitis. Mild stranding of overlying soft-tissue planes (asterisk) is evident. Left hip joint is normal without joint effusion.

C, Coronal STIR MR image of hips shows large right hip joint effusion (asterisk), edema (curved arrow) of surrounding muscles consistent with myositis, and fluid collection (straight arrow) in muscles of medial right hip.

D, Coronal contrast-enhanced fat-suppressed T1-weighted MR image shows right hip joint effusion (asterisk) with synovial enhancement (long arrow), indicating synovial inflammation, enhancement of periarticular muscles, and rim enhancement of soft-tissue fluid collection (short arrow).
Fig. 14—12-year-old boy with left hip pain for 2 weeks and fever due to osteomyelitis of left femur (biopsy-proven).
A, Frontal radiograph of hips shows focal area of sclerosis (arrow) with central lucency in proximal diaphysis of left femur.
B, Coronal STIR MR image shows localized increased signal intensity (asterisk) in sclerotic area depicted in A.
C, Coronal T1-weighted fat-suppressed gadolinium-enhanced MR image shows enhancement (asterisk) of proximal left femoral diaphysis. Normal proximal right femoral diaphysis also is evident.

Fig. 15—15-year-old girl with bilateral chronic hip pain due to juvenile idiopathic arthritis. Frontal frogleg radiograph shows subchondral sclerosis and erosions in articular surface of both femoral epiphyses and acetabular roofs with substantial joint space narrowing (arrows). Abnormal configuration of pelvis and generalized osteopenia are also evident.

Fig. 16—9-year-old boy with bilateral leg weakness and elevated creatine phosphokinase concentration due to juvenile dermatomyositis. Coronal STIR MR image of both thighs shows marked diffuse increased signal intensity (asterisks) in muscles of pelvic floor and most of thighs, especially lateral compartment (arrows).
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Fig. 17—13-year-old boy with hip pain for 1 week due to right slipped capital femoral epiphysis. A, Frontal radiograph of hips shows subtle widening of physeal plate of right proximal femoral epiphysis (arrow) with accentuated internal position of epiphysis. Klein line sign (oblique line) is not present because line intersects inferolateral corner of femoral epiphysis. B, Frogleg image of hips better shows physeal widening (arrow) and epiphyseal slippage.

Fig. 18—15-year-old boy with left hip pain for 3 months due to left slipped capital femoral epiphysis. Frontal radiograph of hips shows substantial widening and obliteration of left proximal femoral physeal plate (arrow) and inferomedial position of femoral epiphysis. Klein line sign (oblique line) is present in this advanced case.

Fig. 19—12-year-old female runner with left hip pain while running caused by stress fracture of left femoral neck. Coned view frontal radiograph of left hip shows sclerosis (short arrow) and periosteal reaction (long arrow) along medial side of left femoral neck at level of lesser trochanter.

Fig. 20—16-year-old male soccer player with acute right hip pain after failed kick, which caused acute avulsion of ischial apophysis (hamstring insertion). Frontal radiograph of hips shows curvilinear ossific density (arrow) paralleling right ischium and corresponding to avulsed ischial apophysis.
Fig. 21—14-year-old female cheerleader with acute avulsion of anterior superior iliac spine apophysis (sartorius insertion) causing acute left hip pain during practice. Coned view radiograph of left hip and iliac wing shows small linear ossific fragment (arrow) adjacent to anterior superior iliac spine. Finding is diagnostic of avulsed ossification center.

Fig. 22—13-year-old hurdler with acute left hip pain due to acute avulsion of lesser trochanter apophysis (psoas insertion). Frontal radiograph of hip shows separation of lesser trochanter ossification center (arrow). Finding is diagnostic of avulsion fracture.

Fig. 23—7-year-old girl with left limp due to unicameral bone cyst. Frontal radiograph of hips shows large, geographic, lytic, intramedullary lesion (arrows) in left femoral neck and proximal diaphysis.
Fig. 24—9-year-old boy with left pelvic pain due to aneurysmal bone cyst.  

A, Frontal radiograph of pelvis shows geographic lytic lesion (arrows) in left iliac wing abutting ipsilateral sacroiliac joint. Some internal septations are evident in lesion (but more apparent at MRI).  

B, Coronal STIR MR image of pelvis shows that well-defined lesion (arrows) in left iliac wing has fluid signal intensity and contains internal septations.  

C, Axial T2-weighted fat-suppressed MR image shows fluid-fluid levels (arrows) within cystic lesion of left iliac wing.

Fig. 25—14-year-old girl with hip pain due to enchondromatosis. Frontal radiograph shows multiple enchondromas (arrows) involving and deforming left iliac wing, proximal femurs (left more than right), and both ischia.

Fig. 26—16-year-old boy with family history of multiple hereditary exostoses. Frontal radiograph of pelvis shows multiple osteochondromas arising from iliac wing margins (arrows) and both femoral necks, causing undertubulation (asterisks) of femurs.
Fig. 27—11-year-old girl with osteoid osteoma of right femoral neck causing intermittent right hip pain for several months.  
A, Frontal radiograph of pelvis shows small round lucency (circle) in base of right femoral neck with central focus of sclerosis consistent with nidus. 
B, Coronal reformatted CT image shows osteoid osteoma (arrow) as small round lucency containing central sclerotic nidus.

Fig. 28—4-year-old boy with known diagnosis of Langerhans cell histiocytosis and new onset of right hip pain.  
A, Frontal radiograph of hips shows expansile, geographic, lytic lesion (asterisk) of right ischium. 
B, Coronal STIR MR image of pelvis shows lytic lesion (asterisk) to be hyperintense and causing mild cortical breakthrough and surrounding soft-tissue edema. 
C, Coronal T1-weighted gadolinium-enhanced fat-suppressed MR image shows substantial enhancement, not only of ischial lesion (asterisk) but also of adjacent soft-tissue edema (arrows).

Fig. 29—13-year-old boy with polyostotic fibrous dysplasia.  
A, Frontal radiograph of hips shows lytic, expansile, intramedullary, geographic lesions (asterisks) involving both femoral necks and proximal diaphyses with ground-glass matrix. 
B, Left femoral radiograph obtained when acute left hip pain developed 4 years after A shows left coxa vara and shepherd’s crook deformity (arrow) due to pathologic fracture.
Fig. 30—16-year-old boy with Ewing sarcoma causing right hip pain for 3 months.
A, Frontal radiograph of sacroiliac joints shows sclerosis (arrows) surrounding right sacroiliac joint.
B, Coronal STIR MR image of pelvis shows large hyperintense lobulated soft-tissue mass (asterisk) adjacent to right iliac wing. Iliac bone (arrow) is diffusely hyperintense.
C, Coronal T1-weighted fat-suppressed gadolinium-enhanced MR image shows diffuse enhancement of soft-tissue mass (asterisk) and entire iliac wing, including roof of acetabulum.

Fig. 31—17-year-old male adolescent with non-Hodgkin lymphoma causing fatigue, weakness, and right hip pain for 2 months.
A, Frontal radiograph of pelvis shows poorly defined permeative lesion (circle) in right femoral neck.
B, Coronal T2-weighted fat-suppressed MR image clearly depicts multifocal femoral involvement with several patchy hyperintense areas (asterisks) involving left femoral epiphysis and greater trochanter and right femoral neck. Associated soft-tissue mass (arrow) is present along undersurface of right femoral neck.
C, Coronal PET scan shows global extension of disease. Multifocal hypermetabolic adenopathy is present in both axillae, mediastinum, abdomen, and retroperitoneum. Involvement of both kidneys and proximal femurs also is evident.
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Fig. 32—3-year-old boy with diffuse bilateral hip pain due to metastatic neuroblastoma. 

A, Frontal radiograph of hips shows permeative pattern (asterisks) involving both iliac wings and femoral necks. 

B, Whole-body MIBG scan shows hot areas in entire spine, both iliac wings, femurs, and humeri, indicating diffuse metastatic disease. Physiologic uptake of radiopharmaceutical by salivary glands is evident.