ACR Appropriateness Criteria® Limping Child—Ages 0 to 5 Years

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The appropriate imaging for pediatric patients (ages 0-5 years) being evaluated for limping depends on the clinical presentation, specifically, the presence of signs of infection, any localization of pain, and history of or suspected trauma. Common diagnoses causing limping in children are briefly reviewed, and recommended imaging techniques are discussed, including toddler's fracture, transient synovitis, septic arthritis, Legg-Calvé-Perthes disease, and osteomyelitis.

The ACR Appropriateness Criteria® are evidence-based guidelines for specific clinical conditions that are reviewed every 2 years by a multidisciplinary expert panel. The guideline development and review include an extensive analysis of current medical literature from peer-reviewed journals and the application of a well-established consensus methodology (modified Delphi) to rate the appropriateness of imaging and treatment procedures by the panel. In those instances in which evidence is lacking or not definitive, expert opinion may be used to recommend imaging or treatment.

Key Words: Appropriateness criteria, limping child, hip pain, toddler's fracture, transient synovitis, septic arthritis

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SUMMARY OF LITERATURE REVIEW

A limping child can be a diagnostic dilemma for clinicians [1-10]. The role of radiology in the evaluation varies depending on the clinical presentation, signs, and symptoms. In general, the differential diagnosis of limping depends on the patient's age, the presence of signs of infection, any localization of pain, and a history of trauma [11]. The presence of fever, elevated white blood count, elevated erythrocyte sedimentation rate (ESR), or elevated C-reactive protein may suggest infection. Increased heart rate may be a sign of infection but may also be explained by the presence of pain. The presence of erythema, swelling, or maximal tenderness may help localization. Physical maneuvers and signs such as the Trendelenburg test, Galeazzi sign, Patrick (flexion, abduction, and external rotation) test, pelvic compression test, and psoas sign may also help localize pain [12]. A detailed analysis of gait can also suggest the diagnosis [11].

Many articles discussing clinical evaluation and differential diagnoses have been written, with several clinical algorithms proposed [1,10,13-15], but there are no pro-

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The ACR seeks and encourages collaboration with other organizations on the development of the ACR Appropriateness Criteria® through society representation on expert panels. Participation by representatives from collaborating societies on the expert panel does not necessarily imply individual or society endorsement of the final document.

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Variant 1. Nonlocalizable pathology by clinical evaluation (no concern for infection)

Radiologic Procedure	Rating	Comments	Relative Radiation Level
X-ray lower leg	8	Tibia/fibula only.	☢
Ultrasound hip	6	Toxic synovitis and septic arthritis usually present with localizing symptoms.	O
X-ray pelvis and leg and foot	5	May be considered as secondary investigation after negative tibia/fibula examination.	☢☢
X-ray lumbar spine	5	Frontal and lateral views.	☢☢
^{99m}Tc 3-phase bone scan lower thoracic spine to distal lower extremities	5		☢☢☢
MRI lower thoracic spine to lower extremities without contrast	5	Superior to bone scan for soft tissue pathology. Data for contrast administration in this scenario are limited. Sedation risks should be considered.	O
MRI lower thoracic spine to lower extremities without and with contrast	5	Superior to bone scan for soft tissue pathology. Data for contrast administration in this scenario are limited. Use contrast if needed based on evaluation of noncontrast MRI findings. Sedation risks should be considered. See statement regarding contrast in text under "Anticipated Exceptions."	O

Note: Rating scale: 1, 2, and 3 = usually not appropriate; 4, 5, and 6 = may be appropriate; 7, 8, and 9 = usually appropriate.

spective studies using imaging algorithms for evaluation of a limping child.

To provide clear and helpful recommendations, the differential diagnosis can be narrowed down by clinical scenarios: (1) trauma, (2) no trauma and no signs of infection, and (3) possible presence of infection. These scenarios, when paired with the ability to localize the pain, allow a radiologic algorithm to help guide appropriate imaging (see Variants 1-3).

Scenario 1: Trauma

The most common etiology of acute limping in children is traumatic injury [1]. Clinical examination and history may allow localization of the pain or injury to a specific area, which can target the radiologic examination. Targeted radiographs in 2 or 3 planes of the area of concern are appropriate in this scenario. Unfortunately, particularly in small children, it is common that the pain cannot be accurately localized to one focal area.

Variant 2. Localized pathology by clinical evaluation (no concern for infection)

Radiologic Procedure	Rating	Comments	Relative Radiation Level
X-ray area of interest	9		NS
MRI area of interest without contrast	6	Sedation risks should be considered.	O
MRI area of interest without and with contrast	6	Use contrast if needed based on evaluation of noncontrast MRI findings. Sedation risks should be considered. See statement regarding contrast in text under "Anticipated Exceptions."	O
Ultrasound area of interest	5	Consider for palpable soft tissue mass or suspected joint effusion. Provides only limited data for evaluation of osseous abnormalities.	O
CT area of interest without contrast	3		Varies
CT area of interest with contrast	2		Varies
CT area of interest without and with contrast	1		Varies

Note: Rating scale: 1, 2, and 3 = usually not appropriate; 4, 5, and 6 = may be appropriate; 7, 8, and 9 = usually appropriate.

Variant 3. Concern for infection, including septic arthritis

Radiologic Procedure	Rating	Comments	Relative Radiation Level
Ultrasound hips	9		O
X-ray pelvis	8		☢☢
MRI pelvis without contrast	7	Sedation risks should be considered.	O
MRI pelvis without and with contrast	7	Use contrast if needed based on evaluation of noncontrast MRI findings. Sedation risks should be considered. See statement regarding contrast in text under "Anticipated Exceptions."	O
X-ray lumbar spine	5		☢☢
^{99m}Tc 3-phase bone scan area of interest	5	If MRI is not available or contraindicated.	☢☢☢
CT area of interest with contrast	4	If MRI is not available or contraindicated.	Varies
CT area of interest without contrast	2		Varies
CT area of interest without and with contrast	1		Varies

Radiography. In children aged <4 years, it is common for clinicians to order plain radiographs from the pelvis to feet because of patients' typical lack of verbalization and the inability to localize symptoms [14,16]. Radiographs of the lower extremities often reveal normal results [17,18], with reports of fracture incidence ranging from 4% to 20%. Tibial fractures are among the most common diagnoses in this scenario [19]. Recently, Baron et al [20] retrospectively evaluated the use of total-extremity radiographs (133 patients) vs tibia films alone (128 patients) in children aged <4 years presenting with non–weight-bearing and nonfocal examinations. Of these 261 patients, 36 (14%) had tibial fractures on initial radiographic imaging. The study found one nontibial fracture (metatarsal) on total-extremity imaging over tibial films and suggests limited imaging focused on the tibia in patients in this age range with nonfocal clinical examinations. The concept of fracture diagnosis with decreased radiography and improved clinical criteria has been documented even in the broader pediatric age range [21,22]. McConnochie et al [21] used logit analysis and statistical modeling to determine that using the most predictive clinical signs and symptoms would avoid 25.8% of lower-extremity radiographs. Rivara et al [22] found that gross deformity and point tenderness detected 97% of lower-extremity fractures in children aged 1 to 15 years and suggested that in the absence of these findings, diagnosing a fracture by radiographs is unlikely.

If initial imaging results are normal but symptoms persist, follow-up imaging may be useful. In the study of Baron et al [20], follow-up radiography in a portion of patients with continued symptoms yielded 4 additional missed tibial fractures, shown to be subtle toddler's fractures with interval development of periosteal reaction. One patient who was discharged later returned with worsening symptoms and signs of infection and was found to have spinal discitis and epidural abscess. As these examples demonstrate, if the results of initial evaluation are negative, follow-up instructions and evaluation may be necessary.

Nuclear Medicine. Radionuclide bone scans have shown some efficacy in evaluating limping children aged <5 years, particularly when the examination is nonfocal [23,24]. Bone scanning provides a total-body screen and is sensitive in detecting bone or soft-tissue abnormalities. Englaro et al [18] studied patients without radiographic abnormalities of the lower extremities and no histories of fever or infection, child abuse, or malignancy and found that 30 of 56 patients had abnormal bone scan results, with the dominant finding of tarsal uptake (16 patients) thought to be due to stress injury. Aronson et al [17] studied a group of 50 children and showed similar findings of localization of abnormal uptake in 54% of patients. It is rare for bone scanning to be the first study in a child with trauma. There are instances in which bone scintigraphy may be helpful in detecting injury, particularly in nonverbal, neurodevelopmentally delayed children [25]. Toddler's fractures are well visualized by bone scans [26], but given the additional cost and radiation exposure, this is not usually the preferred modality of diagnosing toddler's fractures.

CT. The role of CT is limited in the early workup of a child with a limp because of the ionizing radiation and the efficacy of other imaging modalities. It can be useful in preoperative evaluation of known fractures [27], in diagnosing osteoid osteoma, and detecting osteopenia in early tibial stress fractures [28].

MRI. Magnetic resonance imaging is a costly examination and, in this age range, often requires sedation because of the length of the examination. Magnetic resonance imaging is sensitive for soft-tissue and bony injuries, with particular use in the detection of stress fractures [28,29]. It may be performed in selected younger children, when complications, alternate diagnoses, or subtle injuries need to be diagnosed or excluded.

Scenario 2: No Trauma and No Signs of Infection

In this scenario, patients may present with nonacute development of limping or possibly unwitnessed acute trauma. The differential diagnosis in this scenario is broader and encompasses other entities, such as toxic synovitis, Legg-Calvé-Perthes disease, juvenile idiopathic arthritis (JIA), developmental dysplasia of the hip, child abuse, and neoplasm.

Transient synovitis of the hip, also known as toxic synovitis, affects approximately 3% of children, typically during the ages of 3 to 10 years. Although the etiology is not completely elucidated, many children who present with transient synovitis will have had upper respiratory illnesses in the preceding 2 weeks, suggesting an inflammatory postviral response. Nearly all children recover with rest and anti-inflammatory medication within 2 weeks [30]. In a prospective study of 243 children aged <14 years presenting with atraumatic limps [31], the most common diagnosis was transient synovitis. Radiographs may demonstrate subtle signs of toxic synovitis, such as hip joint space widening, loss of soft tissue planes around the hip joint, or slight demineralization of the bone of the proximal femoral metaphysis. However, the sensitivity and specificity of radiographs for this diagnosis are low. Making an accurate and specific diagnosis on the basis of a bone scan may be difficult because the scan may show decreased uptake early in the disease process and increased uptake later because of hyperemic response.

Ultrasound of the hip is a fast, radiation-free examination that has high sensitivity for detecting hip effusions [32]. Given the frequency of diagnosis, Fischer and Beattie [31] routinely use ultrasound as the primary imaging modality, reserving radiography for cases in which the results of ultrasound were negative. Terjesen and Osthus [33] also suggested ultrasound as the primary imaging technique in transient synovitis, with radiography being unnecessary in uncomplicated cases. False-negative results can occur with ultrasound, with a reported rate of 5%, because of inadequate examinations or very early scanning [34]. One study showed that radionuclide bone scan in the workup for irritable hip had limited diagnostic value when findings on ultrasound were negative [35]. Because transient synovitis may have overlap clinically with septic arthritis, laboratory values and fluid aspiration are key in differentiating the two entities [36]. MRI has been shown to be helpful in differentiating transient synovitis from septic arthritis [37,38].

Legg-Calvé-Perthes disease is an idiopathic avascular necrosis of the proximal femoral epiphysis. It is a rare condition, affecting 0.005% to 0.016% of the population, with a predisposition toward boys (5:1). It is typically diagnosed between 2 and 14 years of age, with peak incidence at 5 to 6 years of age. Typically unilateral, Legg-Calvé-Perthes disease can occur in both hips in 15% of patients. Evaluation traditionally begins with radiography (anteroposterior and frog-leg lateral positions). Early in the disease process, subcortical lucency may be seen, with progression to femoral head cortical collapse, fragmentation, sclerosis, and widening and shortening of the femoral head and neck.

There are definite roles for contrast-enhanced MRI and bone scintigraphy, particularly in classification and outcome prediction in patients with Langerhans cell histiocytosis [39-47]. Postcontrast MRI can show its avascular appearance within the proximal femoral epiphysis and better delineates its extent and severity to allow a more accurate prognosis [40].

Juvenile idiopathic arthritis is a diagnosis that applies to any arthritis of unknown origin that occurs before the age of 16 years and persists for >6 weeks. The classification of JIA is recent (2000) and encompasses many subgroups (and previous classifications) of arthritides, including juvenile chronic arthritis and juvenile rheumatoid arthritis. Its overall incidence is not well reported, but it is thought to be a rare cause of limping in children and can present even in the preschool years. Initial radiographic findings can be normal or show minor nonspecific changes such as soft tissue swelling, joint effusion, or osteopenia. Progressive radiographic changes such as joint space narrowing, erosive changes, and joint ankylosis are seen later in the disease course [48]. Ultrasound has been shown to be an excellent tool in the evaluation and follow-up of JIA and more sensitive than radiography or clinical examination in detecting effusions, synovial hypertrophy, and synovial cysts. MRI is superior to both ultrasound and radiography in detecting inflammatory changes in the joint and cartilage damage. Subtle erosions, loss of joint space, cartilage damage, and ligamentous involvement are also better detected and delineated with MRI [49]. Although ultrasound and MRI are the best modalities for detection and follow-up of JIA, limited use of bone scanning is reported. Actively inflamed joints can be demonstrated. However, increased uptake is also seen in normal growth plates, which may be very close to the adjacent joints, thus limiting the evaluation [50].

Developmental dysplasia of the hip is often diagnosed within the first year of life by physical examination or radiologic screening in predisposed populations. Specific ACR Appropriateness Criteria® have been constructed for this scenario [51]. If clinical history suggests undiagnosed developmental dysplasia of the hip in an older

infant or child, anteroposterior radiography of the hips will confirm the diagnosis.

Child abuse should be considered a possibility if soft tissue or skeletal injuries are identified without the appropriate traumatic clinical history. Because this is an extremely important topic, separate ACR Appropriateness Criteria have been constructed for guidance in imaging [52].

Neoplasm may present in scenario 2 or 3 and is discussed below.

Scenario 3: Possible Infection

Limping in the presence of one or more of the following clinical and laboratory signs should suggest the possibility of infection: fever, elevated white blood count, elevated ESR, or elevated C-reactive protein. The differential diagnoses in this scenario most commonly include septic arthritis, transient synovitis, osteomyelitis, discitis, and psoas abscess. Neoplastic entities, such as leukemia, osteosarcoma, Ewing's sarcoma, Langerhans cell histiocytosis, and osseous metastatic disease, may present in either scenario 2 or 3.

Septic arthritis is the most common cause of acute severe monoarticular pain in children. It typically results from hematogenous and subsequent intra-articular *Staphylococcus aureus*, with the hip being the most common site of involvement [53,54]. Septic arthritis requires rapid diagnosis to prevent or limit adverse outcomes [55].

Osteomyelitis is most common in young children, peaking at about 3 years of age, with approximately half of the cases occurring in children aged <5 years. Hematogenous spread of disease is the most common source, and *S aureus* is the most common organism isolated. One-third of children presenting with osteomyelitis will have histories of recent trauma at the site, and involvement is most common at the metaphyseal region of the long bones of the lower extremities [6,56].

Discitis is a rare inflammatory or infectious process of the intervertebral disc, which may involve the adjacent vertebral bodies (osteomyelitis) and may extend into the adjacent soft tissues and epidural space. An incidence of 1 in 100,000 is reported with a bimodal distribution, with a peak incidence at ages 1 to 4 years and less commonly at 10 to 14 years. A recent study and review of cases suggests that discitis can be a difficult diagnosis to make, particularly because of the lack of early radiographic and definitive bone scan findings [57].

Neoplasm should be included in the differential diagnosis because the laboratory findings and presentation may overlap with osteomyelitis. Diffuse marrow abnormalities may suggest leukemia or metastatic disease, particularly in neuroblastoma. Soft tissue masses and associated calcification should raise concern for osteosarcoma and Ewing's sarcoma, although they are less common in the patients aged 1 to 5 years.

Langerhans cell histiocytosis is an aggressive marrow-replacing histiocytic disorder thought to be either inflammatory or neoplastic, with a reported incidence of 8 to 9 in 1 million. Involvement can be at a single site or can involve multiple organs. Imaging appearance may be benign, as with a well-circumscribed lytic lesion, or can be aggressive with associated soft tissue mass, overlapping in appearance with osteomyelitis and tumor.

Myositis and soft tissue abscesses are less common but have been reported in all ages of children, including infants and toddlers, but the largest clustering in children seems to be in children aged 6 to 17 years [58-60].

Given the spectrum of these differential diagnoses, imaging guidelines can be further classified by the clinical examination: localized pain (hip or nonhip) or nonlocalizable pain.

Scenario 3A: Localized Pain to the Hip

Localization is important in the radiologic evaluation of the patient. If the pain seems localized to the hip, the diagnosis of exclusion is septic arthritis. As mentioned in the discussion of transient synovitis above, ultrasound of the hip allows the quick and accurate diagnosis of a joint effusion. Aspiration is the gold standard in differentiating septic arthritis from transient synovitis [32,61,62]. There are studies suggesting that clinical data can help determine which effusions need to be aspirated [53,63,64]. The presence of fever, an elevated C-reactive protein level, an elevated ESR, lack of weight bearing, and an elevated serum white blood cell count have been shown to be indicators of septic arthritis, with the presence of several of these factors and documented joint indicating a >90% probability of septic arthritis [55,63]. However, this clinical protocol has proven less specific in other researchers' studies [62]. MRI of the pelvis in cases of septic arthritis may demonstrate associated osteomyelitis or associated soft tissue abscess [65] and may be considered after sonography if clinical history suggests a long-standing infection.

In the absence of a hip effusion and with signs of infection and hip localization, a diagnosis of pelvic osteomyelitis or pyomyositis should be considered. A study by Karmazyn et al [66] concluded that plain radiographs of the pelvis may be somewhat useful, but their sensitivity for detecting abnormalities may be as low as 11% to 30%. MRI, given its sensitivity to musculoskeletal injury and inflammation, is extremely useful in diagnosing infection, specifically osteomyelitis and pyomyositis [67-70]. Findings of infection on MRI include abnormal bone marrow signal, soft tissue inflammation, abnormal enhancement and intraosseous, subperiosteal, or soft tissue abscess formation. Contrast administration in the MR evaluation of suspected soft tissue or osseous infection does not increase sensitivity or specificity but may increase reader confidence and better delineate abscesses [71,72]. As stated earlier, a benefit of MRI is its lack of ionizing radiation; however, the need for sedation in young patients may complicate its use in diagnosis. Although bone scanning has been shown to detect osteo-

myelitis in radiographically silent cases, in the study of Karmazyn et al, bone scanning was found to have only 70% sensitivity in 33 patients compared with MRI. Consequently, the investigators recommended pelvic MRI in pediatric patients with acute hip pain, ESRs >30 mm/h, and no evidence of septic hip.

Scenario 3B: Localized Pain, Nonhip or Lower Extremity

Plain radiographs of the localized area of pain should be obtained. Irregular or mottled lucencies reflect marrow abnormality, and periosteal elevation demonstrates inflammatory reaction and chronicity, as in infection or neoplasm. Soft tissue mass and calcification without a history of trauma suggest neoplasm. MRI, given its sensitivity to musculoskeletal injury and inflammation, is extremely useful in diagnosing infection, specifically osteomyelitis and pyomyositis [67-70]. Findings of infection on MRI include abnormal bone marrow signal, soft tissue inflammation, abnormal enhancement, and intraosseous, subperiosteal, or soft tissue abscess formation. Contrast administration in the MR evaluation of suspected soft tissue or osseous infection does not increase sensitivity or specificity but may increase reader confidence and better delineate abscesses [71,72]. As stated earlier, a benefit of MRI is the lack of ionizing radiation, but the need for sedation in young patients may complicate its use in diagnosis. Because of the severity of late diagnosis of infection, the presence of signs and symptoms of infection often outweighs the risks of sedation in this scenario. Although bone scanning has been reported to have high sensitivity for the diagnosis of osteomyelitis [73], MRI has been advocated as the imaging technique of choice for the evaluation of pelvic osteomyelitis because of its lack of ionizing radiation and better ability to detect abscesses [74]. Although no prospective study of MRI vs bone scanning has been performed in this scenario, review of recent literature suggests that MRI is commonly used in the evaluation. A recent retrospective study examining bone scanning and MRI demonstrated a much higher sensitivity of MRI (99%) compared with bone scan (53%) and suggested that the imaging algorithm of plain radiography be followed by MRI [75]. Even after positive results on bone scanning, MRI is often performed for further evaluation of soft tissues to detect any abscess formation [76].

Scenario 3C: Nonlocalized Pain

In nonlocalizable limping with possible infection, radiographs of the spine, pelvis, and lower extremities may help localize an abnormality. However, low sensitivities have been reported [66,75]. As stated above, in the acute presentation of osteomyelitis, plain radiographic results are typically normal. MRI or bone scanning can be considered in this scenario. Although there have been no prospective studies comparing MRI and bone scanning in the evaluation for osteomyelitis, both imaging techniques have reported high sensitivity for the diagnosis. Positives for performing MRI include lack of ionizing radiation and better resolution and soft tissue evaluation, with the dominant negative being the need for sedation in this age group. Contrast administration during MRI has not been shown to be necessary in the evaluation for soft tissue or osseous infection, particularly in the absence of signs of edema [71,72]. Positives for bone scanning include cost-effective diagnosis and whole-body imaging for site localization, with the dominant negative being the lack of soft tissue detail and abscess detection [73] and slightly decreased sensitivity [75,76]. As stated above, review of the literature suggests that more centers may be using MRI in the evaluation for osteomyelitis, but no prospective study has fully evaluated the scenario of a limping child without a localizable site.

Fluorine-18-2-fluoro-2-deoxy-D-glucose PET imaging and leukocyte scintigraphy can be useful in evaluating chronic osteomyelitis, outperforming MRI and radiography in a study by Termaat et al [77]. Whole-body MRI may also be helpful in children with multifocal abnormalities [78].

SUMMARY

- The type of imaging evaluation to be used for a limping child can be determined after a thorough clinical evaluation. Eliciting a history of trauma or signs of infection can help focus the imaging pathway to diagnosis.
- Imaging pathways for the above-described 3 scenarios (trauma, no trauma and no signs of infection, and possible presence of infection) vary because of the diverse differential diagnoses in these subgroups.
- In a posttraumatic setting, localized radiography or tibial radiography is most appropriate.
- In a patient with an atraumatic and noninfectious history, hip ultrasound may be the initial study of choice, with radiography to follow if the ultrasound findings are negative. If there is a suggestion of infection, MRI is the study of choice, with radiography a low-sensitivity but commonly obtained initial imaging modality. Bone scanning may also be considered in this setting, particularly if the site of tenderness or pain cannot be determined.

ANTICIPATED EXCEPTIONS

Nephrogenic systemic fibrosis is a disorder with a scleroderma-like presentation and a spectrum of manifestations that can range from limited clinical sequelae to fatality. It seems to be related to both underlying severe renal dysfunction and the administration of gadolinium-based contrast agents. It has occurred primarily in patients on dialysis, rarely in patients with very limited glomerular filtration rates (ie, <30 mL/min/1.73 m^2), and almost never in other patients. There is growing

Table 1. Relative radiation level designations

Relative Radiation Level	Adult Effective Dose Estimate Range (mSv)	Pediatric Effective Dose Estimate Range (mSv)
O	0	0
☢	<0.1	<0.03
☢☢	0.1-1	0.03-0.3
☢☢☢	1-10	0.3-3
☢☢☢☢	10-30	3-10
☢☢☢☢☢	30-100	10-30

Note: Relative radiation level assignments for some of the examinations cannot be made because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The relative radiation levels for these examinations are designated as varies.

literature regarding nephrogenic systemic fibrosis. Although some controversy and lack of clarity remain, there is a consensus that it is advisable to avoid all gadolinium-based contrast agents in dialysis-dependent patients unless the possible benefits clearly outweigh the risk and to limit the type and amount in patients with estimated glomerular filtration rates < 30 mL/min/1.73 m^2. For more information, please see the ACR's *Manual on Contrast Media* [79].

RELATIVE RADIATION LEVEL INFORMATION

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level indication has been included for each imaging examination. The relative radiation levels are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the relative radiation level dose estimate ranges for pediatric examinations are lower compared with those specified for adults (Table 1). Additional information regarding radiation dose assessment for imaging examinations can be found in *ACR Appropriateness Criteria®: Radiation Dose Assessment Introduction* [80].

For additional information on ACR Appropriateness Criteria, refer to http://www.acr.org/ac.

REFERENCES

1. Barkin RM, Barkin SZ, Barkin AZ. The limping child. J Emerg Med 2000;18:331-9.
2. Blickman JG, van Die CE, de Rooy JW. Current imaging concepts in pediatric osteomyelitis. Eur Radiol 2004;14(suppl):L55-64.
3. De Boeck H, Vorlat P. Limping in childhood. Acta Orthop Belg 2003; 69:301-10.
4. De Inocencio J. Epidemiology of musculoskeletal pain in primary care. Arch Dis Child 2004;89:431-4.
5. Flynn JM, Widmann RF. The limping child: evaluation and diagnosis. J Am Acad Orthop Surg 2001;9:89-98.
6. Frank G, Mahoney HM, Eppes SC. Musculoskeletal infections in children. Pediatr Clin North Am 2005;52:1083-106.
7. Gunner KB, Scott AC. Evaluation of a child with a limp. J Pediatr Health Care 2001;15:38-40.
8. Leet AI, Skaggs DL. Evaluation of the acutely limping child. Am Fam Physician 2000;61:1011-8.
9. Newberg AH, Newman JS. Imaging the painful hip. Clin Orthop Relat Res 2003;Jan:19-28.
10. Swischuk LE. Emergency pediatric imaging: changes over the years. Part II. Emerg Radiol 2005;11:253-61.
11. Swischuk LE. The limping infant: imaging and clinical evaluation of trauma. Emerg Radiol 2007;14:219-26.
12. Sawyer JR, Kapoor M. The limping child: a systematic approach to diagnosis. Am Fam Physician 2009;79:215-24.
13. Fordham L, Auringer ST, Frush DP. Pediatric imaging perspective: acute limp. J Pediatr 1998;132:906-8.
14. Oudjhane K, Newman B, Oh KS, Young LW, Girdany BR. Occult fractures in preschool children. J Trauma 1988;28:858-60.
15. Saigal G, Azouz EM, Abdenour G. Imaging of osteomyelitis with special reference to children. Semin Musculoskelet Radiol 2004;8:255-65.
16. Katz DA. Slipped capital femoral epiphysis: the importance of early diagnosis. Pediatr Ann 2006;35:102-11.
17. Aronson J, Garvin K, Seibert J, Glasier C, Tursky EA. Efficiency of the bone scan for occult limping toddlers. J Pediatr Orthop 1992;12:38-44.
18. Englaro EE, Gelfand MJ, Paltiel HJ. Bone scintigraphy in preschool children with lower extremity pain of unknown origin. J Nucl Med 1992;33:351-4.
19. John SD, Moorthy CS, Swischuk LE. Expanding the concept of the toddler's fracture. Radiographics 1997;17:367-76.
20. Baron CM, Seekins J, Hernanz-Schulman M, Yu C, Kan JH. Utility of total lower extremity radiography investigation of nonweight bearing in the young child. Pediatrics 2008;121:e817-20.
21. McConnochie KM, Roghmann KJ, Pasternack J, Monroe DJ, Monaco LP. Prediction rules for selective radiographic assessment of extremity injuries in children and adolescents. Pediatrics 1990;86:45-57.
22. Rivara FP, Parish RA, Mueller BA. Extremity injuries in children: predictive value of clinical findings. Pediatrics 1986;78:803-7.
23. Connolly LP, Connolly SA. Skeletal scintigraphy in the multimodality assessment of young children with acute skeletal symptoms. Clin Nucl Med 2003;28:746-54.
24. Connolly LP, Treves ST. Assessing the limping child with skeletal scintigraphy. J Nucl Med 1998;39:1056-61.
25. Nadel HR. Pediatric bone scintigraphy update. Semin Nucl Med 2010; 40:31-40.
26. Miller JH, Sanderson RA. Scintigraphy of toddler's fracture. J Nucl Med 1988;29:2001-3.

27. Cutler L, Molloy A, Dhukuram V, Bass A. Do CT scans aid assessment of distal tibial physeal fractures? J Bone Joint Surg Br 2004;86:239-43.
28. Gaeta M, Minutoli F, Scribano E, et al. CT and MR imaging findings in athletes with early tibial stress injuries: comparison with bone scintigraphy findings and emphasis on cortical abnormalities. Radiology 2005;235: 553-61.
29. Ishibashi Y, Okamura Y, Otsuka H, Nishizawa K, Sasaki T, Toh S. Comparison of scintigraphy and magnetic resonance imaging for stress injuries of bone. Clin J Sport Med 2002;12:79-84.
30. McCarthy JJ, Noonan KJ. Toxic synovitis. Skeletal Radiol 2008;37: 963-5.
31. Fischer SU, Beattie TF. The limping child: epidemiology, assessment and outcome. J Bone Joint Surg Br 1999;81:1029-34.
32. Zawin JK, Hoffer FA, Rand FF, Teele RL. Joint effusion in children with an irritable hip: US diagnosis and aspiration. Radiology 1993;187: 459-63.
33. Terjesen T, Osthus P. Ultrasound in the diagnosis and follow-up of transient synovitis of the hip. J Pediatr Orthop 1991;11:608-13.
34. Gordon JE, Huang M, Dobbs M, Luhmann SJ, Szymanski DA, Schoenecker PL. Causes of false-negative ultrasound scans in the diagnosis of septic arthritis of the hip in children. J Pediatr Orthop 2002;22:312-6.
35. Royle SG. Investigation of the irritable hip. J Pediatr Orthop 1992;12: 396-7.
36. Kocher MS, Zurakowski D, Kasser JR. Differentiating between septic arthritis and transient synovitis of the hip in children: an evidence-based clinical prediction algorithm. J Bone Joint Surg Am 1999;81:1662-70.
37. Lee SK, Suh KJ, Kim YW, et al. Septic arthritis versus transient synovitis at MR imaging: preliminary assessment with signal intensity alterations in bone marrow. Radiology 1999;211:459-65.
38. Yang WJ, Im SA, Lim GY, et al. MR imaging of transient synovitis: differentiation from septic arthritis. Pediatr Radiol 2006;36:1154-8.
39. Comte F, De Rosa V, Zekri H, et al. Confirmation of the early prognostic value of bone scanning and pinhole imaging of the hip in Legg-Calve-Perthes disease. J Nucl Med 2003;44:1761-6.
40. Dillman JR, Hernandez RJ. MRI of Legg-Calve-Perthes disease. AJR Am J Roentgenol 2009;193:1394-407.
41. Gent E, Antapur P, Fairhurst J, Taylor GR, Clarke NM. Perthes' disease in the very young child. J Pediatr Orthop B 2006;15:16-22.
42. Huang GS, Chan WP, Chang YC, Chang CY, Chen CY, Yu JS. MR imaging of bone marrow edema and joint effusion in patients with osteonecrosis of the femoral head: relationship to pain. AJR Am J Roentgenol 2003;181:545-9.
43. Kaniklides C, Lonnerholm T, Moberg A, Sahlstedt B. Legg-Calve-Perthes disease. Comparison of conventional radiography, MR imaging, bone scintigraphy and arthrography. Acta Radiol 1995;36:434-9.
44. Kramer PP. The value of MRI in early Perthes' disease. Pediatr Radiol 1998;28:196-7.
45. Lahdes-Vasama T, Lamminen A, Merikanto J, Marttinen E. The value of MRI in early Perthes' disease: an MRI study with a 2-year follow-up. Pediatr Radiol 1997;27:517-22.
46. Lamer S, Dorgeret S, Khairouni A, et al. Femoral head vascularisation in Legg-Calve-Perthes disease: comparison of dynamic gadolinium-enhanced subtraction MRI with bone scintigraphy. Pediatr Radiol 2002;32: 580-5.
47. Mahnken AH, Staatz G, Ihme N, Gunther RW. MR signal intensity characteristics in Legg-Calve-Perthes disease. Value of fat-suppressed (STIR) images and contrast-enhanced T1-weighted images. Acta Radiol 2002;43:329-35.
48. Johnson K. Imaging of juvenile idiopathic arthritis. Pediatr Radiol 2006; 36:743-58.
49. Lamer S, Sebag GH. MRI and ultrasound in children with juvenile chronic arthritis. Eur J Radiol 2000;33:85-93.
50. Azouz EM. Juvenile idiopathic arthritis: how can the radiologist help the clinician? Pediatr Radiol 2008;38(suppl):S403-8.
51. Karmazyn BK, Gunderman RB, Coley BD, et al. ACR Appropriateness Criteria® on developmental dysplasia of the hip—child. J Am Coll Radiol 2009;6:551-7.
52. Meyer JS, Gunderman R, Coley BD, et al. ACR Appropriateness Criteria® on suspected physical abuse—child. J Am Coll Radiol 2011;8: 87-94.
53. Sherry DD. Limb pain in childhood. Pediatr Rev 1990;12:39-46.
54. Wang CL, Wang SM, Yang YJ, Tsai CH, Liu CC. Septic arthritis in children: relationship of causative pathogens, complications, and outcome. J Microbiol Immunol Infect 2003;36:41-6.
55. Caird MS, Flynn JM, Leung YL, Millman JE, D'Italia JG, Dormans JP. Factors distinguishing septic arthritis from transient synovitis of the hip in children. A prospective study. J Bone Joint Surg Am 2006;88:1251-7.
56. Ranson M. Imaging of pediatric musculoskeletal infection. Semin Musculoskelet Radiol 2009;13:277-99.
57. Arthurs OJ, Gomez AC, Heinz P, Set PA. The toddler refusing to weightbear: a revised imaging guide from a case series. Emerg Med J 2009;26: 797-801.
58. Hernandez RJ, Strouse PJ, Craig CL, Farley FA. Focal pyomyositis of the perisciatic muscles in children. AJR Am J Roentgenol 2002;179:1267-71.
59. Karmazyn B, Kleiman MB, Buckwalter K, Loder RT, Siddiqui A, Applegate KE. Acute pyomyositis of the pelvis: the spectrum of clinical presentations and MR findings. Pediatr Radiol 2006;36:338-43.
60. Okan F, Ince Z, Coban A, Can G. Neonatal psoas abscess simulating septic arthritis of the hip: a case report and review of the literature. Turk J Pediatr 2009;51:389-91.
61. Do TT. Transient synovitis as a cause of painful limps in children. Curr Opin Pediatr 2000;12:48-51.
62. Luhmann SJ, Jones A, Schootman M, Gordon JE, Schoenecker PL, Luhmann JD. Differentiation between septic arthritis and transient synovitis of the hip in children with clinical prediction algorithms. J Bone Joint Surg Am 2004;86-A:956-62.
63. Kocher MS, Mandiga R, Zurakowski D, Barnewolt C, Kasser JR. Validation of a clinical prediction rule for the differentiation between septic arthritis and transient synovitis of the hip in children. J Bone Joint Surg Am 2004;86-A:1629-35.
64. Skinner J, Glancy S, Beattie TF, Hendry GM. Transient synovitis: is there a need to aspirate hip joint effusions? Eur J Emerg Med 2002;9:15-8.
65. Wang E, Ma L, Edmonds EW, Zhao Q, Zhang L, Ji S. Psoas abscess with associated septic arthritis of the hip in infants. J Pediatr Surg 2010;45:2440-3.
66. Karmazyn B, Loder RT, Kleiman MB, et al. The role of pelvic magnetic resonance in evaluating nonhip sources of infection in children with acute nontraumatic hip pain. J Pediatr Orthop 2007;27:158-64.
67. Kim J, Jaramillo D. Imaging of acute hematogenouse osteomyelitis and septic arthritis in children and adults. In: Medina LS, Blackmore CC, eds. Evidence-based imaging: optimizing imaging in patient care. New York: Springer; 2006:591.
68. Koulouris G, Morrison WB. MR imaging of hip infection and inflammation. Magn Reson Imaging Clin N Am 2005;13:743-55.
69. Tas F, Oguz S, Bulut O, Bulut S, Isik AO. Comparison of the diagnosis of plain radiography ultrasonography and magnetic resonance imaging in early diagnosis of acute osteomyelitis experimentally formed on rabbits. Eur J Radiol 2005;56:107-12.
70. White PM, Boyd J, Beattie TF, Hurst M, Hendry GM. Magnetic resonance imaging as the primary imaging modality in children presenting with acute non-traumatic hip pain. Emerg Med J 2001;18:25-9.
71. Averill LW, Hernandez A, Gonzalez L, Pena AH, Jaramillo D. Diagnosis of osteomyelitis in children: utility of fat-suppressed contrast-enhanced MRI. AJR Am J Roentgenol 2009;192:1232-8.
72. Kan JH, Young RS, Yu C, Hernanz-Schulman M. Clinical impact of gadolinium in the MRI diagnosis of musculoskeletal infection in children. Pediatr Radiol 2010;40:1197-205.
73. Connolly LP, Connolly SA, Drubach LA, Jaramillo D, Treves ST. Acute hematogenous osteomyelitis of children: assessment of skeletal

scintigraphy-based diagnosis in the era of MRI. J Nucl Med 2002;43:1310-6.

74. Connolly SA, Connolly LP, Drubach LA, Zurakowski D, Jaramillo D. MRI for detection of abscess in acute osteomyelitis of the pelvis in children. AJR Am J Roentgenol 2007;189:867-72.
75. Browne LP, Mason EO, Kaplan SL, Cassady CI, Krishnamurthy R, Guillerman RP. Optimal imaging strategy for community-acquired Staphylococcus aureus musculoskeletal infections in children. Pediatr Radiol 2008;38:841-7.
76. Kumar J, Ramachandran M, Little D, Zenios M. Pelvic osteomyelitis in children. J Pediatr Orthop B 2010;19:38-41.
77. Termaat MF, Raijmakers PG, Scholten HJ, Bakker FC, Patka P, Haarman HJ. The accuracy of diagnostic imaging for the assessment of chronic osteomyelitis: a systematic review and meta-analysis. J Bone Joint Surg Am 2005;87:2464-71.
78. Mentzel HJ, Kentouche K, Sauner D, et al. Comparison of whole-body STIR-MRI and 99mTc-methylene-diphosphonate scintigraphy in children with suspected multifocal bone lesions. Eur Radiol 2004; 14:2297-302.
79. American College of Radiology. Manual on contrast media v7. Available at: http://www.acr.org/Quality-Safety/Resources/Contrast-Manual. Accessed June 16, 2012.
80. American College of Radiology. ACR Appropriateness Criteria®: radiation dose assessment introduction. Available at: http://www.acr.org/~/media/ACR/Documents/AppCriteria/RRLInformation.pdf. Accessed June 16, 2012.