

**American College of Radiology  
ACR Appropriateness Criteria®  
Developmental Dysplasia of the Hip-Child**

**Variant: 1 Child, younger than 4 weeks of age. Equivocal physical examination or risk factors for DDH. Initial imaging.**

Procedure	Appropriateness Category	Peds Relative Radiation Level
US hips	Usually Not Appropriate	○
Radiography pelvis	Usually Not Appropriate	☢☢

**Variant: 2 Child, between 4 weeks to 4 months of age. Equivocal physical examination or risk factors for DDH. Initial imaging.**

Procedure	Appropriateness Category	Peds Relative Radiation Level
US hips	Usually Appropriate	○
Radiography pelvis	Usually Not Appropriate	☢☢

**Variant: 3 Child, younger than 4 months of age. Physical findings of DDH. Initial imaging.**

Procedure	Appropriateness Category	Peds Relative Radiation Level
US hips	Usually Appropriate	○
Radiography pelvis	Usually Not Appropriate	☢☢

**Variant: 4 Child, between 4 to 6 months of age. Concern for DDH. Initial imaging.**

Procedure	Appropriateness Category	Peds Relative Radiation Level
Radiography pelvis	Usually Appropriate	☢☢
US hips	May Be Appropriate	○

**Variant: 5 Child, older than 6 months of age. Concern for DDH. Initial imaging.**

Procedure	Appropriateness Category	Peds Relative Radiation Level
Radiography pelvis	Usually Appropriate	☢☢
US hips	Usually Not Appropriate	○

**Variant: 6 Child, younger than 6 months of age. Known diagnosis of DDH, nonoperative surveillance imaging in harness.**

Procedure	Appropriateness Category	Peds Relative Radiation Level
US hips	Usually Appropriate	○
Radiography pelvis	Usually Not Appropriate	☢☢
MRI pelvis without and with IV contrast	Usually Not Appropriate	○
MRI pelvis without IV contrast	Usually Not Appropriate	○
CT pelvis with IV contrast	Usually Not Appropriate	☢☢☢☢
CT pelvis without IV contrast	Usually Not Appropriate	☢☢☢☢
CT pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢

**Panel Members**

Jie C. Nguyen, MD, MS<sup>a</sup>, Scott R. Dorfman, MD<sup>b</sup>, Cynthia K. Rigsby, MD<sup>c</sup>, Ramesh S. Iyer, MD<sup>d</sup>, Adina L. Alazraki, MD<sup>e</sup>, Sudha A. Anupindi, MD<sup>f</sup>, Dianna M. E. Bardo, MD<sup>g</sup>, Brandon P. Brown, MD<sup>h</sup>, Sherwin S. Chan, MD, PhD<sup>i</sup>, Tushar Chandra, MD<sup>j</sup>, Matthew D. Garber, MD<sup>k</sup>, Michael M. Moore, MD<sup>l</sup>, Nirav K. Pandya, MD<sup>m</sup>, Narendra S. Shet, MD<sup>n</sup>, Alan Siegel, MD, MS<sup>o</sup>, Boaz Karmazyn, MD<sup>p</sup>

## Summary of Literature Review

### Introduction/Background

Developmental dysplasia of the hip (DDH) comprises a spectrum of abnormalities from hip instability to frank dislocation [1,2]. The mildest end of the spectrum overlaps with physiologic immaturity, therefore making it difficult to determine its true incidence, which is estimated to be 1.5 to 20 per 1,000 births, depending on the demographics of the study population and the inclusion criteria [3-5]. The diagnosis and monitoring of teratologic hips from neuromuscular or syndromic causes will not be covered.

The pathophysiology of DDH is multifactorial and not completely understood. The 2 leading causes are laxity induced by maternal hormones and limited in utero hip mobility. In infants with DDH, abnormally increased laxity of the hip capsule and surrounding ligaments have been attributed to the effects of maternal hormone relaxin [1] and a higher concentration of estrogen receptors [6]. In utero restriction to hip mobility can be encountered with oligohydramnios, first-born infants, and prolonged breech positioning. Breech fetal positioning produces extreme hip flexion with knee extension. This leads to shortening and contracture of the iliopsoas muscle, which promotes femoral head dislocation. Studies demonstrating increased prevalence of DDH among monozygotic twins as compared to dizygotic twins [7] and chromosomal analysis in familial DDH and population-based DDH suggest genetic predisposition to DDH [8-10].

The most important risk factors for DDH are female gender, breech positioning in utero, and a positive family history, carrying relative risks of 2.5, 3.8, and 1.4, respectively, in a large meta-analysis [8-11]. Another risk factor is infant swaddling [12,13]. First born, torticollis, foot abnormalities, and oligohydramnios have not been proven to increase the risk of DDH [11]. The left hip is three times more frequent to have DDH with a relative risk of 1.5 [9], theorized to be the result of more common left occiput anterior in utero position, which places the left hip against the mother's spine and limits its abduction. Preterm infants are not at an increased risk for DDH [3,14-16], and there is a lack of consensus on the association between multiparity and DDH [3,8,13].

The natural history of DDH depends on the type and degree of abnormality. Most borderline "abnormal" hips during the neonatal period likely represent physiologic immaturity, as 60% to 80% identified by physical examination and more than 90% identified by ultrasound (US) spontaneously normalize at follow-up [12,17-21]. Late presentation is a major negative prognostic factor, with these patients more likely to require complex treatment [22], surgical intervention [4], and to experience long-term complications [22-24]. Unrecognized and untreated subluxation and dislocation inevitably lead to early degenerative joint disease. It is estimated that DDH is the cause of up to a third of all total hip arthroplasties performed in patients <60 years of age, which emphasizes the importance of proper screening, early diagnosis, and appropriate intervention [25].

The goals of an ideal screening program are early detection of patients who have DDH when

therapy is typically noninvasive and often most effective and exclusion of patients without DDH for whom unnecessary treatment could be costly and potentially harmful. The most important screening method is a hip examination at every well-baby visit according to the recommended periodicity schedule for well-baby examinations (2–4 days for newborns discharged in <48 hours after delivery, by 1 month, 2 months, 4 months, 6 months, 9 months, and 12 months of age) [1,5]. The most serious complication of treatment is avascular necrosis [1,5,26], which is a predictor of poor prognosis [27,28]. Screening can be universal, when all neonates are evaluated, or selective, when only those at risk are evaluated [1,5,26].

Universal US screening for DDH in newborns is performed in some European countries [29], which increases the detection rate of "abnormal" hips. However, there is no evidence that it significantly decreases late diagnosis of DDH [1,5,16,30-32], and the higher rates of abduction splinting carry the risk of overtreatment and iatrogenic avascular necrosis [1,5,26,33]. For these reasons, the American Academy of Pediatrics (AAP) recommends selective screening [1,11] of children with risk factors [34,35] or based on physical examination findings [11]. A positive Barlow or Ortolani test implies an unstable femoral head that can be dislocated or relocated, respectively. Ortolani and Barlow tests are less sensitive after the age of 2 to 3 months because of increased tightening of the hip capsule. After that age, physical examination is less accurate, and the most important finding is limited hip abduction. Other findings may include asymmetric buttock creases and leg length discrepancy [7,11,36].

In the past 2 decades, imaging has become an integral part of screening, diagnosis, and monitoring of children with DDH [20]. A prospective 33-center United Kingdom Hip Trial [37] found that US of children with clinically detected hip instability allowed for a reduction in abduction splinting and was not associated with an increase in abnormal hip development or higher rates of surgical intervention [37].

## Special Imaging Considerations

### US

US is performed using a high-frequency linear array transducer [38]. Two techniques have emerged: a static acetabular morphology method proposed by Graf and a dynamic stress technique proposed by Harcke [39-42].

The Graf method uses coronal imaging of the hip joint. Graf developed a morphologic and geometric hip classification scheme (Types I–IV) using the alpha angle, which measures the osseous acetabular roof angle. The beta angle, which defines the position of the echogenic fibrocartilaginous acetabular labrum, was part of the initial classification but is now infrequently used in routine practice. Femoral head coverage method (Terjesen method) uses a 50% cutoff between normal and abnormal hips [43]. The different types can be broadly grouped into three major categories [40]:

- *Normal hip*: Type I hips are normal and require no treatment. The alpha angle is  $\geq 60^\circ$ .
- *Immature hip*: Type IIa hips are seen in infants <3 months of age. The hip is normally located, but the bony acetabular promontory is rounded, and the alpha angle is  $50^\circ$  to  $59^\circ$ . These patients have a small risk of delayed DDH. This group can be further divided to type IIa+ (alpha angle between  $55^\circ$  and  $59^\circ$ ) and type IIa– (alpha angle between  $50^\circ$  and  $54^\circ$ ). Most

children with stable hips and Graf type IIa will have spontaneous normalization and only conservative management is recommended. The management of type IIa– is controversial as some children (up to 15%, mainly female) have abnormalities that will not resolve [44].

- *Dysplastic hip:* Type IIb has similar features to type IIa, but it is detected in children >3 months of age. Types IIc, IIId, III, and IV represent progressively abnormal hips with frank subluxation in types III and IV. The alpha angle is <50° in types IIc and IIId and <43° in types III and IV.

Harcke [45] developed the dynamic method, using US to attempt to visualize Barlow and Ortolani tests. This technique is performed in both coronal and transverse planes, with and without stress. The modified Barlow test is performed by holding the knee with the hip flexed at 90° and in adduction. The femur is pushed (pistoned) posteriorly. The ACR–AIUM–SPR–SRU Practice Parameter for the Performance of the Ultrasound Examination for Detection and Assessment of Developmental Dysplasia of the Hip combines both static and dynamic techniques [42], which is the most commonly used imaging protocol practiced at most children’s hospitals throughout the United States. The main disadvantage of US is that it has high interobserver variability, particularly for milder cases of dysplasia [39,46-48].

## Radiography

An anteroposterior radiograph of the pelvis with the hips in neutral position allows visualization of the femoral head ossific nucleus and acetabular morphology. Proper positioning is critical as both pelvic rotation and inclination can hinder diagnostic accuracy, producing false-positive and false-negative results.

The most commonly used measurement is the acetabular index [49]. This index is 30° in a newborn and decreases progressively with growth and maturation [49-51]. In dysplastic hips, the acetabular index is increased, which then decreases in response to successful treatment [52,53]. The position of the femoral head is evaluated based on the relationship of the ossific nucleus or proximal femoral metaphysis to the Hilgenreiner and Perkin lines and by evaluating for disruption of the Shenton arc [31]. A radiographic classification system has been developed by the International Hip Dysplasia Institute, which uses the midpoint of the proximal femoral metaphysis as a reproducible reference landmark [54].

## Discussion of Procedures by Variant

### **Variant 1: Child, younger than 4 weeks of age. Equivocal physical examination or risk factors for DDH. Initial imaging.**

For infants with equivocal physical examination or risk factors for DDH, there is evidence that the vast majority spontaneously normalize [21,55,56], and a short delay in intervention has no negative impact on outcome [22,57,58]. Therefore, the potential benefits of early diagnosis and treatment must be weighed against the risk of overtreatment and potential for iatrogenic complications [31]. Thus, the AAP recommends screening with US at the age of 4 to 6 weeks [1], and the American Academy of Orthopaedic Surgeons (AAOS) recommends pediatric orthopedic referral before 4 weeks of age [20].

### **Variant 1: Child, younger than 4 weeks of age. Equivocal physical examination or risk factors for DDH. Initial imaging.**

#### **A. US Hips**

Although US can be performed shortly after birth, its high sensitivity for the detection of mild acetabular immaturity and minor degrees of hip laxity can suggest pathology, potentially leading to overdiagnosis (false-positives) and overtreatment [3,5,18]. Therefore, US is not recommended during the newborn period [59].

**Variant 1: Child, younger than 4 weeks of age. Equivocal physical examination or risk factors for DDH. Initial imaging.**

**B. Radiography Pelvis**

There is no relevant literature regarding the use of radiographs for screening of DDH in children <4 weeks of age.

**Variant 2: Child, between 4 weeks to 4 months of age. Equivocal physical examination or risk factors for DDH. Initial imaging.**

Although most physicians recommend the first imaging screening for nondislocated hips to be performed at 4 to 6 weeks of age, thus allowing time for normalization of neonatal physiologic immaturity and laxity, this remains an arbitrary time-point, balancing the risk of increased false-positive studies in early age with the potential benefits of early treatment. In a study of 5,170 infants screened at 1 month of age, 99.6% remained normal and 84% to 95% of Graf type II hips normalized at 3 months, indicating that the vast majority continue to normalize after the first month of life [60]. Because of the high false-positive rate of diagnosis with US, the AAP recommends selective US only in the highest risk group, girls with breech presentation at birth [1]. AAP also suggests US as an option in girls with a positive family history, boys with breech presentation, and when the physical examination is inconclusive [1].

**Variant 2: Child, between 4 weeks to 4 months of age. Equivocal physical examination or risk factors for DDH. Initial imaging.**

**A. US Hips**

A prospective study using US screening was performed on 2,578 children with an unstable hip on physical examination or risk factors for developmental dysplasia. Screening US was shown to reduce the number of delayed diagnoses and decrease the rate of surgical intervention when compared to clinical screening alone [61]. Other studies have shown that US can help confirm the diagnosis of DDH, leading to a change in the clinical management [62,63].

**Variant 2: Child, between 4 weeks to 4 months of age. Equivocal physical examination or risk factors for DDH. Initial imaging.**

**B. Radiography Pelvis**

Pelvic radiographs are limited for evaluation for DDH in the first 3 months of life. The ossific nucleus of the femoral head usually appears between 4 to 6 months (range 1.5–8 months), but for dysplastic hips, its appearance is often delayed [54]. The acetabular margin is also largely cartilaginous, hindering the assessment of acetabular morphology and femoral alignment [64,65].

**Variant 3: Child, younger than 4 months of age. Physical findings of DDH. Initial imaging.**

For the purpose of this variant, positive physical examination is defined as a positive Barlow or Ortolani test, which implies an unstable femoral head that can be dislocated or relocated, respectively [66].

**Variant 3: Child, younger than 4 months of age. Physical findings of DDH. Initial imaging.**

**A. US Hips**

The AAP guideline published in 2000 [1] did not recommend US screening after a positive physical

examination. However, recent studies have shown that 41% to 58% of abnormal findings from a physical examination were false-positive findings when correlated with US, thus leading to unnecessary treatment [1]. A prospective 33-center United Kingdom Hip Trial [37] addressed the value of selected US screening in infants following a positive physical examination. It found that US examinations in infants with clinically detected hip instability allowed for a reduction in abduction splinting and was not associated with an increase in abnormal hip development or higher rates of surgical treatment [37]. This policy was found to reduce costs [37]. A 15-year longitudinal observation study found the sensitivity, specificity, and positive predictive value of clinical screening for diagnosing DDH to be 62%, 99.8%, and 24%, as opposed to US screening at 77%, 99.8%, and 49%, respectively [7].

### **Variant 3: Child, younger than 4 months of age. Physical findings of DDH. Initial imaging.**

#### **B. Radiography Pelvis**

There is no relevant literature regarding the use of radiographs in children <3 months of age with physical findings of DDH, which is in part because the ossific nucleus of the femoral head usually appears between 4 to 6 months (range 1.5–8 months) [54].

### **Variant 4: Child, between 4 to 6 months of age. Concern for DDH. Initial imaging.**

Late-presenting DDH, defined as diagnosis after 3 months of age, is uncommon, occurring at an estimated rate of 0.22 per 1,000 births [55]. At this age, the clinical assessment is less reliable and imaging is often required to confirm the diagnosis. By 8 to 12 weeks of age, the capsule laxity decreases, muscle tightness increases, and the Barlow and Ortolani maneuvers may not be positive regardless of the status of the femoral head. Thus, the finding of limited hip abduction becomes the most important screening method in older children. However, currently there is no consensus on the reliability of this test for diagnosing DDH [5], with one study demonstrating a positive predictive value of 40% for DDH that can increase up to 55% after 8 weeks of age [36], while another study demonstrated no correlation between a positive abduction test and an abnormal acetabular angle [66]. Other screening methods, such as the findings of asymmetric skin folds in the proximal thigh and shortening of the limb on the dislocated side, lack specificity for the diagnosis of DDH [66]. These inconsistencies among various studies may reflect differences in patient selection or inclusion, expertise of the examiners, and the defined gold standard [1,67-69].

### **Variant 4: Child, between 4 to 6 months of age. Concern for DDH. Initial imaging.**

#### **A. US Hips**

The AAP and AAOS do not advocate the use of US for the screening of DDH after 4 to 5 months [1,20]. There is limited evidence on the use of US for screening of DDH beyond 4 months. A study that obtained anteroposterior radiographs in patients who are 4 to 6 months of age with positive US found that US overdiagnosed DDH in 40% of patients [58].

### **Variant 4: Child, between 4 to 6 months of age. Concern for DDH. Initial imaging.**

#### **B. Radiography Pelvis**

Shortly after the appearance of the ossific nucleus, pelvic radiography becomes the preferred confirmatory imaging modality, as it allows for the assessment of the femoral head ossific nucleus, the development of the proximal femur, and bony acetabular morphology [1]. Normal pelvic radiograph at 4 months can reliably exclude DDH in children with risk factors [56] and decrease the need for treatment in infants who are 4 to 6 months of age with positive US by 40% [58]. This eliminates unnecessary serial follow-ups and potential for iatrogenic treatment-related complications. Thus, for infants with suspected hip dysplasia, a radiograph is often obtained

between 4 to 6 months of age [21,56-58]. However, there are a few limitations to pelvic radiograph. The timing for the appearance of the ossific nucleus varies widely, from 1.5 to 8 months of age [65], and in dysplastic hips, its appearance is often delayed and, when it does appear, is often eccentric [54,70].

#### **Variant 5: Child, older than 6 months of age. Concern for DDH. Initial imaging.**

Clinical assessment at this age is often limited, as the traditional physical examination findings—such as the Ortolani and Barlow tests, hip abduction, asymmetric proximal thigh skin folds, and limb length—lack sensitivity and specificity [5,22,36,66]. This leads to a great reliance on imaging for the confirmation and monitoring of DDH.

#### **Variant 5: Child, older than 6 months of age. Concern for DDH. Initial imaging.**

##### **A. US Hips**

There is insufficient evidence to recommend the use of US as the evaluation may be inadequate because of the suboptimal visualization of the anatomy of the hip joint from decreased acoustic penetration.

#### **Variant 5: Child, older than 6 months of age. Concern for DDH. Initial imaging.**

##### **B. Radiography Pelvis**

Shortly after the appearance of the ossific nucleus, pelvic radiography becomes the preferred imaging modality as it facilitates the assessment of the femoral head ossific nucleus and the development of the proximal femur and bony acetabular morphology [1]. There is ongoing debate regarding the necessity of serial radiographic studies for mild acetabular dysplasia in the setting of normal clinical examination and normalized US findings, with one study reporting that up to 17% had radiographic signs of dysplasia at 6 months [71], another study concluding only 5% at 12 months and none at 21 months of age, and a different study citing 24% at a mean follow-up of 9 years [72]. These inconsistencies likely reflect differences in patient selection/inclusion, but the long-term implication of these imaging findings remain unknown.

#### **Variant 6: Child, younger than 6 months of age. Known diagnosis of DDH, nonoperative surveillance imaging in harness.**

The treatment algorithm for DDH varies among practices but typically includes a trial of nonoperative management using abduction splinting, often with a Pavlik harness. The efficacy of the Pavlik harness decreases with age. It is most effective if the harness is applied before 6 weeks of age, and the harness can be used up to 6 months of age. The overall success rate of the harness ranges from 67% to 83% [28]. Surgical intervention is typically reserved for children with severe dysplasia or dislocation, late presentation or diagnosis, or failed nonoperative management [73].

#### **Variant 6: Child, younger than 6 months of age. Known diagnosis of DDH, nonoperative surveillance imaging in harness.**

##### **A. US Hips**

In children who are undergoing nonoperative treatment with Pavlik harness, US can be used to confirm concentric hip reduction [74,75], assess treatment response [73,76-79], and identify signs of therapy failure [80]. Predictors of failure include low postreduction alpha angle and <20% femoral head coverage [81]. US is typically performed without applied stress to the hips and with the child either in or out of brace, depending on the discretion of the referring provider.

#### **Variant 6: Child, younger than 6 months of age. Known diagnosis of DDH, nonoperative surveillance imaging in harness.**

##### **B. Radiography Pelvis**

Radiography is not the preferred modality for monitoring children undergoing nonoperative treatment using a harness [76,82] because of the delay in the appearance of the femoral head ossific nucleus and suboptimal patient positioning (within the harness). Rather, radiographs are often obtained at or near the conclusion of the treatment to document bony acetabular development and to provide a baseline for future surveillance [59].

**Variation 6: Child, younger than 6 months of age. Known diagnosis of DDH, nonoperative surveillance imaging in harness.**

**C. CT Pelvis**

There is no relevant literature regarding the use of CT to monitor children with DDH who are being treated nonoperatively using a harness.

**Variation 6: Child, younger than 6 months of age. Known diagnosis of DDH, nonoperative surveillance imaging in harness.**

**D. MRI Pelvis**

There is no relevant literature regarding the use of MRI to monitor children with DDH who are being treated nonoperatively using a harness.

**Summary of Highlights**

- **Variation 1:** Imaging is not recommended for the initial imaging of children younger than 4 weeks of age with an equivocal physical examination or risk factors shown for DDH.
- **Variation 2:** US of the hips is usually appropriate for the initial imaging of children between 4 weeks to 4 months of age with an equivocal physical examination or risk factors shown for DDH.
- **Variation 3:** US of the hips is usually appropriate for the initial imaging of children younger than 4 months of age with physical findings of DDH at initial imaging.
- **Variation 4:** Radiographs of the pelvis is usually appropriate for the initial imaging of children between 4 to 6 months of age with a concern for DDH at initial imaging.
- **Variation 5:** Radiographs of the pelvis is usually appropriate for the initial imaging of children older than 6 months of age with a concern for DDH.
- **Variation 6:** US of the hips is usually appropriate for children younger than 6 months of age with a known diagnosis of DDH during nonoperative surveillance imaging in harness.

**Supporting Documents**

The evidence table, literature search, and appendix for this topic are available at <https://acsearch.acr.org/list>. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents, please go to the ACR website at <https://www.acr.org/Clinical-Resources/Clinical-Tools-and-Reference/Appropriateness-Criteria>.

**Appropriateness Category Names and Definitions**

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
-------------------------------	------------------------	-------------------------------------

Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

### 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 (RRL) indication has been included for each imaging examination. The RRLs 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, because of both organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared with those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® [Radiation Dose Assessment Introduction](#) document.

### Relative Radiation Level Designations

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

\*RRL 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 (e.g., region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies."

### References

1. Clinical practice guideline: early detection of developmental dysplasia of the hip. Committee

on Quality Improvement, Subcommittee on Developmental Dysplasia of the Hip. American Academy of Pediatrics. *Pediatrics*. 2000; 105(4 Pt 1):896-905.

2. Palmén K. Prevention of congenital dislocation of the hip. The Swedish experience of neonatal treatment of hip joint instability. *Acta Orthop Scand Suppl*. 1984;208:1-107.
3. Kolb A, Schweiger N, Mailath-Pokorny M, et al. Low incidence of early developmental dysplasia of the hip in universal ultrasonographic screening of newborns: analysis and evaluation of risk factors. *Int Orthop*. 2016;40(1):123-127.
4. Phelan N, Thoren J, Fox C, O'Daly BJ, O'Beirne J. Developmental dysplasia of the hip: incidence and treatment outcomes in the Southeast of Ireland. *Ir J Med Sci*. 2015;184(2):411-415.
5. Shipman SA, Helfand M, Moyer VA, Yawn BP. Screening for developmental dysplasia of the hip: a systematic literature review for the US Preventive Services Task Force. *Pediatrics*. 2006; 117(3):e557-576.
6. Desteli EE, Piskin A, Gulman AB, Kaymaz F, Koksall B, Erdogan M. Estrogen receptors in hip joint capsule and ligamentum capitis femoris of babies with developmental dysplasia of the hip. *Acta Orthop Traumatol Turc*. 2013;47(3):158-161.
7. Mace J, Paton RW. Neonatal clinical screening of the hip in the diagnosis of developmental dysplasia of the hip: a 15-year prospective longitudinal observational study. *Bone Joint J*. 2015;97-B(2):265-269.
8. de Hundt M, Vlemmix F, Bais JM, et al. Risk factors for developmental dysplasia of the hip: a meta-analysis. *Eur J Obstet Gynecol Reprod Biol*. 2012;165(1):8-17.
9. Ortiz-Neira CL, Paolucci EO, Donnon T. A meta-analysis of common risk factors associated with the diagnosis of developmental dysplasia of the hip in newborns. *Eur J Radiol*. 2012;81(3):e344-351.
10. Talbot CL, Paton RW. Screening of selected risk factors in developmental dysplasia of the hip: an observational study. *Arch Dis Child*. 2013;98(9):692-696.
11. Shaw BA, Segal LS. Evaluation and Referral for Developmental Dysplasia of the Hip in Infants. *Pediatrics*. 2016;138(6).
12. Barlow TG. Early Diagnosis and Treatment of Congenital Dislocation of the Hip. *Proc R Soc Med*. 1963;56:804-806.
13. Barr LV, Rehm A. Should all twins and multiple births undergo ultrasound examination for developmental dysplasia of the hip?: A retrospective study of 990 multiple births. *Bone Joint J*. 2013;95-B(1):132-134.
14. Orak MM, Onay T, Gumustas SA, Gursoy T, Muratli HH. Is prematurity a risk factor for developmental dysplasia of the hip? : a prospective study. *Bone Joint J*. 2015;97-B(5):716-720.
15. Quan T, Kent AL, Carlisle H. Breech preterm infants are at risk of developmental dysplasia of the hip. *J Paediatr Child Health*. 2013;49(8):658-663.
16. Rosendahl K, Markestad T, Lie RT. Ultrasound screening for developmental dysplasia of the hip in the neonate: the effect on treatment rate and prevalence of late cases. *Pediatrics*. 1994; 94(1):47-52.

17. Clarke NM, Clegg J, Al-Chalabi AN. Ultrasound screening of hips at risk for CDH. Failure to reduce the incidence of late cases. *J Bone Joint Surg Br.* 1989; 71(1):9-12.
18. Gardiner HM, Dunn PM. Controlled trial of immediate splinting versus ultrasonographic surveillance in congenitally dislocatable hips. *Lancet.* 1990; 336(8730):1553-1556.
19. Marks DS, Clegg J, al-Chalabi AN. Routine ultrasound screening for neonatal hip instability. Can it abolish late-presenting congenital dislocation of the hip? *J Bone Joint Surg Br.* 1994; 76(4):534-538.
20. Mulpuri K, Song KM, Goldberg MJ, Sevarino K. Detection and Nonoperative Management of Pediatric Developmental Dysplasia of the Hip in Infants up to Six Months of Age. *J Am Acad Orthop Surg.* 2015;23(3):202-205.
21. Terjesen T, Holen KJ, Tegnander A. Hip abnormalities detected by ultrasound in clinically normal newborn infants. *J Bone Joint Surg Br.* 1996; 78(4):636-640.
22. Mulpuri K, Schaeffer EK, Andrade J, et al. What Risk Factors and Characteristics Are Associated With Late-presenting Dislocations of the Hip in Infants? *Clin Orthop Relat Res.* 2016;474(5):1131-1137.
23. Eamsobhana P, Kamwong S, Sisuchinthara T, Jittivilai T, Keawpornawan K. The Factor Causing Poor Results in Late Developmental Dysplasia of the Hip (DDH). *J Med Assoc Thai.* 2015;98 Suppl 8:S32-37.
24. Price KR, Dove R, Hunter JB. Current screening recommendations for developmental dysplasia of the hip may lead to an increase in open reduction. *Bone Joint J.* 2013;95-B(6):846-850.
25. Wenger D, Duppe H, Tiderius CJ. Acetabular dysplasia at the age of 1 year in children with neonatal instability of the hip. *Acta Orthop.* 2013;84(5):483-488.
26. Mahan ST, Katz JN, Kim YJ. To screen or not to screen? A decision analysis of the utility of screening for developmental dysplasia of the hip. *J Bone Joint Surg Am.* 2009; 91(7):1705-1719.
27. Novais EN, Hill MK, Carry PM, Heyn PC. Is Age or Surgical Approach Associated With Osteonecrosis in Patients With Developmental Dysplasia of the Hip? A Meta-analysis. *Clin Orthop Relat Res.* 2016;474(5):1166-1177.
28. Tibrewal S, Gulati V, Ramachandran M. The Pavlik method: a systematic review of current concepts. *J Pediatr Orthop B.* 2013;22(6):516-520.
29. Dorn U, Neumann D. Ultrasound for screening developmental dysplasia of the hip: a European perspective. *Curr Opin Pediatr.* 2005; 17(1):30-33.
30. Holen KJ, Tegnander A, Bredland T, et al. Universal or selective screening of the neonatal hip using ultrasound? A prospective, randomised trial of 15,529 newborn infants. *J Bone Joint Surg Br.* 2002; 84(6):886-890.
31. Patel H. Preventive health care, 2001 update: screening and management of developmental dysplasia of the hip in newborns. *CMAJ.* 2001; 164(12):1669-1677.
32. Woolacott NF, Puhan MA, Steurer J, Kleijnen J. Ultrasonography in screening for developmental dysplasia of the hip in newborns: systematic review. *BMJ.* 2005; 330(7505):1413.

33. Bracken J, Ditchfield M. Ultrasonography in developmental dysplasia of the hip: what have we learned? *Pediatr Radiol*. 2012;42(12):1418-1431.
34. Lowry CA, Donoghue VB, Murphy JF. Auditing hip ultrasound screening of infants at increased risk of developmental dysplasia of the hip. *Arch Dis Child*. 2005; 90(6):579-581.
35. Tonnis D, Storch K, Ulbrich H. Results of newborn screening for CDH with and without sonography and correlation of risk factors. *J Pediatr Orthop*. 1990; 10(2):145-152.
36. Choudry Q, Goyal R, Paton RW. Is limitation of hip abduction a useful clinical sign in the diagnosis of developmental dysplasia of the hip? *Arch Dis Child*. 2013;98(11):862-866.
37. Elbourne D, Dezateux C, Arthur R, et al. Ultrasonography in the diagnosis and management of developmental hip dysplasia (UK Hip Trial): clinical and economic results of a multicentre randomised controlled trial. *Lancet*. 2002; 360(9350):2009-2017.
38. Peterlein CD, Fuchs-Winkelmann S, Schuttler KF, et al. Does probe frequency influence diagnostic accuracy in newborn hip ultrasound? *Ultrasound Med Biol*. 2012;38(7):1116-1120.
39. Engesaeter LB, Wilson DJ, Nag D, Benson MK. Ultrasound and congenital dislocation of the hip. The importance of dynamic assessment. *J Bone Joint Surg Br*. 1990; 72(2):197-201.
40. Graf R. The diagnosis of congenital hip-joint dislocation by the ultrasonic Compound treatment. *Arch Orthop Trauma Surg*. 1980; 97(2):117-133.
41. Graf R. [The sonographic evaluation of hip dysplasia using convexity diagnosis]. *Z Orthop Ihre Grenzgeb*. 1983;121(6):693-702.
42. American College of Radiology. ACR–AIUM–SPR–SRU Practice Parameter for the Performance of the Ultrasound Examination for Detection and Assessment of Developmental Dysplasia of the Hip. Available at: <https://gravitas.acr.org/PPTS/GetDocumentView?docId=27+&releaseId=2>
43. Terjesen T, Bredland T, Berg V. Ultrasound for hip assessment in the newborn. *J Bone Joint Surg Br*. 1989;71(5):767-773.
44. Roovers EA, Boere-Boonekamp MM, Mostert AK, Castelein RM, Zielhuis GA, Kerkhoff TH. The natural history of developmental dysplasia of the hip: sonographic findings in infants of 1-3 months of age. *J Pediatr Orthop B*. 2005; 14(5):325-330.
45. Harcke HT, Grissom LE. Infant hip sonography: current concepts. *Semin Ultrasound CT MR*. 1994; 15(4):256-263.
46. Dias JJ, Thomas IH, Lamont AC, Mody BS, Thompson JR. The reliability of ultrasonographic assessment of neonatal hips. *J Bone Joint Surg Br*. 1993; 75(3):479-482.
47. Jomha NM, Mclvor J, Sterling G. Ultrasonography in developmental hip dysplasia. *J Pediatr Orthop*. 1995; 15(1):101-104.
48. Rosendahl K, Aslaksen A, Lie RT, Markestad T. Reliability of ultrasound in the early diagnosis of developmental dysplasia of the hip. *Pediatr Radiol*. 1995; 25(3):219-224.
49. Tonnis D. Normal values of the hip joint for the evaluation of X-rays in children and adults. *Clin Orthop Relat Res*. 1976(119):39-47.
50. Caffey J, Ames R, Silverman WA, Ryder CT, Hough G. Contradiction of the congenital dysplasia-predislocation hypothesis of congenital dislocation of the hip through a study of the normal variation in acetabular angles at successive periods in infancy. *Pediatrics*.

1956;17(5):632-641.

51. Carbonell PG, de Puga DB, Vicente-Franqueira JR, Ortuno AL. Radiographic study of the acetabulum and proximal femur between 1 and 3 years of age. *Surg Radiol Anat.* 2009;31(7):483-487.
52. Li Y, Xu H, Li J, et al. Early predictors of acetabular growth after closed reduction in late detected developmental dysplasia of the hip. *J Pediatr Orthop B.* 2015;24(1):35-39.
53. Zamzam MM, Kremli MK, Khoshhal KI, et al. Acetabular cartilaginous angle: a new method for predicting acetabular development in developmental dysplasia of the hip in children between 2 and 18 months of age. *J Pediatr Orthop.* 2008;28(5):518-523.
54. Narayanan U, Mulpuri K, Sankar WN, Clarke NM, Hosalkar H, Price CT. Reliability of a New Radiographic Classification for Developmental Dysplasia of the Hip. *J Pediatr Orthop.* 2015;35(5):478-484.
55. Boeree NR, Clarke NM. Ultrasound imaging and secondary screening for congenital dislocation of the hip. *J Bone Joint Surg Br.* 1994; 76(4):525-533.
56. Garvey M, Donoghue VB, Gorman WA, O'Brien N, Murphy JF. Radiographic screening at four months of infants at risk for congenital hip dislocation. *J Bone Joint Surg Br.* 1992;74(5):704-707.
57. Gerscovich EO. A radiologist's guide to the imaging in the diagnosis and treatment of developmental dysplasia of the hip. I. General considerations, physical examination as applied to real-time sonography and radiography. *Skeletal Radiol.* 1997;26(7):386-397.
58. Tudor A, Sestan B, Rakovac I, et al. The rational strategies for detecting developmental dysplasia of the hip at the age of 4-6 months old infants: a prospective study. *Coll Antropol.* 2007;31(2):475-481.
59. Harcke HT, Grissom LE. Performing dynamic sonography of the infant hip. *AJR Am J Roentgenol.* 1990;155(4):837-844.
60. Roovers EA, Boere-Boonekamp MM, Castelein RM, Zielhuis GA, Kerkhoff TH. Effectiveness of ultrasound screening for developmental dysplasia of the hip. *Arch Dis Child Fetal Neonatal Ed.* 2005;90(1):F25-30.
61. Paton RW, Hinduja K, Thomas CD. The significance of at-risk factors in ultrasound surveillance of developmental dysplasia of the hip. A ten-year prospective study. *J Bone Joint Surg Br* 2005;87:1264-6.
62. LeBa TB, Carmichael KD, Patton AG, Morris RP, Swischuk LE. Ultrasound for Infants at Risk for Developmental Dysplasia of the Hip. *Orthopedics.* 2015;38(8):e722-726.
63. Ashby E, Roposch A. Diagnostic yield of sonography in infants with suspected hip dysplasia: diagnostic thinking efficiency and therapeutic efficiency. *AJR Am J Roentgenol.* 2015;204(1):177-181.
64. Boniforti FG, Fujii G, Angliss RD, Benson MK. The reliability of measurements of pelvic radiographs in infants. *J Bone Joint Surg Br.* 1997;79(4):570-575.
65. Harcke HT, Lee MS, Sinning L, Clarke NM, Borns PF, MacEwen GD. Ossification center of the infant hip: sonographic and radiographic correlation. *AJR Am J Roentgenol.* 1986;147(2):317-321.

66. Groarke PJ, McLoughlin L, Whitla L, Lennon P, Curtin W, Kelly PM. Retrospective Multicenter Analysis of the Accuracy of Clinical Examination by Community Physicians in Diagnosing Developmental Dysplasia of the Hip. *J Pediatr*. 2017;181:163-166 e161.
67. Andersson JE, Funnemark PO. Neonatal hip instability: screening with anterior-dynamic ultrasound method. *J Pediatr Orthop*. 1995; 15(3):322-324.
68. Place MJ, Parkin DM, Fritton JM. Effectiveness of neonatal screening for congenital dislocation of the hip. *Lancet*. 1978; 2(8083):249-250.
69. Poul J, Bajerova J, Sommernitz M, Straka M, Pokorny M, Wong FY. Early diagnosis of congenital dislocation of the hip. *J Bone Joint Surg Br*. 1992; 74(5):695-700.
70. Cuomo AV, Fedorak GT, Moseley CF. A Practical Approach to Determining the Center of the Femoral Head in Subluxated and Dislocated Hips. *J Pediatr Orthop*. 2015;35(6):556-560.
71. Sarkissian EJ, Sankar WN, Zhu X, Wu CH, Flynn JM. Radiographic Follow-up of DDH in Infants: Are X-rays Necessary After a Normalized Ultrasound? *J Pediatr Orthop*. 2015;35(6):551-555.
72. Sibinski M, Adamczyk E, Higgs ZC, Synder M. Hip joint development in children with type IIb developmental dysplasia. *Int Orthop*. 2012;36(6):1243-1246.
73. Omeroglu H, Kose N, Akceylan A. Success of Pavlik Harness Treatment Decreases in Patients  $\geq$  4 Months and in Ultrasonographically Dislocated Hips in Developmental Dysplasia of the Hip. *Clin Orthop Relat Res*. 2016;474(5):1146-1152.
74. Lorente Molto FJ, Gregori AM, Casas LM, Perales VM. Three-year prospective study of developmental dysplasia of the hip at birth: should all dislocated or dislocatable hips be treated? *J Pediatr Orthop*. 2002;22(5):613-621.
75. Suzuki S. Ultrasound and the Pavlik harness in CDH. *J Bone Joint Surg Br*. 1993;75(3):483-487.
76. Cashman JP, Round J, Taylor G, Clarke NM. The natural history of developmental dysplasia of the hip after early supervised treatment in the Pavlik harness. A prospective, longitudinal follow-up. *J Bone Joint Surg Br*. 2002;84(3):418-425.
77. Hedequist D, Kasser J, Emans J. Use of an abduction brace for developmental dysplasia of the hip after failure of Pavlik harness use. *J Pediatr Orthop*. 2003;23(2):175-177.
78. Malkawi H. Sonographic monitoring of the treatment of developmental disturbances of the hip by the Pavlik harness. *J Pediatr Orthop B*. 1998;7(2):144-149.
79. Ucar DH, Isiklar ZU, Kandemir U, Tumer Y. Treatment of developmental dysplasia of the hip with Pavlik harness: prospective study in Graf type IIc or more severe hips. *J Pediatr Orthop B*. 2004;13(2):70-74.
80. Hangen DH, Kasser JR, Emans JB, Millis MB. The Pavlik harness and developmental dysplasia of the hip: has ultrasound changed treatment patterns? *J Pediatr Orthop*. 1995;15(6):729-735.
81. Lerman JA, Emans JB, Millis MB, Share J, Zurakowski D, Kasser JR. Early failure of Pavlik harness treatment for developmental hip dysplasia: clinical and ultrasound predictors. *J Pediatr Orthop*. 2001;21(3):348-353.
82. Ohmori T, Endo H, Mitani S, Minagawa H, Tetsunaga T, Ozaki T. Radiographic prediction of

the results of long-term treatment with the Pavlik harness for developmental dislocation of the hip. *Acta Med Okayama*. 2009;63(3):123-128.

83. American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: <https://edge.sitecorecloud.io/americancoldf5f-acrorgf92a-productioncb02-3650/media/ACR/Files/Clinical/Appropriateness-Criteria/ACR-Appropriateness-Criteria-Radiation-Dose-Assessment-Introduction.pdf>.

## Disclaimer

The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.

<sup>a</sup>Children's Hospital of Philadelphia, Philadelphia, Pennsylvania. <sup>b</sup>Texas Children's Hospital, Houston, Texas. <sup>c</sup>Panel Chair, Ann & Robert H. Lurie Children's Hospital of Chicago, Chicago, Illinois. <sup>d</sup>Panel Vice-Chair, Seattle Children's Hospital, Seattle, Washington. <sup>e</sup>Children's Healthcare of Atlanta, Atlanta, Georgia. <sup>f</sup>Children's Hospital of Philadelphia, Philadelphia, Pennsylvania. <sup>g</sup>Phoenix Children's Hospital, Phoenix, Arizona. <sup>h</sup>Riley Hospital for Children Indiana University, Indianapolis, Indiana. <sup>i</sup>Children's Mercy Hospital, Kansas City, Missouri. <sup>j</sup>Nemours Children's Hospital, Orlando, Florida. <sup>k</sup>Wolfson Children's Hospital, Jacksonville, Florida; American Academy of Pediatrics. <sup>l</sup>Penn State Health Children's Hospital, Hershey, Pennsylvania. <sup>m</sup>University of California San Francisco Benioff Children's Hospital, San Francisco, California; American Academy of Orthopaedic Surgeons. <sup>n</sup>Children's National Health System, Washington, District of Columbia. <sup>o</sup>Dartmouth-Hitchcock Medical Center, Lebanon, New Hampshire. <sup>p</sup>Specialty Chair, Riley Hospital for Children Indiana University, Indianapolis, Indiana.