Developmental Dysplasia of the Hip
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Developmental Dysplasia of the Hip

David D. Aronsson, MD*; Michael J. Goldberg, MD†; Thomas F. Kling, Jr, MD‡; and Dennis R. Roy, MD§

ABSTRACT. Objective. The definition and early treatment of congenital dysplasia of the hip are controversial. The purpose of this study was to discuss the reasons for changing the acronym to developmental dysplasia of the hip (DDH) and to address its early detection and treatment.

Design. This multicenter study was designed to provide an updated assessment of the definition, pathologic anatomy, prevalence, etiology, natural history, early detection, and treatment of DDH.

Results. DDH more accurately describes the condition previously termed congenital dysplasia of the hip. The disorder is not always present at birth (congenital) and an infant may have a normal neonatal hip screening examination and subsequently develop a dysplastic or dislocated hip. Developmental dysplasia encompasses the wide spectrum of hip problems seen in infants and children. Physicians should understand that a normal neonatal screening examination does not assure normal hip development. The diagnosis of developmental dysplasia is made by physical examination. The Ortolani and Barlow maneuvers were designed to detect a subluxatable, dislocatable, or dislocated hip in the neonatal period. In the older child, limited abduction becomes a more reliable sign. The examination is variable depending on the type of dysplasia and changes with growth. The ultrasound is proving to be a sensitive tool in confirming the diagnosis in newborns and infants from birth to 4 months of age. The ultrasound is also valuable in older infants in terms of documenting that the dysplasia is responding to treatment. However, the ultrasound depends on an experienced sonographer and, in some cases, may be too sensitive, resulting in overtreatment. After 3 to 4 months of age, an anteroposterior pelvis radiograph can confirm the diagnosis.

Conclusions. All newborns should have a neonatal hip screening physical examination. After screening, the hips should be re-examined during health examination visits at 2 weeks, 2 months, 4 months, 6 months, 9 months, and 1 year of age. If any question arises during these visits or if there are associated risk factors, we recommend an ultrasound if the infant is <4 months of age or an anteroposterior pelvis radiograph if >4 months of age. Pediatrics 1994;94:201–208; developmental dysplasia of the hip, congenital dislocation of the hip, ultrasound for hip instability.

ABBREVIATIONS. CDH, congenital dislocation of the hip; DDH, developmental dysplasia of the hip.

The acronym congenital dysplasia of the hip (CDH) is confusing and has been used synonymously with congenital dislocation or congenital disease of the hip. This lack of precision in terminology is understood by experienced physicians who mentally define CDH according to the context in which it is used, but this abbreviation is confusing and misleading to patients, attorneys, and juries. A dislocated hip is a physical sign, not a diagnosis, and the term congenital means present at birth. Because CDH was thought to be present at birth, physicians were taught that if the neonatal examination was normal, the hip would develop normally. This is clearly not the case as several reports have documented dislocation or dysplasia of the hip occurring after a normal neonatal screening examination.1–6 We believe the acronym developmental dysplasia of the hip (DDH) should replace CDH. The word “developmental” invokes the dimension of time acknowledging that the dysplasia or dislocation may occur before or after birth. Dysplasia means an abnormality of development and encompasses a wide spectrum of hip problems. By changing from CDH to DDH, the acronym will no longer falsely characterize a disorder in instances when the condition being described is neither congenital nor dislocated. To understand the spectrum of hip problems included in DDH, a knowledge of the embryology of the hip joint is beneficial.

METHODS

Embryology

In the embryo the limb buds first appear at 4 weeks gestation. The hip joint begins to develop at 8 weeks gestation when a cleft occurs between the acetabulum and the femoral head and development is usually complete by 11 weeks.7 As a result, the hip is always located early in the embryologic stage because it forms from the pelvis. Hip dysplasia or dislocation may then occur in utero, perinatally, or subsequently with development. Moving from the fetal position of hip flexion to one of extension as occurs after birth increases the susceptibility of dislocation.

Definitions

DDH includes hips that are unstable, malformed, subluxated, or dislocated. Instability is the inability of the hip to resist an externally applied force without developing a subluxation or dislocation. A malformation includes any abnormality in the development of the femur and/or acetabulum. A subluxation is an incomplete dislocation with some residual contact between the femoral head and acetabulum, and a dislocation indicates complete displacement of the femoral head from the acetabulum. Previous authors have differentiated between a teratologic and
typical dislocation of the hip. A teratologic dislocation occurs early in utero and is associated with other malformations such as chromosomal abnormalities and neuromuscular disorders. A typical dislocation occurs in an otherwise healthy infant and may occur in utero, at birth, or after birth.

Pathologic Anatomy

Because DDH includes a wide spectrum of hip problems, the pathologic anatomy is dependent on the type, grade, and duration of the dislocation. In the neonatal period, there may be sufficient ligamentous laxity that the hip spontaneously dislocates and reduces. The newborn may dislocate and reduce the hip with kicking movements of the lower extremity. In utero the hip is in a concentrically reduced position. The acraniotome examination and later were found to have DDH. Davies and Walker reported that 10% of newborns with metatarsus adductus had DDH but there is a correlation between postnatal positioning and DDH. The incidence is lower in India where newborns are carried astride the waist of the mother with the hips in an attitude of flexion and abduction. This is a stable position for most hips and most treatment devices attempt to duplicate this position. In contrast, the incidence is high in American Indians who position their newborns on a cradle board with the hips swaddled in extension and abduction. Kutlu et al evaluated 4173 infants and found DDH in 56, and 55 of these had been swaddled in infancy for an average of 45 days. Green and Griffin reported on 18 infants who had DDH in conjunction with an abduction contracture of the contralateral hip. All patients responded to abduction splinting of the dys-
plastic hip and stretching of the abduction contracture of the contralateral hip.

Several early investigators postulated that the etiology of DDH was secondary to primary acetabular dysplasia. Subsequent reports have demonstrated that the acetabular dysplasia is not the cause of the dislocation but is a result of the femoral head not being concentrically reduced in the acetabulum. The acetabular dysplasia is reversible by restoring a normal relationship between the acetabulum and femoral head. The femoral head needs to be in contact with the triradiate cartilage for normal acetabular development.

**Natural History**

The natural history of DDH remains controversial as newborn instability may spontaneously resolve, develop progressive subluxation, or progress to complete dislocation. McKinnon et al. studied 1549 newborns and found subluxatable hips in 92. The patient profile of the newborns with subluxatable hips was similar to those with dislocated hips with an increased frequency of females, breech presentations, left-sided involvement, and associated postural deformities. They concluded that the newborn subluxatable hip arises from the same antecedents as a frank dislocation and is best managed if detected and treated early.

Cooperman et al. studied 20 adults (32 hips) with acetabular dysplasia to determine the natural history of the disorder. After an average follow-up of 22 years, 30 (94%) had severe or moderate osteoarthritis. Wedge and Wasylenko reported on 54 adults (80 hips) who had previously been affected by dysplasia, subluxation, or dislocation. At follow-up, only 41% of dislocated hips and 42% of subluxated and dysplastic hips received a good score. In contrast to the dislocated group, the patients with subluxation and dysplasia tended to be younger and had more pain.

**History**

The previously held view, that if the newborn was examined at birth all dislocated hips would be diagnosable, is both outdated and inaccurate. There are dislocations that are not detected and dislocations that occur late. If several basic principles are followed, the ability to detect DDH can be improved.

Asking the family about potential risk factors including a family history of hip dislocation, ligamentous laxity, pre and postnatal positioning, and genetic and environmental factors is recommended. A history of breech position, even if it was transient or if the delivery was by cesarean section, is an important risk factor. Conditions including plagiocephaly, clubfeet, metatarsus adductus, and congenital muscular torticollis may be associated with DDH. The mother may note a difference in the length of the legs or that one leg will not come out far enough (limited abduction) when changing diapers. In the older child, a limp, toe-walking, intoeing, or outtoeing may be secondary to DDH.

**RESULTS AND DISCUSSION**

**Physical Examination**

In the neonatal period, the diagnosis is made by physical examination. The physical signs change and none are pathognomonic. The examination requires patience and skill and the newborn must be relaxed on a firm surface. It is impossible to perform an adequate physical examination on a crying, fussy newborn. When performing the examination the physician looks for asymmetry between the lower extremities. Asymmetric thigh folds, a short leg appearance, a prominent greater trochanter, or limitation of abduction or adduction may be significant findings. In the supine position, with the hip in 90° of flexion and one hand stabilizing the pelvis, each hip should easily abduct to 75° and adduct to 30° past the midline.

The examiner attempts to reproduce the dislocation or subluxation using the Ortolani and Barlow maneuvers. With the newborn supine the tips of the examiner’s long and index fingers are placed over the greater trochanter with the thumb along the medial thigh. The leg is positioned in neutral rotation with 90° of hip flexion and is gently abducted while lifting the leg anteriorly. With abduction one can feel a clunk as the femoral head slides over the posterior rim of the acetabulum and into the socket. This is called the sign of entry. The Barlow provocative test is obtained by abducting the hip and pushing gently on the knee and a palpable "clunk" is felt as the femoral head slides over the posterior rim of the acetabulum and out of the socket. This is called the sign of exit.

**Fig. 1.** Drawings demonstrating the technique for performing the Ortolani and Barlow maneuvers. The Ortolani sign is obtained by gently abducting the leg and a palpable "clunk" is felt as the femoral head slides over the posterior rim of the acetabulum into the socket. This is called the sign of entry. The Barlow provocative test is obtained by abducting the hip and pushing gently on the knee and a palpable "clunk" is felt as the femoral head slides over the posterior rim of the acetabulum and out of the socket. This is called the sign of exit.

**Fig. 2.** A drawing demonstrating limited abduction of this infant’s left hip. The infant is placed supine on a firm table and the examiner simultaneously abducts both hips. Asymmetrical abduction is often associated with developmental dysplasia of the hip (DDH), particularly in infants over 2 months of age.
capsular laxity, which usually disappears by 10 to 12 weeks of age.

The physical examination is performed one hip at a time using the other hand to stabilize the pelvis. The amount of force required to illicit an Ortolani or Barlow sign is minimal. It is important to distinguish the clunk of an Ortolani or Barlow maneuver from a high-pitched click, that may occur with flexion and extension in an abducted position. A subluxatable hip is characterized by a feeling of telescoping or sliding movement of the temporal head. The Ortolani and Barlow maneuvers are negative because there is no palpable clunk of exit or entry.

In the 3- to 12-month-old infant, there is less ligamentous and capsular laxity so the Ortolani and Barlow tests usually disappear. The best physical finding in this age group is limitation of hip abduction (Fig 2). A unilateral dislocation is identified by limited abduction of the hip, a positive Galleazzi’s sign (relative shortening of the femur), and extra thigh folds secondary to shortening.

The diagnosis of bilateral hip dislocation is more difficult as the limitation of abduction may be symmetric. Hip abduction in bilateral DDH is typically limited to 30 to 40° although in the normal 3- to 12-month-old infant, it should be 75 to 80° with the hip in 90° of flexion. This test offers another clue to the difficult diagnosis of bilateral DDH. Nélaton’s line is an imaginary line between the ischial tuberosity and the anterosuperior iliac spine. The greater trochanter in a dislocated hip lies cephalad to this line while the trochanter in a normal hip lies caudad. A high index of suspicion is required to detect bilateral DDH.

Once a child is walking the physical signs become more obvious. There is a typical limp and the child will often toe-walk on the affected side. If both hips are dislocated, increased lumbar lordosis, prominent buttocks, and a waddling gait are noted. When the patient is asked to stand on the affected leg, the pelvis drops to the opposite side and the trunk leans toward the affected side (positive Trendelenburg test). This test is positive because the superiorly dislocated hip mechanically shortens the abductor muscles decreasing their strength.

The diagnosis of hip dysplasia is more difficult. The adolescent patient may note pain or discomfort after walking and may limp intermittently. The physical examination may be normal or some discomfort may be elicited at the extremes of range of motion, particularly abduction and internal rotation. If any of these signs are present, an anteroposterior pelvis radiograph is recommended.

Radiographic Evaluation

The anteroposterior pelvis radiograph is difficult to interpret in the neonatal period.1,38 A normal newborn radiograph may be misleading and deceptive because much of the neonatal pelvis and femoral head are cartilaginous so the relationship between the femoral head and acetabulum is difficult to determine. In positioning the newborn for the radiograph, the technician may spontaneously reduce a dislocated hip producing a normal radiograph. In addition, if the newborn is not positioned properly, asymmetry is introduced that makes interpretation difficult.

From a properly positioned anteroposterior pelvis radiograph several parameters are used to evaluate the hips. Hilgenreiner’s line is a horizontal line connecting the top of the triradiate cartilages. Perkins’ line is perpendicular to Hilgenreiner’s line through the lateral ossified margin of the acetabulum. Shenton’s line forms a continuous contour between the obturator foramen and the medial border of the femoral neck. There is DDH on the right with a delay in the appearance of the ossific nucleus, lateral displacement of the proximal femoral metaphysis, an elevated acetabular index (40°), and a “break” in Shenton’s line.

Fig. 3. A, An anteroposterior pelvis radiograph of an 8-month-old infant with DDH on the right. B. The drawing of the radiograph shows Hilgenreiner’s line connecting the top of the triradiate cartilages. Perkins’ line is perpendicular to Hilgenreiner’s line through the lateral ossified margin of the acetabulum. Shenton’s line forms a continuous contour between the obturator foramen and the medial border of the femoral neck. There is DDH on the right with a delay in the appearance of the ossific nucleus, lateral displacement of the proximal femoral metaphysis, an elevated acetabular index (40°), and a “break” in Shenton’s line.
months old. It consists of three lines: a lateral semicircular line corresponding to the cortical surface of the acetabular fossa, a medial line corresponding to the medial cortex of the pelvic wall, and a short, curved line connecting these two lines corresponding to the semicylindrical cortex of the acetabular notch. Delay in the ossification of the teardrop may result from a lack of stimulation from a concentrically reduced femoral head suggesting DDH. Similarly, a delay in the appearance of the ossification center of the femoral head, which normally appears between 3 and 7 months of age, also suggests DDH.

Shenton's line is a line drawn along the medial border of the neck of the femur and the superior border of the obturator foramen and should form a continuous contour. If there is superolateral subluxation of the femoral head, Shenton's line is interrupted (Fig 3). The acetabular index represents the angle formed between Hilgenreiner's line and a line beginning at the lateral ossified margin of the roof of the acetabulum and extending to the intersection between the depth of the acetabular socket and Hilgenreiner's line. The acetabular index is helpful in evaluating the development of the acetabulum. In the newborn the acetabular index averages 28° and decreases to 20° by 2 years of age. Coleman reported on 1155 newborns who were examined both clinically and radiographically and found 77 that had abnormal clinical examinations. The acetabular index averaged 29° in the healthy newborns and 35° in those with abnormal clinical findings. It is important to remember that a radiograph with positive findings may be misleading while a normal-appearing radiograph may be misleading. The diagnosis in the newborn is made by clinical examination and can be confirmed by ultrasound examination.

Ultrasound

In 1980, Graf developed the idea of adopting ultrasound to study the neonatal hip joint. The two methods currently in use include the static technique proposed by Graf, and the dynamic or real time method as described by Harcke et al. The static technique is performed with the infant in the lateral decubitus position and the hip in 35° of flexion and 10° of internal rotation. A coronal image of the hip is obtained and three lines are constructed from the image. A vertical line is drawn parallel to the ossified lateral wall of the ilium. A second line is drawn along the roof of the cartilaginous acetabulum from the lateral ossified margin of the ilium, and a short, curved line connecting these two lines corresponding to the bony acetabulum. A third line is drawn along the inferior edge of the cartilaginous acetabulum. The alpha angle measures 56° (Normal >55°) and the beta angle measures 45° (Normal <72°).

>72°, it indicates eversion of the labrum and subluxation of the hip (Fig 4). The problem with the static method is that the alpha and beta angles are difficult to reproduce accurately and if the image is not precise, the hip may appear more dysplastic than it really is.

The dynamic or real time method attempts to visualize the Barlow and Ortolani maneuvers on the ultrasound screen. The technique is dependent on ligamentous or capsular laxity and just like the physical examination, the ultrasound examination is dependent on the operator. The dynamic technique is performed with the infant in both the lateral decubitus and supine positions and imaging in the coronal and transverse planes with and without stress. The coronal image is obtained with the hip flexed to 90° and posterior stress is applied to the knee with the palm of the hand (Barlow provocative test) and any subluxation is noted (Fig. 5). Six mm of subluxation on the left and 4 mm on the right is normal during the first few days of life. If the hip subluxates or dislocates, an attempt at reduction is performed (the Ortolani maneuver). The second stage of the dynamic method consists of similar imaging in the
Fig. 5. A, A coronal ultrasound of the left hip in a 2-month-old infant with DDH showing an alpha angle of 42° and a beta angle of 69°. B, The coronal ultrasound of the same hip after stress was applied demonstrating subluxation of the hip. The alpha angle is unchanged but the beta angle has increased from 69° to 75° indicating eversion of the roof of the cartilaginous acetabulum (labrum).

The clinical use of ultrasound for neonatal screening has resulted in a high false positive rate and a high treatment rate. The ultrasound has allowed physicians to establish the correct diagnosis at an earlier age, but has failed to reduce the incidence of late DDH. Clarke et al. reported on 448 newborns that were referred for possible DDH. Seventeen had positive clinical examinations and were treated. In addition to these 17 cases, 81 newborns had abnormal ultrasound examinations on the first visit. None of these newborns was treated and in all cases follow-up ultrasounds showed resolution of the instability. Berman and Klenerman compared the ultrasound and clinical findings in 1001 newborns and found the ultrasound to be a more sensitive diagnostic tool. These studies document that the ultrasound is sensitive, but it may be too sensitive in identifying clinically insignificant instability.

Castelein et al. reported on 144 neonatal hips with ultrasound abnormalities that were screened from a population of 691 clinically normal hips. The prevalence of sonographic abnormalities in clinically normal hips was thus 21%. None were treated and after 6 months only four had DDH and of these, three had risk factors. They concluded that ultrasound should not be performed as a general screening procedure in clinically healthy newborns. Gardiner et al. reported that abnormal neonatal sonograms resolved rapidly and questioned whether ultrasound could predict the need for treatment in the neonatal period.

The ultrasound is useful in longitudinal follow-up of infants. The newborn with ligamentous laxity and instability can be followed up with a repeat ultrasound examination to document resolution of the instability. The infant undergoing treatment with a Pavlik harness can be followed up with ultrasound examinations to document that the hip is responding to treatment and limit the number of radiographs required.

The advantages of the ultrasound examination are its accuracy, safety, and ability to detect abnormalities when the physical examination is normal, leading to earlier treatment. The disadvantages include that it is operator-dependent, detects abnormalities that may have no clinical significance, may lead to unnecessary treatment, and does not eliminate late dislocations.

If a positive Ortolani or Barlow test is noted on neonatal screening, it is clear that the newborn has DDH and an ultrasound is not necessary. In this case, repeating the clinical examination daily is recommended and if the hip spontaneously reduces, an ultrasound is obtained at 2 weeks of age to document the reduction. If the hip does not spontaneously reduce, treatment is instituted and an ultrasound is obtained 1 to 3 weeks later to document that the hip is responding to treatment.

If the neonatal hip examination is questionable or if there are associated risk factors, obtaining an ultrasound at 2 to 4 weeks of age is recommended. If the ultrasound is abnormal, treatment is instituted. If the ultrasound is normal with associated risk factors, an anteroposterior pelvis radiograph at 4 months of age is recommended to rule out any dysplasia. After the appearance of the ossification center of the femoral head (3 to 7 months), the ultrasound becomes less reliable in visualizing the bony anatomy and the radiograph becomes increasingly accurate.
Treatment

The goal of treatment is to safely obtain and maintain a concentric reduction of the hip to provide an environment for normal bony development. The technique is dependent on the age of the patient, the type of DDH, and the amount of bony deformity.

The rationale for treatment in the neonatal period is to position the legs in a manner that fosters reduction of the dislocated hip, creating stability. Although untreated unstable hips may stabilize spontaneously without treatment, some will develop persistent subluxation or dislocation. Abduction diaperaing has been recommended to maintain the hips in a position of flexion and abduction. The results in achieving a reduction were satisfactory, but excessive abduction was associated with a high incidence of avascular necrosis of the femoral head.

In 1950, Pavlik\textsuperscript{58} described a dynamic positioning device designed to guide the hips into flexion and abduction yet allow the infant to move the legs. The spontaneous kicking movements allowed a gentle reduction with a low incidence of avascular necrosis. Although popular in central Europe for over 30 years, the Pavlik harness has only recently gained wide acceptance in the United States. Pavlik’s original concept of self reduction without force has proven itself over time and the harness has become the gold standard for treating DDH in the neonatal period.\textsuperscript{59,60}

The indications for Pavlik harness treatment include unstable, subluxated, and dislocated hips in newborns and infants from 0 to 6 months of age. The harness is not recommended for infants >9 months of age or when the dislocation is secondary to paralysis (eg, myelomeningocele). In dislocated hips, the harness needs to be closely monitored as failure of reduction within 2 to 3 weeks may cause erosive changes in the superolateral acetabulum.\textsuperscript{61}

The Pavlik harness should be applied and monitored by the treating physician, not the orthotist. A maladjusted harness will not benefit the infant, may aggravate the dislocation, and may cause complications. A repeat ultrasound examination is performed after 1 to 3 weeks to document that the hip is responding to treatment. The Pavlik harness is worn full-time until the hip becomes clinically stable.\textsuperscript{62}

Once stability is achieved, the harness can be worn part-time, being removed for bathing and play a few hours per day, but the hip should be treated in the harness until both the clinical examination and radiographs are normal. The ultrasound helps particularly during the weaning stage to limit the number of radiographs. Hangen et al\textsuperscript{63} reported that the average number of radiographs obtained during the first year of life decreased 50% with the advent of ultrasound at their institution.

Early detection is important as it decreases the length of treatment in the Pavlik harness. Ramsey et al\textsuperscript{64} reported if the age at onset of treatment was under 1 month, the average length of treatment was 3.6 months; if the age at onset was 1 to 3 months, the length increased to 7 months; and if the age at onset was 3 to 6 months, the length of treatment increased to 9.3 months.

Mubarak et al\textsuperscript{65} have identified several pitfalls associated with the Pavlik harness. The most serious was failure to obtain a reduction, often related to improper adjustment of the device. It is beneficial for the infant to have full movement while in the harness. Iwasaki\textsuperscript{66} reported that infants who were treated with the Pavlik harness in the hospital in the supine position had a 28% incidence of avascular necrosis whereas those treated at home with no activity restrictions had an avascular necrosis rate of only 7%. Tucci et al\textsuperscript{67} reported on Pavlik harness treatment in 61 patients and at 5-year follow-up, all of the hips appeared radiographically normal, but at 12-year follow-up, 17% demonstrated changes in the acetabulum. This study emphasizes the importance of continued follow-up of patients with DDH until skeletal maturity.

For infants >6 months of age or those that have not responded to treatment in the Pavlik harness, preliminary traction followed by closed reduction, adductor release, and application of a spica cast are recommended. In severe cases or in older children, an open surgical reduction may be required to relocate the hip. If there is significant bony deformity of the acetabulum or proximal femur, most surgeons will correct these deformities at the time of open reduction.

Principles To Detect DDH

All newborns are recommended to have a neonatal hip screening physical examination. If the neonatal examination is normal, sequential hip examinations at 2 weeks, 2 months, 4 months, 6 months, 9 months, and 1 year of age are recommended. If there are associated risk factors or if any of the examinations are abnormal, an ultrasound examination is recommended if the infant is 1 to 4 months of age or an anteroposterior pelvis radiograph if the infant is >4 months of age.

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REFERENCES


ERRATUM

In the article by Aronsson et al entitled “Developmental Dysplasia of the Hip” that appears in the August issue of Pediatrics (1994;94:201–208), page 203, part of the legend in Figure 1 is incorrect. It should read as follows:

Drawings demonstrating the technique for performing the Ortolani and Barlow maneuvers. The Ortolani sign is obtained by gently abducting the leg and a palpable “clunk” is felt as the femoral head slides over the posterior rim of the acetabulum into the socket. This is called the sign of entry. The Barlow provocative test is obtained by adducting the hip and pushing gently on the knee and a palpable “clunk” is felt as the femoral head slides over the posterior rim of the acetabulum and out of the socket. This is called the sign of exit.
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