The term “developmental dysplasia or dislocation of the hip” (DDH) refers to the complete spectrum of abnormalities involving the growing hip, with varied expression from dysplasia to subluxation to dislocation of the hip joint. Unlike the term “congenital dysplasia or dislocation of the hip,” DDH is not restricted to congenital problems but also includes developmental problems of the hip. It is important to diagnose these conditions early to improve the results of treatment, decrease the risk of complications, and favorably alter the natural history. Careful history taking and physical examination in conjunction with advances in imaging techniques, such as ultrasonography, have increased the ability to diagnose and manage DDH. Use of the Pavlik harness has become the mainstay of initial treatment for the infant who has not yet begun to stand. If stable reduction cannot be obtained after 2 weeks of treatment with the Pavlik harness, alternative treatment, such as examination of the hip under general anesthesia with possible closed reduction, is indicated. If concentric reduction of the hip cannot be obtained, surgical reduction of the dislocated hip is the next step. Toward the end of the first year of life, the toddler’s ability to stand and bear weight on the lower extremities, as well as the progressive adaptations and soft-tissue contractures associated with the dislocated hip, preclude use of the Pavlik harness.


The term “developmental dysplasia or dislocation of the hip” (DDH) refers to the complete spectrum of abnormalities involving the growing hip, with varied expression from dysplasia to subluxation to dislocation of the hip joint. Unlike the traditional term “congenital dysplasia or dislocation of the hip,” the designation DDH has been officially endorsed by the American Academy of Orthopaedic Surgeons, the American Academy of Pediatrics, and the Pediatric Orthopaedic Society of North America because it is not restricted to congenital dislocation of the hip and includes developmental problems of the hip. This more comprehensive term refers to alterations in hip growth and stability in utero, in the newborn period, and in the neonatal period that may result in dysplasia, ranging from subluxation to dislocation of the joint. Although congenital dysplasia or dislocation of the hip is the most common subset of disorders under the rubric DDH, the term also refers to hip disorders associated with neurologic disorders (e.g., myelomeningocele), connective tissue disorders (e.g., Ehlers-Danlos syndrome), myopathic disorders (e.g., arthrogryposis multiplex congenita), and syndromic conditions (e.g., Larsen syndrome). None of the hip abnormalities associated with these less common conditions is precisely or adequately addressed by the term congenital dislocation of the hip.

The term “dysplasia” denotes an abnormality in development, such as an alteration in size, shape, or organization. Hip-joint dysplasia refers to alterations in the structure of the femoral head, the acetabulum, or both. The well-developed cup-shaped structure is absent in acetabular dysplasia and is replaced by a shallow saucer-shaped acetabulum that is not congruent with the femoral head. Dysplasia of the infant femoral head is difficult to evaluate radiographically because the proximal femoral ossific center does not appear until 4 to 7 months of age. Technological advances and...
increased experience with ultrasonographic evaluation of the infant hip have improved our understanding of the structural changes that may exist in the cartilaginous portions of the femoral head and acetabulum. Congruent stability of the femoral head within the acetabulum is essential for normal growth and development of the hip joint.

The term “dislocated hip” indicates that the femoral head has been displaced from the confines of the acetabulum. In most instances, the femoral head lies posterosuperior to the acetabulum. A dislocated hip may be reducible or irreducible. A dislocatable hip is one in which the femoral head is located within the acetabulum but can be completely displaced from it by the gentle application of posteriorly directed forces to the hip positioned in adduction. When a similar maneuver is performed with resultant gliding of the femoral head, which remains within the confines of the acetabulum, the hip joint is unstable and is thus termed “subluxatable.”

**Etiology and Causative Factors**

One in 1,000 children is born with a dislocated hip, and 10 in 1,000 children are born with hip subluxation or dysplasia. The condition occurs with greater prevalence in Native Americans and Laplanders and is rarely seen in infants of African descent. Cultural traditions, such as swaddling of the infant with the hips together in extension, have been implicated as important causative factors in these groups. Eighty percent of affected children are female. The left hip is affected in 60% of children, the right hip in 20%, and both hips in 20%. It is believed that the left hip is more frequently involved because it is adducted against the mother’s lumbosacral spine in the most common intrauterine position (left occiput anterior); in that position, less cartilage is covered by the bone of the acetabulum, and instability is, therefore, more likely to develop. Females may be affected more frequently because of the increased ligamentous laxity that transiently exists as the result of circulating maternal hormones and the additional effect of estrogens that are produced by the female infant’s uterus.

Developmental dysplasia or dislocation of the hip occurs more often in infants who present in the breech position, whether delivered vaginally or by cesarean section. The in utero knee extension of the infant in the breech position results in sustained hamstring forces about the hip with subsequent hip instability. While breech presentation occurs in fewer than 5% of newborns, Dunn and Barlow noted breech position in 32% and 17.3%, respectively, of children with DDH. Twice as many female infants as male infants present in the breech position, and 60% of breech presentations are noted in firstborn children. Firstborn children are affected twice as often as subsequent siblings, presumably on the basis of an unstretched uterus and tight abdominal structures, which may compress the uterine contents. Postural deformities and oligohydramnios are also associated with DDH. The probability of having a child with DDH in at-risk families has been determined by Wynnedavies: 6% if there are normal parents and one affected child, 12% if there is one affected parent but no prior affected child, and 36% if there is one affected parent and one affected child.

**Pathologic Anatomy**

The secondary changes observed in the hip joint reflect significant soft-tissue contracture and alterations in normal growth of the femoral head and acetabulum. The most consistent finding in DDH is a shallow acetabulum with persistent femoral anteversion. The longer the femoral head remains out of the acetabulum, the more severe the acetabular dysplasia and the greater the femoral head distortion. Persistent subluxation of the hip results in progressive deformation of both the acetabulum and the femoral head.

Soft-tissue adaptations develop at the labrum, limbus, ligamentum teres, pulvinar, transverse acetabular ligament, iliofemoral tendon, and hip-joint capsule. The acetabular labrum, a fibrocartilaginous structure located at the acetabular rim, enhances the depth of the acetabulum by 20% to 50% and contributes to the growth of the acetabular rim. In the older infant with DDH, the labrum may be inverted and may mechanically block concentric reduction of the hip.

The limbus, which is frequently confused with the labrum, represents a pathologic response of the acetabulum to abnormal pressures about the hip. With superior migration of the femoral head, the labrum is gradually everted, with capsular tissue interposed between it and the outer wall of the acetabulum. Mechanical stimulation results in the formation of fibrous tissue, which merges with the hyaline cartilage of the acetabulum at its rim. The resultant structure, the limbus, may then prevent concentric reduction of the hip.

The status of the labrum is best evaluated by arthrographic studies of the hip or by magnetic resonance (MR) imaging. Surgical excision of the labrum will result in persistent alterations in acetabular growth. Closed reduction of the dislocated hip with an inverted labrum has been associated with increased prevalence of avascular necrosis of the femoral head, perhaps secondary to increased intra-articular pressure.
The blood vessels of the ligamentum teres provide minimal circulation to the femoral head. However, in persistent dislocation of the hip, the ligamentum teres lengthens, hypertrophies, and may block concentric reduction of the femoral head in the acetabulum. Fibrofatty tissue, known as the pulvinar, may be found within the depths of the acetabulum and may prevent acceptable reduction of the femoral head within the acetabulum. Closed reduction of the femoral head within the acetabulum will result in spontaneous recession of the pulvinar. Open reduction of the fixed dislocated hip joint involves resection of the ligamentum teres and the pulvinar to ensure congruent reduction.

The transverse acetabular ligament, located at the caudal perimeter of the acetabulum, contracts in patients with persistent hip dislocation and is a major block to concentric reduction of the hip. Incising the transverse acetabular ligament is essential for complete reduction of the hip joint. With long-standing dislocation, the stretched hip capsule becomes constricted by the contracted iliopsoas tendon to assume an hourglass configuration that prevents reduction.

In summary, any of the following structures or conditions may be a block to concentric reduction in the patient with DDH: inverted labrum, presence of a limbus, hypertrophied ligamentum teres, pulvinar, contracted capsule, contracted transverse acetabular ligament, and contracted iliopsoas.

Physical Examination

All newborn infants are examined by a physician in the nursery. The history obtained at that first evaluation includes gestational age, presentation (breech versus vertex), type of delivery (cesarean versus vaginal), sex, birth order, and family history of hip dislocation, ligamentous laxity, or myopathy. There is a higher prevalence of DDH in breech babies, girls, firstborn infants, and those with a positive family history of DDH, hyperlaxity syndromes, and myopathies.

The baby should be relaxed and examined in a warm, quiet environment with removal of the diaper. A general examination, beginning at the head, should be done to detect conditions that are associated with an increased prevalence of DDH, such as torticollis, congenital dislocation of the knee or foot, lower-extremity deformities, and ligamentous laxity. A baseline neurologic evaluation to assess motor impairment or alterations in muscle tone is necessary. Spine deformity or midline spinal cutaneous lesions, such as a sinus, hemangioma, or hairy patch, may suggest the existence of underlying spinal anomalies.

Evaluation of the hip begins with observation of both lower extremities for asymmetric inguinal or thigh skin folds (Fig. 1, A) or femoral shortening. The Galeazzi, or Allis, sign is elicited by placing the child supine with the hips and knees flexed. Unequal knee heights suggest congenital femoral shortening or dislocation of the hip joint (Fig. 1, B). Bilateral hip dislocation may be present and may not reveal asymmetry of femoral length or hip joint motion. An infant with unilateral hip dislocation will eventually exhibit limited hip abduction on the affected side but perhaps not for several months (Fig. 1, C).

Each hip is examined individually with the opposite hip held in maximum abduction to lock the pelvis. Gentle, repetitive passive motion of the hip joint will allow detection of subtle instability. Marked limitation of motion of the hip joint in the newborn period with irreducible hip dislocation is evidence of a teratologic hip dislocation due to syndromic, genetic, or neuromuscular causes. Soft-tissue clicks felt while adducting or abducting the hip in the absence of other abnormal findings are considered benign.

The Ortolani and Barlow tests are performed to evaluate hip sta-
The infant must be examined in a relaxed state while positioned supine on a firm surface. Each hip is examined separately. To perform the Ortolani test on the left hip, the examiner’s right hand gently grasps the left thigh with the middle or ring finger over the greater trochanter and the thumb over the lesser trochanter (Fig. 2, A). The examiner’s left hand is used to stabilize the infant’s right hip in abduction. The examination is initiated by slowly and gently abducting the left thigh while simultaneously exerting an upward force on the left greater trochanter. Abduction of each hip should be symmetric. The sensation of a palpable “clunk” when the Ortolani maneuver is performed represents mechanical reduction of the femoral head into the confines of the acetabulum, signifying a dislocated but reducible hip. The process is then repeated on the right hip with the left hip locked against the pelvis in abduction.

The infant is positioned similarly for performance of the Barlow test; however, the thumb is positioned at the distal medial thigh and is used to apply a gentle lateral and downward force at the hip joint in an attempt to dislocate the femoral head from the acetabulum (Fig. 2, B). When the hip is displaced from the acetabulum, the hip is described as dislocatable. When the Barlow test results in positioning of the femoral head within the confines of the acetabulum, the hip is described as subluxatable. After the age of 3 months, the Ortolani and Barlow tests become negative as progressive soft-tissue contracture evolves.

**Radiologic Examination**

In the normal newborn with clinical evidence of DDH, routine radiography of the hips and pelvis may be confirmatory, but a normal radiograph does not exclude the presence of instability. If fixed dislocation and limited abduction are noted in the hip, an anteroposterior radiograph of the hips and pelvis is indicated to evaluate for teratologic dislocation of the hip and to rule
out congenital anomalies of the proximal femur, pelvis, or caudal spine. Abnormal findings on the radiograph may confirm or suggest a diagnosis, but a normal radiograph does not exclude the presence of instability. If subluxation of the hip is suspected, dynamic ultrasonography of the hip joint by an experienced ultrasonographer may be used to confirm the diagnosis.

Radiographic evaluation is most reliable when the infant is relaxed and placed supine on the examination table. The pelvis must be neutral to the table with the lower extremities held in neutral abduction-adduction and the hips in slight flexion to reproduce the physiologic hip-flexion contracture. If the pelvis is rotated to one side, the anteroposterior radiograph will demonstrate asymmetry of the obturator foramina, with the spurious finding of deficient acetabular coverage of one hip and normal coverage of the opposite hip. If the physiologic hip-flexion contracture is not respected and the lower extremities are forced down on the examination table, the pelvis will rotate anteriorly and will give the appearance of distorted acetabular anatomy.

Several reference lines and angles may be helpful in the critical evaluation of the anteroposterior radiograph of the infant’s pelvis (Fig. 3). Hilgenreiner’s line is a line drawn horizontally through each triradiate cartilage of the pelvis. Perkins’ line is drawn perpendicular to Hilgenreiner’s line at the lateral edge of the acetabulum, which may be difficult to identify in the dysplastic hip. The femoral head should lie within the inferomedial quadrant formed by Hilgenreiner’s and Perkins’ lines. Shenton’s line is a continuous arch drawn along the medial border of the neck of the femur and the superior border of the obturator foramen. Displacement of the femoral head or severe external rotation of the hip will result in a break in the continuity of Shenton’s line.

The acetabular index is calculated by drawing an oblique line through the outer edge of the acetabulum tangential to Hilgenreiner’s line. In the newborn, the normal value averages 27.5 degrees; an index greater than 35 degrees may herald acetabular dysplasia. In addition to the numeric acetabular index, the absence of a sharply defined lateral edge of the acetabulum may suggest dysplasia.

When the proximal femoral ossification center is present, the center-edge angle may be calculated. A line is drawn vertically through the center of the femoral head and perpendicular to Hilgenreiner’s line. A second line is drawn obliquely from the outer edge of the acetabulum through the center of the femoral head. The resulting center-edge angle reflects both the degree of acetabular coverage of the femoral head in acetabular dysplasia and the degree of femoral head displacement in the unstable hip. A center-edge angle less than 20 degrees is considered abnormal and may be associated with acetabular dysplasia or subluxation of the hip. The values obtained by these methods are not absolute and must be considered in conjunction with the entire history and physical examination.

Weintroub et al. studied the growth and development of congenitally dislocated hips that were reduced early in infancy and compared the results with the growth and development of a group of normal hips. In 56 normal hips in children between the ages of 3 and 6 months, the mean acetabular index was 21 degrees (range, 15 to 30 degrees; SD, 3 degrees), and the mean center-edge angle was 21 degrees (range, 12 to 30 degrees; SD, 6 degrees). In 36 abnormal hips in the same age group, the mean acetabular index was 38 degrees (range, 29 to 48 degrees; SD, 6 degrees), and the mean center-edge angle was 21 degrees (range, 12 to 30 degrees; SD, 6 degrees). The authors reported that the acetabular index was reproducible in all studied age groups,
but that the center-edge angle in children less than 3 years old is difficult to measure due to incomplete or irregular ossification of the femoral head and should be reserved for children older than 5 years. Delay in the appearance of the ossific nucleus of the proximal femur in DDH is expected in persistent instability of the hip joint or as the result of an avascular insult following intervention. Persistent subluxation or dislocation of the hip results in widening of the acetabular “teardrop.” The lateral line of the teardrop represents the cortical surface of the acetabular fossa. The medial line represents the medial cortex of the pelvic wall at the posterior margin of the acetabulum. The observation of widening of the teardrop as the child grows may suggest low-grade instability that is not clinically apparent.

In the past two decades, dynamic ultrasonography of the infant hip before the appearance of the proximal femoral ossification center has advanced evaluation and understanding of DDH. Ultrasonography is capable of visualizing the cartilaginous anatomy of the femoral head and acetabulum without ionizing radiation. Graf’s pioneering studies produced static measurements of normal infantile hip anatomy, and Harcke’s dynamic hip ultrasonographic techniques provided clinically relevant information for critically evaluating the stability of the hip. Ultrasonography is useful in confirming subluxation of the hip, identifying dysplasia of the cartilaginous portion of the acetabulum, and documenting reducibility and stability of the hip in the infant undergoing treatment with the Pavlik harness. When reduction of the hip is maintained by a spica cast, ultrasonography of the hip requires a large window, which is destabilizing and therefore should be avoided. Appearance of the proximal femoral ossification center will interfere with ultrasound evaluation of the hip joint. Patients treated for hip instability may demonstrate delay in the appearance of the proximal femoral ossification center as long as 1 year after hip reduction. The delay in ossification of the femoral head in this population allows continued utilization of ultrasonography in the evaluation of hip stability.

Computed tomography of the hip is effective in evaluating hip position in a spica cast after closed or open reduction. Radiographs of the hips and pelvis may be obscured by a hip spica and may not clearly demonstrate posterior subluxation of the femoral head. Computed tomography is able to more precisely document concentric hip reduction. In addition, the presence of excessive hip abduction, which may be associated with the development of avascular necrosis of the femoral head, can be more critically evaluated.

The role of MR imaging in the management of DDH has not yet been defined. Although MR imaging allows visualization of soft-tissue anatomy, it offers no substantial advantage over standard imaging techniques.

Arthographic evaluation of the hip demonstrates the cartilaginous anatomy of the acetabulum and femoral head and is a dynamic test to evaluate the stability and quality of reduction. Arthography plays an important role in deciding between closed and open reduction in older infants and toddlers.

**Treatment**

 Debate continues concerning which abnormal hips actually require active intervention. Subluxation of the hip at birth often corrects spontaneously and may be observed for 3 weeks without treatment. The triple-diaper technique, which prevents hip adduction, is still utilized but has demonstrated no improvement in results compared with no intervention at all in the first 3 weeks of life. When evidence of subluxation of the hip persists beyond 3 weeks on physical examination or ultrasonographic evaluation, treatment is indicated. When actual hip dislocation is noted at birth, treatment is indicated without need for an observation period (Fig. 4).

Various devices have been used for the treatment of hip instability in infants, including hip spica casts, the Frejka pillow, the Craig splint, the Ilfeld splint, and the von Rosen splint. These devices are not commonly used as initial treatment today and have been replaced almost exclusively in the United States by the Pavlik harness.

**Pavlik Harness**

The Pavlik harness was introduced in eastern Europe in 1944 and has been used in the United States for more than 30 years (Fig. 5). The harness is a dynamic positioning device that allows the child to move freely within the confines of its restraints. It consists of a circumferential chest strap with shoulder straps that provide sites of attachment for lower-extremity straps. The function of the anterior lower-extremity straps is to flex the hips, whereas the posterior lower-extremity straps prevent adduction of the hips. The posterior lower-extremity straps should not be used to produce abduction of the hips, which is associated with avascular necrosis.

Indications for use of the Pavlik harness include the presence of a reducible hip in an infant who is not yet making attempts to stand. The child’s family must be able to follow instructions and be available for frequent evaluations and harness adjustments. When radiographs of the hips and pelvis in flexion and abduction indicate that the femoral neck
Developmental Dysplasia of the Hip

Figure 4  Algorithm for evaluation and treatment of DDH.

The following treatment protocol is commonly utilized for children from birth to the age of 6 months. The Pavlik harness is initially applied and adjusted by the treating physician. Evaluation is done on a weekly basis, and a radiograph or sonogram of the hips in the harness is obtained when there is full range of motion (Fig. 6). If the hip is not reduced and stable by 2 weeks, other treatment options should be considered.

If the hip is stable and reduced at 2 weeks, follow-up visits to confirm continuing stability of the hips in the Pavlik harness and to adjust the harness straps are scheduled every 2 weeks. The harness is worn full-time for half of the treatment time. Weaning may be initiated at the midpoint of treatment if there is both clinical and radiographic evidence of stability. At the midpoint of the treatment program, the child is taken out of the Pavlik harness the night before the office visit, and a radiograph of the hips and pelvis out of the harness is obtained the following day. If the findings from the clinical examination and radiographs are consistent with hip stability, weaning from the harness is initiated with the child out of the harness for 4 hours a day for the first third of the remaining treatment period. Reevaluation is at 2-week intervals. If stability is maintained, the child is progressively weaned out of the harness 8 hours a day for the next third of the weaning period and as long as 12 hours a day for the final third of the weaning period.

An anteroposterior radiograph of the hips and pelvis is obtained at the end of the weaning process. If the hip is radiographically normal, the harness is discontinued. If residual acetabular dysplasia exists, the harness is worn for 12 hours a day until the dysplasia resolves on radiographic evaluation. When the child begins to pull to stand, an Ilfeld brace is substituted for the Pavlik harness and is used until the hip is radiographically normal.

Ramsey et al. reported the results of treatment of 27 dislocated hips in 23 children who were less than 6 months old. The clinical and radiograph criteria for use of the Pavlik harness included the ability to direct the femoral head toward the triradiate cartilage. Twenty-four dislocations were successfully reduced, and all were clinically and radiographically normal at follow-up with no evidence of avascular necrosis. The authors introduced the concept of the “safe zone,” which is the difference in degrees between the angle of maximal passive hip abduction and the angle of hip abduction at which the femoral head displaces from the acetabulum.