Chapter 10
Developmental Dysplasia of the Hip (DDH)

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Brief Overview

Developmental dysplasia of the hip (DDH) refers to a spectrum of hip disorders with varying degrees of dysplasia of the femoral head or acetabulum. Presentation can vary from full dislocation in a newborn to mild acetabular changes in an adolescent or adult. Several terms are used to describe the hip throughout this spectrum of disease including subluxation, dysplasia, dislocation, or teratologic dislocation. Hip subluxation refers to a hip joint with slight displacement, but some maintained contact between articular surfaces. Hip dysplasia refers to a shallow or underdeveloped acetabulum. A dislocated hip refers to complete displacement of the femoral head, with no contact with the acetabulum. A teratologic dislocation is a more severe dislocation, with increased stiffness and inability to reduce the femoral head to its anatomic position within the acetabulum. Teratologic dislocations are typically dislocated in utero and associated with genetic and neuromuscular conditions.

DDH is one of the most common musculoskeletal disorder among newborns [1]. The initial hip instability is felt to be multifactorial in cause. This instability leads to alteration in normal hip positioning, which in turn affects the normal development and relationship of the femoral head and acetabulum. DDH is one of several "packaging deformities," which include congenital muscular torticollis, metatarsus adductus, and congenital knee dislocation. Frank instability and dislocation can be

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picked up on examination as an infant; however, subtle forms of dysplasia may be missed due to less obvious clinical presentation [2]. Early detection is crucial since the success of treatment is related to the severity of the condition and the child's age at presentation. The goal of treatment is to restore the "normal" position of the hip at the earliest age possible in order to ensure proper development of the femoral head and acetabulum.

Epidemiology

DDH is one of the most common orthopedic disorders found in newborns [1]. The estimated incidence of instability is 1 in 1000 newborns. This does not take into account the more subtle and clinically unnoticeable presentations, which puts the estimation of actual dysplasia as high as 1:50 or 1:100 depending on the inclusion criteria [2]. This pathology is most commonly seen in Native American and Laplanders and is uncommon in African Americans [3, 4]. One potential contributing factor is thought to be the cultural tradition of swaddling infants with their legs held together [5, 6]. Females also see a higher rate of hip dysplasia possibly due to the effects of maternal hormones at birth with rates as high as 6:1 compared with men [7]. The left hip is the most commonly affected, up to 60% of the time, with right side affected 20% and bilateral presentation in 20% of cases [8, 9]. It is felt that the left hip is affected more as the most common intrauterine position is left occiput anterior. In this position, the left hip is adducted against the lumbosacral spine of the mother [9].

The most notable risk factors for DDH include female gender, firstborn child, breech presentation, positive family history, and oligohydramnios. Firstborn children are thought to be at risk due to an unstretched uterus and other structures within the abdomen compressing the uterus. A similar mechanism is observed in oligohydramnios, in which decreased intrauterine fluid results in less space for the child, putting the hip at risk for abnormal positioning [9, 10]. Breech presentation puts the hip at risk for dysplasia regardless of vaginal or cesarean delivery [9]. The risk is higher with frank or single breech position when compared to footling breech position [11]. It is important to screen newborns for the above risk factors. The presence of one or more should raise suspicion and result in careful evaluation of the newborn hip. Clinical guidelines released by the American Academy of Orthopedic Surgeons (AAOS) support performing an ultrasound (2–6 weeks of age) or an X-ray (by 4 months of age) in infants with one or more of the following risk factors: breech presentation, family history, or history of clinical instability [12]. This recommendation was also endorsed by the American Academy of Pediatrics (AAP) and the Pediatric Orthopedic Society of North America (POSNA) [12].

Pathophysiology

Normal Anatomy

A normal hip consists of a spherical femoral head concentrically reduced within the hemispheric acetabulum. Maintenance of this relationship is important in the development of both the femoral head and acetabulum. The development of the hip joint occurs around the seventh week of gestation. The mesenchymal cells of this structure develop into a cartilaginous femoral head and acetabulum around the 11th week [13, 14]. Contact between the femoral head and acetabulum results in the concave hemispherical acetabular shape.

At birth, the acetabulum is composed of hyaline cartilage and is surrounded by a rim of fibrocartilage called the labrum. Growth of the acetabulum takes place at multiple growth centers. The shape of the acetabulum is typically determined by age 8, and the growth centers fully fuse during adolescence. The femoral head is also cartilaginous at birth, and an ossification center develops around 4–6 months after birth. Growth centers in the femoral head and greater and lesser trochanters all contribute to the growth and shape of the proximal femur (Fig. 10.1).

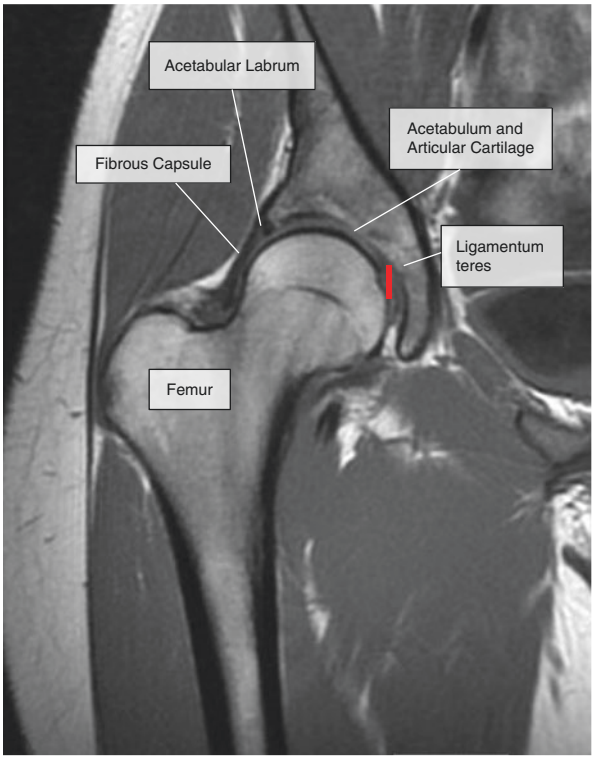

Fig. 10.1 Coronal T1 MRI of the right hip demonstrating the anatomy of a normal hip joint

Pathologic Changes

In DDH, multiple factors such as maternal or fetal laxity, intrauterine malpositioning, and postnatal positioning are thought to lead to instability and alter the normal femoral head and acetabular relationship. The alteration in normal positioning can lead to anatomic changes in the proximal femur such as increased anteversion or flattening of the head. Changes in the acetabulum can include increased acetabular anteversion, decreased concavity, or increased obliquity. The abnormal position can also result in hypertrophy of the ligamentum teres or transverse acetabular ligament, capsular laxity, and constriction of the capsule by the iliopsoas tendon. A ridge of thickened articular cartilage, called the limbus, can be formed by abnormal contact pressure. The dysplastic acetabulum may also be filled with a fibrofatty tissue called the pulvinar. All of the above can serve as blocks to concentric reduction, further potentiating the dysplasia (Fig. 10.2).

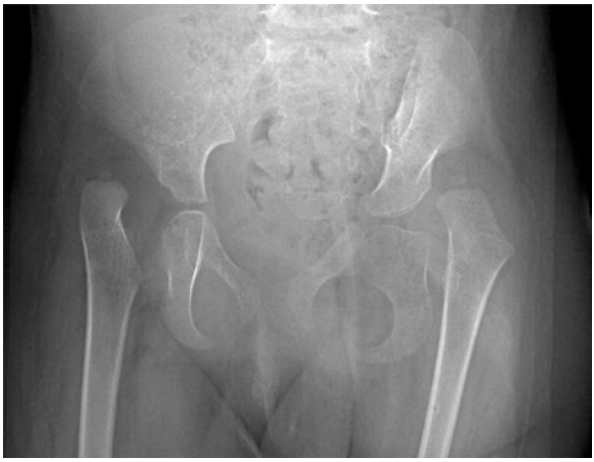

Fig. 10.2 X-ray AP pelvis of a 23-month-old with bilateral hip dislocations that are irreducible as a result of intraarticular obstacles. Obstacles to reduction can include an elongated ligamentum teres, inverted limbus, transverse acetabular ligament pulled upward, and fibrofatty pulvinar in the acetabulum

Clinical Presentation

History and Physical

Physical examination is paramount in the newborn and young infant as diagnosis is possible with several different tests. The two most common tests to aid in diagnosis are the Barlow and Ortolani tests [15, 16]. These two tests help identify the different phases of hip dysplasia which include a subluxatable, dislocatable, or dislocated hip. The Barlow test is performed with the child supine on the exam table. With the hips and knees flexed at 90°, the hip is slightly adducted and a steady posterior pressure is directed through the femur (Fig. 10.3). A clunk may be felt and is thought to be a "click of exit" when the femoral head subluxates or dislocates. A dislocatable hip is said to be "Barlow positive." The Ortolani test is also performed supine with the hips and knees flexed to 90°; however, the femur starts in a full abducted position. Elevation or anterior pressure is placed through the femur in an attempt to

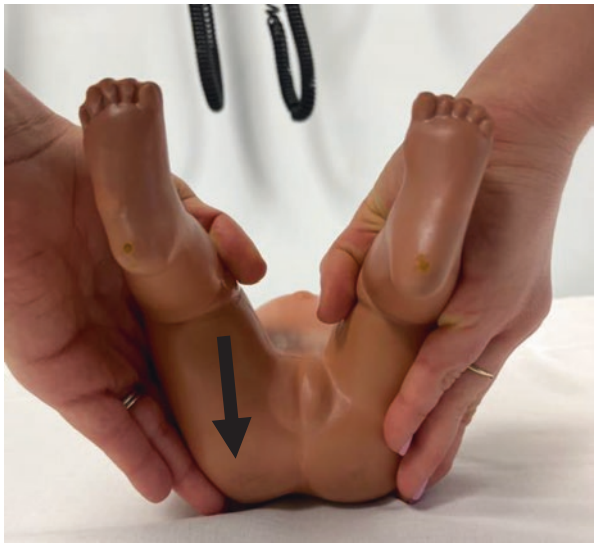

Fig. 10.3 The Barlow test. A positive Barlow test occurs when a palpable dislocation of the femur occurs

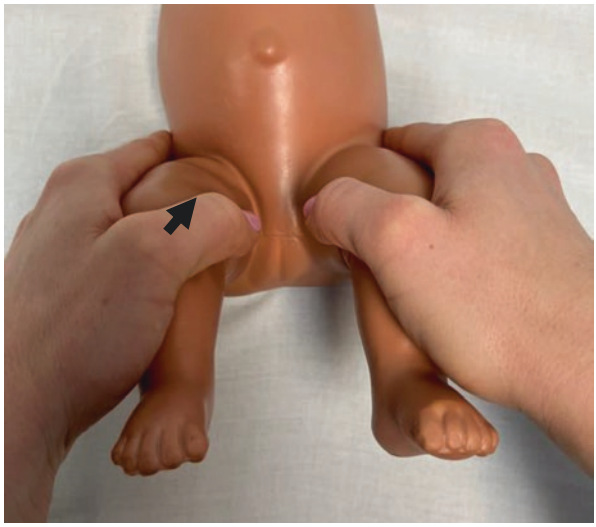

Fig. 10.4 The Ortolani test. A positive Ortolani test occurs when a palpable clunk is heard indicating the reduction of a dislocated hip into the acetabulum

reduce an already dislocated hip (Fig. 10.4). A "clunk of entry" may be felt as the femoral head is reduced in the acetabulum. When this reduction is possible, the hip is "Ortolani positive" and if a reduction is not felt it is "Ortolani negative." In summary, a hip that is reduced at rest but is able to be dislocated is Barlow positive (Ortolani negative) while the hip which is dislocated at rest but is able to be reduced is Ortolani positive (Barlow negative). Hip clicks felt throughout range of motion in examining the hips are nonspecific [17]. These tests are reliable up to 3 months of age. After this period, the pathologic changes to the hip make positive exam findings difficult.

Another common exam finding is the Galeazzi sign, which evaluates for limb length discrepancy. The child is placed supine on the exam table, hips are flexed to 90°, and the feet remain on the table. When examining the legs from the end of the table, one knee may appear "taller" than the other side and, in the case of DDH, may signify a dislocated hip (Fig. 10.5). Leg lengths may be measured as well, with a shorter side potentially due to a dislocated hip.

The Klisic test is an additional exam to help evaluate for DDH. In this exam, the examiner's long finger is placed at the tip of the greater trochanter, and the index finger is placed on the anterior superior iliac spine (ASIS). A line drawn between these points should point toward or proximal to the umbilicus; however, in a dislocated hip, this line will point between the umbilicus and the pubis (Fig. 10.6). This test may be helpful in detecting bilateral dislocations.

It is important to examine range of motion of both hips. Abduction to 70° is normal in a newborn. A significant limitation in abduction compared with the contralateral side may help identify a dislocated or subluxed hip. This is thought to be one of the most sensitive exam findings in an older infant but may be less sensitive in the first 6 weeks of life. This finding may be more subtle and difficult to detect in

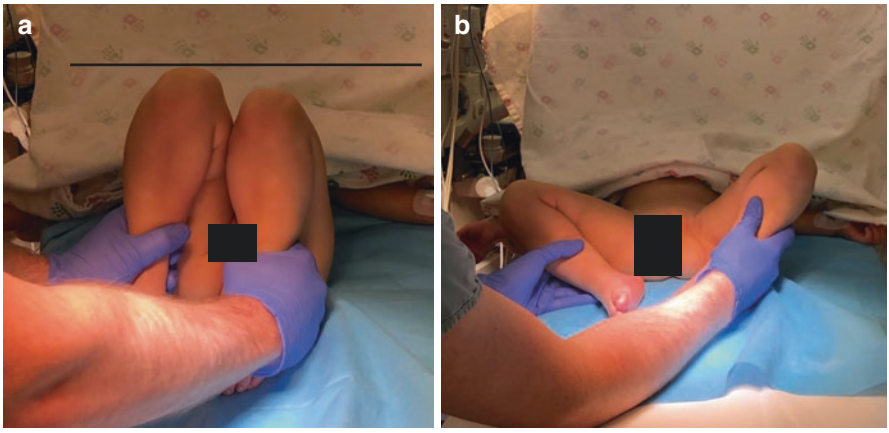

Fig. 10.5 A pre-operative examination of a patient with a left hip dislocation. Image (**a**) demonstrated a positive Galeazzi sign with apparent shortening of the femur as knees are flexed and pressed to buttocks. Image (**b**) demonstrated limited left hip abduction due to dislocation

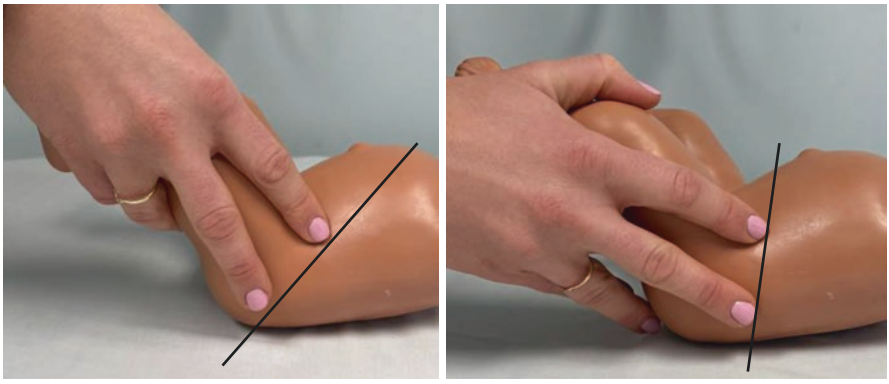

Fig. 10.6 The Klisic test. Developmental dysplasia of the hip is suspected when the imaginary line connecting the anterior superior iliac spine and greater trochanter passes below the umbilicus

bilateral dislocations. Asymmetry in the child's gluteal folds has also been described but is less reliable and specific than other findings.

As the child gets older and begins to ambulate, other exam findings may become more evident. Increases in pelvic obliquity or lumbar lordosis may be noted in response to hip contractures. A limb length discrepancy may again be noted, resulting in an ambulatory child unilaterally toe walking in an effort to compensate for the shortened extremity. Trendelenburg gait may be observed on the affected side due to abductor insufficiency.

Imaging

Several imaging studies are available to help diagnose DDH in the early phases, and other advanced imaging studies are available to help guide treatment. Ultrasound of the hip and pelvic X-rays are the most common modalities used in early diagnosis.

Ultrasound of the hip should be considered from birth to 4–6 months of age in children with a positive physical exam or significant risk factors as discussed above [12]. Radiographs are typically not useful in the prior to 6 months of age as the femoral head has not yet ossified and is not identifiable on X-ray. Since the ultrasound is a dynamic test, it can be used to see the hip moving in and out of the acetabulum. Ultrasound is also useful in monitoring reduction of the hip during treatment in a Pavlik harness.

The femoral head, labrum, ligamentum teres, hip capsule, and acetabular anatomy are all visible with an ultrasound. The examiner can identify a frank dislocation versus mild acetabular dysplasia. When examining a hip using ultrasound in a coronal view, the femoral head is typically bisected by a line drawn through the ilium. Measurements including the "alpha" and "beta" angles help in defining the amount of dysplasia. The alpha angle is defined as an angle created by a line drawn along the ilium and a line drawn along the bony acetabulum. A normal angle is greater than 60° (Fig. 10.7). The beta angle is created by measuring the angle created between a line through the labrum and one through the ilium. A normal angle is less than 55° (Fig. 10.7). Some physicians feel that adding dynamic adduction contributes to the sensitivity of these measurements [18]. Evaluation with ultrasound and measurement of these angles can help monitor treatment including observation or use of a Pavlik harness.

A commonly used classification system devised by Graf helps guide the treatment based on ultrasound measurements [19]. The Graf classification is broken up into four classes. In class I, the alpha angle is greater than 60° and beta angle is less

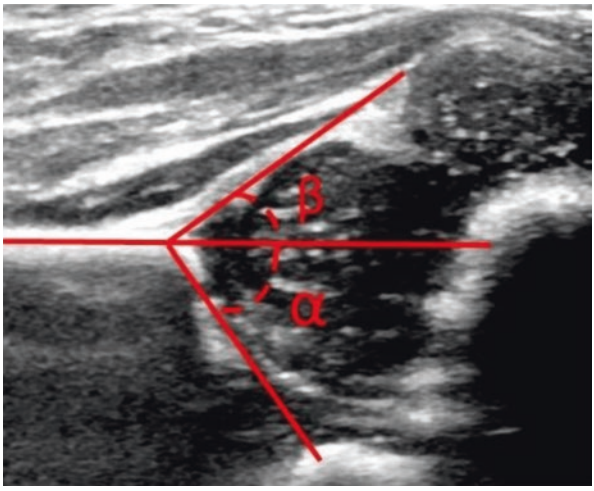

Fig. 10.7 Ultrasound demonstrating a coronal view of a normal hip joint. Alpha (α) angle should be greater than 60°. Beta (β) angle should be less than 55°

than 55°. This is felt to be a normal hip and no treatment is recommended. In class II, the alpha angle is between 43 and 60° and the beta angle is between 55 and 77°. This class has been further divided, but results in a significant gray area between observation and treatment with a Pavlik harness. Class III is a hip with an alpha angle less than 43° and a beta angle greater than 77°. This is felt to be a lateralized hip and is treated with a Pavlik harness. Class IV hips are dislocated, and the alpha and beta angles are unable to be measured. These are treated with Pavlik harness initially but failure to stabilize the hip may result in a closed or open reduction of the hip.

Universal screening of infants with an ultrasound of the hip has been previously considered in an effort to reduce the number of patients with DDH missed on clinical examination [2, 20]. This screening process has never implemented due to the limited evidence that it would prevent adverse outcomes. Both the AAOS and AAP have recommended against universal ultrasound screening in infants and base its use on risk factors (breech positioning and family history) or clinical hip instability [21]. The American Academy of Pediatrics recommends that ultrasound screening be considered between age 6 weeks and 6 months of age for infants with risk factors for hip dysplasia and a normal physical exam. Screening before 6 weeks is not recommended in this population given that mild abnormalities discovered on ultrasound will resolve in the first few months of life [22].

After ossification of the femoral head, typically at 4–6 months of age, radiographs become helpful in diagnosis. A simple AP view of the pelvis is sufficient for evaluation. Radiographs are recommended in a child with positive physical exam findings or previously identified DDH on ultrasound. An infant with obvious limb length discrepancy would also benefit from a pelvic radiograph to determine if DDH is the cause.

There are several radiographic clues to help evaluate for the presence of DDH. The ossification center of the femoral head should be present at 4–6 months of age; however, this may be delayed in the affected hip. Three different radiographic lines are typically described and used to evaluate the hip. These include Hilgenreiner's, Perkin's, and Shenton's lines. Hilgenreiner's line is created by drawing a horizontal line through bilateral triradiate cartilages (Fig. 10.8). Perkin's line is created by drawing a line perpendicular through the most lateral margin of the acetabulum (Fig. 10.8). In a normal hip, the ossification center of the femoral head should be inferior to Hilgenreiner's line and medial to Perkin's line. Shenton's line is created by following the line of the inferior border of the femoral neck and the superior margin of the obturator foramen. Shenton's line should be a continuous, smooth line. A disruption in this line signifies abnormal position of the hip (Fig. 10.8).

Other radiographic measurements including the acetabular index (AI) and center edge angle (CEA) of Wiberg are commonly described. The acetabular index is the angle created by the intersection of Hilgenreiner's line and a line drawn from the triradiate cartilage to the lateral border of the acetabulum. In patients older than 6 months, a normal angle is less than 25° [23] (Fig. 10.8). The center edge angle of Wiberg is the angle created by the intersection of Perkin's line and a line drawn

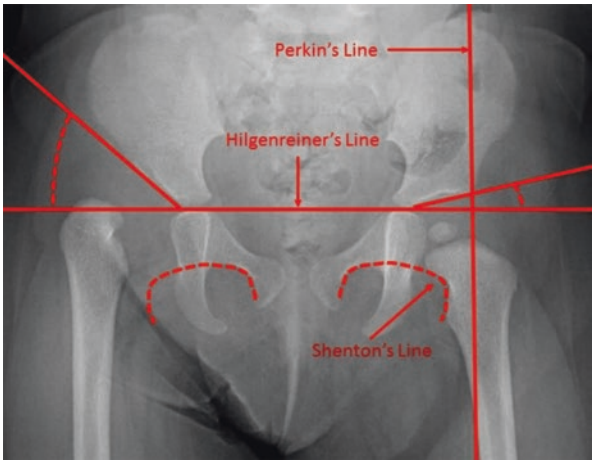

Fig. 10.8 Radiograph of a 15-month-old child demonstrating a right dislocated right hip with acetabular dysplasia. Note the delayed ossification of the femoral head, increased acetabular index, and disruption of Shenton's Line

from the center of the femoral head to the lateral edge of the acetabulum. This angle is greater than 20° in the normal hip [24].

Other imaging modalities useful in the treatment of DDH include arthrogram, CT scan, and MRI. These are typically performed by a pediatric orthopedic surgeon during treatment and are beyond the scope of this chapter.

Management

Treatment of developmental dysplasia of the hip is variable based on where the hip falls in the spectrum of disease and can range from nonoperative treatment, such as observation or the use of a Pavlik harness, to more invasive surgical treatment including pelvic or femoral osteotomies.

One of the most successful conservative treatments for DDH is the Pavlik harness, developed by Arnold Pavlik in 1946 [25]. The Pavlik harness is useful in infants, indicated in children younger than 6 months of age with a reducible hip (Fig. 10.9). The harness provides an early concentric reduction, which promotes normal acetabular development throughout the treatment course. Success rates from 65 to 100% have been reported, but results vary based on initial severity of dysplasia [26]. The Pavlik harness utilizes anterior and posterior straps which control hip flexion and abduction, respectively. The ideal position in the harness is hip flexion of 90–100° and hip abduction of 50°.

There is no consensus as to the daily amount of time in harness, as well as the duration of treatment. Typically, the harness is worn at least 23 h per day and 7 days per week. The reduction can be confirmed with ultrasound immediately following placement of the harness or at the first week follow-up visit. If the hip is found to be stable on the follow-up ultrasound, follow-up ultrasounds are performed every 2–3 weeks. If the hip remains dislocated or significantly subluxated at the initial

Fig. 10.9 Image demonstrating a child in a Pavlik harness

ultrasound in harness, follow-up ultrasounds occur more frequently and the duration of treatment may be altered, or the harness discontinued altogether if there is no improvement. The initial treatment duration is typically 6 weeks. If the initial treatment is successful, some surgeons recommend another 6 weeks in the harness and some recommend weaning from the harness over 2–6 weeks. Complications from this treatment include avascular necrosis (AVN) of the hip, transient femoral nerve palsy, and damage to the posterior acetabulum (Pavlik disease). AVN can be caused with the hips positioned in extreme or forced abduction, usually over 60°. This can result from over-tightening of the posterior strap [27, 28]. Femoral nerve palsy can result from hyperflexion of the hip or when the anterior strap is over-tightened [29]. Femoral nerve function is evaluated by observing the infant kicking their legs in the harness. If they are unable to extend their knee, treatment should be suspended. It may be resumed when the palsy has resolved. Hips that are not concentrically reduced and left in the Pavlik harness too long can lead to Pavlik disease in which the posterosuperior acetabulum erodes due to prolonged contact by the abnormally positioned hip [30].

Several alternative bracing options exist to help treat DDH. Splints such as the Ilfeld, Von Rosen, Hoffman-Daimler, and other semi rigid abduction orthosis are available. One study showed 93% success rate using a semirigid hip abduction orthosis in hips that failed treatment using a Pavlik harness [31].

When conservative treatments do not achieve the desired result or fail altogether, there are several surgical options to help address this. These treatments are typically based on the age of the patient and where they fall in the spectrum of disease.

In hips that fail treatment in a Pavlik harness or patients who are 6–18 months of age, a closed reduction is a suitable treatment option. A hip that is reducible on

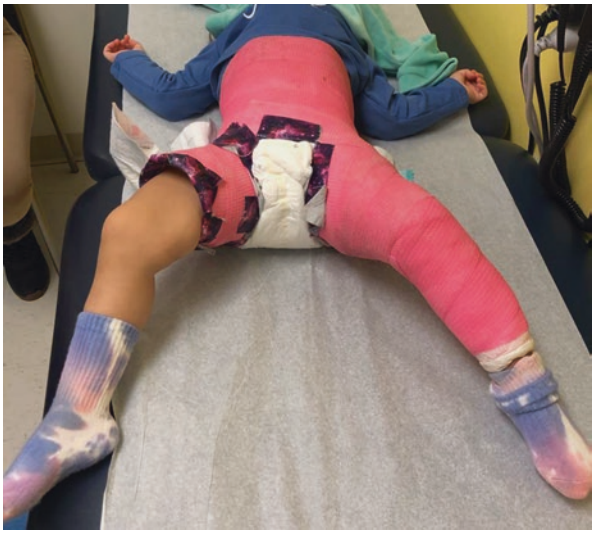

Fig. 10.10 Image demonstrating a child in a hip spica cast

physical exam is more likely to be treated successfully using this method. The hip is reduced under anesthesia and held in a reduced position using a hip spica cast (Fig. 10.10). An arthrogram, in which radiopaque dye is injected into the hip joint, can be useful in identifying an appropriate reduction or detecting pathologic structures blocking reduction. Once the reduction is performed and the cast placed, a CT or MRI of the hip is typically performed to confirm reduction. Children are typically kept in the initial cast for 6 weeks, then taken for a hip examination under anesthesia and spica cast change. The total duration of treatment is approximately 3 months.

In hips that are not amenable to closed reduction, or children who present later in life, an open reduction may be the next treatment option. In this surgery, the hip joint is opened, pathologic obstructions to reduction are removed, and the femoral head is gently guided back into the acetabulum. Surgeons may choose from different approaches, medial or anterior, based on surgeon preference or patient age. These children are also placed in a hip spica cast after surgery to hold the hip in a reduced position. Femoral shortening osteotomies may also need to be performed during this procedure to help decrease the contact pressures of the hip joint when reduced.

In older children (>18 months), there is less potential for acetabular remodeling from the above procedures. Older children with residual dysplasia, or younger children with severe dysplasia, may benefit from pelvic and/or femoral osteotomies to improve their anatomy. Several techniques are available to reshape, redirect, or reconstruct the acetabulum. The type of surgery and techniques are based on the patient's age, severity of dysplasia, and surgeon preference [26].

Hips should be continuously monitored after treatment to ensure appropriate development of the hip. Clinical and radiographic evaluations should continue until the child reaches skeletal maturity [32].

Natural History, Primary and Secondary

The goal of treatment is to improve stability of the hip joint by attempting to recreate normal hip anatomy. Abnormal anatomy of this hip joint may result in hip dysfunction and/or early osteoarthritis. Many studies have examined the relationship between acetabular dysplasia and osteoarthritis and found that dysplasia may lead to early arthritis of the hip. There is some evidence that radiographic findings, such as a center edge angle less than 20°, may predict osteoarthritis of the hip before age 65 [24, 33, 34]. By diagnosing and treating this problem early in life, we hope to decrease the risk of hip dysfunction and early onset arthritis of the hip.

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