Developmental Dysplasia of the Hip From Six Months to Four Years of Age

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Abstract

Developmental dysplasia of the hip (DDH) denotes a wide spectrum of pathologic conditions, ranging from subtle acetabular dysplasia to irreducible hip dislocation. When DDH is recognized in the first 6 months of life, treatment with a Pavlik harness frequently results in an excellent outcome. In children older than 6 months, achieving a concentrically reduced hip while minimizing complications is more challenging. Bracing, traction, closed reduction, open reduction, and femoral or pelvic osteotomies are frequently used treatment modalities for children aged 6 months to 4 years. In the past, treatment recommendations have often been based on the patient's age. However, recent practice has placed more emphasis on addressing the specific disorder and avoiding iatrogenic osteonecrosis. The incidence of osteonecrosis of the femoral head has been reduced by avoiding immobilization of the hip in extreme abduction and by using femur-shortening osteotomies when appropriate. Pelvic osteotomy continues to gain favor for the treatment of selected patients over 18 months of age.

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Despite efforts to identify and treat all cases of developmental dysplasia of the hip (DDH) soon after birth, in some children the diagnosis is delayed, and they are 6 months of age or older when they finally present to the orthopaedic surgeon. The timing of diagnosis is important because the treatment of DDH initially diagnosed between 6 months and 4 years of age differs considerably from that of DDH diagnosed in the immediately postnatal period.

These older children may present for treatment of DDH for any of the following reasons: a delay in diagnosis, failure of Pavlik harness treatment, and late development of the pathologic changes of DDH with maturation. Normal physical examination findings during the immediate postnatal period do not preclude a subsequent diagnosis of DDH. It is less clear, however, whether this is due to subtle pathoanatomic changes that were not initially discernible on examination but progressed with time, or represents the true development of DDH in a previously normal hip. Ilfeld et al[1] reported the cases of 15 patients with DDH who had documented normal physical examinations during infancy but findings of hip dysplasia at a subsequent examination. According to those authors, "the delayed finding of dislocation is not evidence that an inadequate physical examination of the hip was performed."

Definitions

The term "developmental dysplasia of the hip" has replaced the term "congenital dislocation of the hip" because it more accurately reflects the full spectrum of developmental abnormalities of the hip joint. This condition can result in both subluxation and dislocation of the hip and can predispose to the development of early degenerative changes. A subluxated hip is one in which the femoral head is displaced from its normal position but still makes contact with a portion of the acetabulum. With a dislocated hip, there is no articular contact between the femoral head and the acetabulum.

Acetabular dysplasia is characterized by an immature, shallow acetabulum. Dysplasia can exist with or without concomitant instability of the hip and, if untreated, may lead to a poorly located, symptomatic hip. An unstable hip is one that is reduced in the acetabulum but can be provoked to subluxate or

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dislocate (i.e., "Barlow positive"). Teratologic hip dysplasia, which is outside the scope of this discussion, refers to the more severe fixed dislocation that occurs prenatally, and is usually seen in the setting of genetic or neuromuscular disorders.

Natural History

The natural history of DDH in the newborn is quite variable. Neonates with acetabular dysplasia without instability may go on to have normal hips without treatment, but those with instability or frank dislocation often demonstrate progressive radiographic changes and loss of motion, followed by pain. In contrast, spontaneous resolution of dysplasia without intervention is unlikely in children over age 6 months. For a number of reasons, these children almost always require more aggressive treatment than younger children. This is related to the more extensive pathophysiologic changes in older children, as well as the decreased potential for acetabular remodeling with increasing age.

Persistence of hip dysplasia into adolescence and adulthood may result in abnormal gait, decreased abduction, decreased strength, and an increased rate of degenerative joint disease. Wedge and Wasylenko[2] reported that the presence of an abnormal acetabulum was associated with adverse clinical outcomes. Stulberg and Harris[3] demonstrated that 50% of patients with idiopathic osteoarthritis had associated primary acetabular dysplasia, implicating dysplasia as a risk factor for the onset of osteoarthritis. In general, the natural history of adults with unilateral dislocations that have persisted since childhood is less favorable than that for those with bilateral dislocations; the former have the additional problems of limb-length inequality, asymmetrical motion and strength, gait disturbance, and knee disorders. Patients with chronic subluxation may experience symptoms earlier than those with true dislocation. Cooperman et al[4] showed that degenerative joint disease developed early in subluxated hips but later in life in dysplastic hips without overt subluxation. Most authors agree that subluxation will lead to early degenerative disease, but that persistent isolated acetabular dysplasia has a less profound, yet equally predictable, effect on the development of symptoms.

Anatomy

A recent article by Guille et al[5] included an extensive discussion of the general etiology, risk factors, and pathophysiology of DDH in the newborn. The pathologic changes in the newborn are predominantly related to a shallow acetabulum, laxity of the capsule, and soft-tissue interposition. Older children exhibit more advanced changes in both the soft tissues and the osseous architecture. There is a delay in the ossification of the acetabulum, which is most often abnormally shallow, anteverted, and deficient anterolaterally. There is also a delay in ossification of the femoral head and exaggerated femoral anteversion.

The obstacles to a concentric reduction may be classified as either extra-articular or intra-articular (Fig. 1). Extra-articular obstacles include a tight psoas tendon, which can constrict the anterior capsule so as to create an "hourglass" narrowing of the capsule, which prevents reduction. Tight adductor muscles may also prevent sufficient abduction for stable reduction of the femoral head.

Intra-articular obstacles that may impede reduction include a constricted joint capsule, the fibrofatty pulvinar, a hypertrophied ligamentum teres, and an infolded labrum. An infolded labrum is rarely a problem once the other obstacles have been addressed. A hypertrophied transverse acetabular ligament, located in the inferomedial portion of the acetabulum, may also be an absolute block to reduction. It develops secondary to the pull of the ligamentum teres and may migrate superiorly, decreasing the available volume of the inferomedial acetabulum and preventing the femoral head from making contact with the medial wall of the acetabulum. These obstacles to reduction become more fixed with increasing age.

The term "neolimbus" was coined by Ortolani in 1948 and refers to a ridge of cartilage tissue that develops in response to abnormal contact pressures. The neolimbus divides the acetabulum into a true and a false acetabulum. Some have advocated removing this abnormal cartilage during surgery; however, removal of this epiphyseal

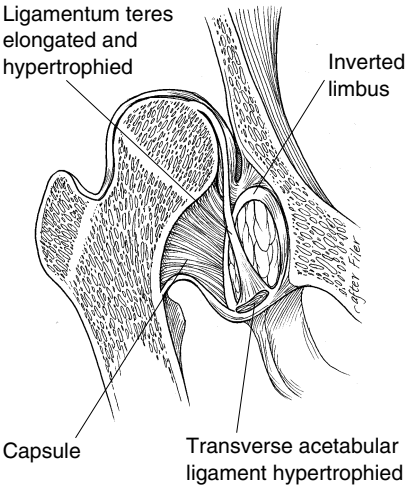

Figure 1 Pathologic changes that present obstacles to reduction in children older than 6 months with DDH. Note that the elongated and hypertrophied ligamentum teres is attached to the hypertrophied transverse acetabular ligament. (Adapted with permission from Tachdjian MO: *Pediatric Orthopedics*. Philadelphia: WB Saunders, 1990, vol 1, p 308.)

cartilage will impede acetabular development and is not recommended.[6]

Diagnosis

Many of the diagnostic characteristics of DDH in children aged 6 months to 4 years are the same as those seen in the newborn. The general aspects of diagnosis have been well reviewed by Guille et al.[5] There are, however, several unique features of the physical examination of the older child with DDH. With increasing age, the soft tissues about the hip tighten. Thus, the Ortolani and Barlow tests usually lose their utility after the first few months of life. Abduction becomes more limited, and asymmetry of abduction becomes more apparent. The Galeazzi test retains its usefulness in the older child. The ambulating child will exhibit a Trendelenburg gait. In children with bilateral dislocated hips, symmetrical hip abduction and a normal Galeazzi test make the diagnosis more challenging. However, a Trendelenburg sign, waddling gait, and decreased but symmetrical hip abduction can be appreciated on careful examination.

In infants less than 4 to 6 months of age, the femoral head is usually not sufficiently ossified to be seen on a radiograph. Ultrasound is the preferred screening modality for DDH. There are, however, a number of helpful radiographic criteria for evaluating dysplastic hips[7] (Table 1). Ossification is normally evident by the age of 6 months but is often delayed in patients with DDH. Serial radiographs showing increasing femoral head ossification are more important than a single radiograph. It has been shown that variability of the acetabular index is greater in dysplastic hips than in normal hips, especially prior to definitive reduction. While it is important to note the direction of change over time, Skaggs et al[8] have shown that, given the intrinsic measurement error of the acetabular index in DDH, a difference of less than 12 degrees on successive radiographs should be interpreted with caution.

Table 1
Radiographic Features in Normal and Dysplastic Hips*

Radiographic Feature	Normal Hip	Dysplastic Hip
Acetabular index, degrees		
24 months	18-21	>24
3 months	20-25	>28
Shenton's line	Continuous	Discontinuous
Ossific nucleus	Present by 4-6 months	Delayed, small

* Adapted with permission from Gillingham BL, Sanchez AA, Wenger DR: Pelvic osteotomies for the treatment of hip dysplasia in children and young adults. *J Am Acad Orthop Surg* 1999;7:325-337.

Treatment

Treatment of children aged 6 months to 4 years who have DDH presents certain challenges and opportunities. Delay in concentric, stable reduction of the hip may result in irreversible changes in the femoral head and acetabulum and can adversely affect outcome. The goal of treatment is to obtain and maintain a stable, concentrically reduced hip joint at as early an age as possible while minimizing complications.[9]

There is a well-established correlation between residual dysplasia and age at reduction. Lindstrom et al[10] have shown that the acetabular index at follow-up is directly related to the age at initial reduction (Fig. 2). Salter and Dubos[11] have stated that acetabular remodeling cannot be ensured after the age of 18 months. Others have suggested that remodeling may occur up to age 8 years.[10,12] Remodeling of the acetabulum is generally considered to be most predictable in children younger than 4 years.[10,12] Although each patient should be treated with individual consideration, following a general treatment algorithm for the appropriate age range is a helpful starting point for devising a logical treatment program (Figs. 3 and 4).

Closed Reduction

In children less than 6 months of age, closed reduction of a dislocated hip can usually be achieved by

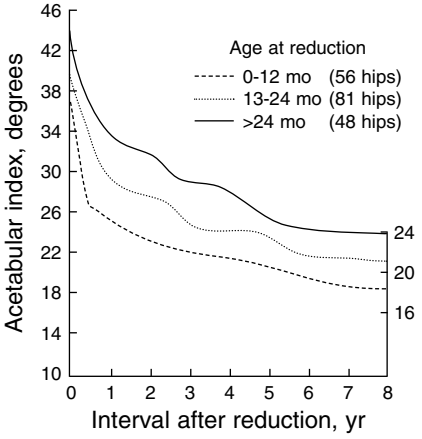

Figure 2 Most acetabular remodeling occurs in the first 3 years after reduction. The age at reduction is a critical determinant of the final radiographic outcome. (Adapted with permission from Lindstrom JR, Ponseti IV, Wenger DR: Acetabular development after reduction in congenital dislocation of the hip. *J Bone Joint Surg Am* 1979;61:112-118.)

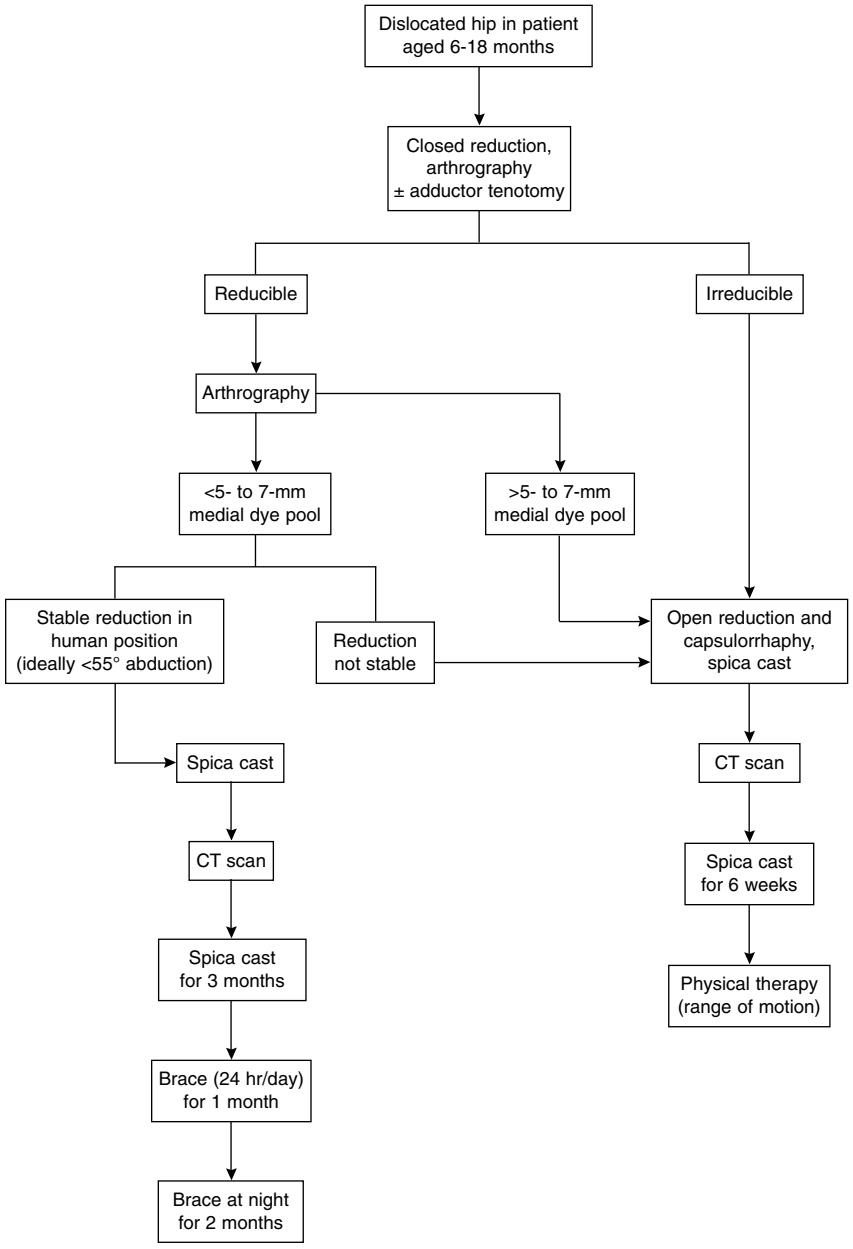

Figure 3 Algorithm for treatment of DDH in children aged 6 to 18 months.

use of the Pavlik harness. Reported success rates have generally been greater than 90%. After the age of 6 months, it is difficult to immobilize the larger, increasingly active child with a Pavlik-type harness. Furthermore, the degree of fixed pathologic change in older children generally precludes the achievement of reduction simply by use of a harness. Rates of failure exceed 50%, and there is, therefore, little role for the use of such a harness in older patients.[13] However, in rare instances, children who are small for their age may be treated with a Pavlik harness. In hips that cannot be reduced with the Pavlik harness, continuation of the harness with the dislocated hip in flexion and abduction appears to potentiate acetabular dysplasia (particularly of the posterolateral rim) and may increase the difficulty of subsequently obtaining a stable closed reduction.[14] This situation has become known as "Pavlik harness disease."

Closed Reduction and Preoperative Traction

Closed reduction of the hip under general anesthesia is typically attempted in children aged 6 to 24 months who have a dislocated hip. The use of traction before an attempted closed reduction is controversial. Proponents of traction believe that slow, gentle stretching of both the neurovascular structures and the soft tissues about the hip increases the likelihood of a successful reduction and minimizes the risk of osteonecrosis. A frequently cited study by Gage and Winter[15] seems to support the use of traction, but the authors did not account for differences in the degree of postreduction abduction between groups, a factor that may affect the rate of osteonecrosis. In contrast, in a study of 210 hips, Brougham et al[16] found that traction did not influence the rate of osteonecrosis. The available data are insufficient to definitively support or refute the effectiveness of traction. In 1991, Fish et al[17] reported that most pediatric orthopaedic surgeons still use prereduction traction, although an informal poll at the Pediatric Orthopaedic Society of North America meeting in 1998 suggested a trend toward decreasing use of traction.

Traction is unlikely to affect some of the major intra-articular structures prohibiting a closed reduction, such as the transverse acetabular ligament, pulvinar, ligamentum teres, and infolded labrum. As traction is generally applied in hip flexion, it does not seem logical that it would effectively elongate the psoas or significantly lengthen the adductors, as

is often necessary at the time of closed reduction in the operating room. Closed reduction should be performed under general anesthesia in the operating room with longitudinal traction, flexion, and abduction of the affected hip, while lifting the greater trochanter anteriorly. It is not unusual to find that a stable, gentle, closed reduction can be achieved with relative ease under general anesthesia, even when the hip appeared irreducible in the office.

Dynamic arthrography with fluoroscopy is useful to assess the quality of reduction, the extent of coverage of the femoral head, and the optimal position for immobilization. There is some debate as to whether soft-tissue interposition (usually acetabular fibrofatty tissue) between the femoral head and the acetabulum interferes with future development of the hip. If the femoral head is not fully reduced in the acetabulum, an intraoperative arthrogram will show a collection of dye medially (the "medial dye pool") in the space between the femoral head and the medial border of the acetabulum. Race and Herring[18] reported that a medial dye pool of less than 5 to 7 mm indicated a concentric reduction and was associated with a good outcome in 11 of 13 hips. Only 5 of 23 hips with a larger dye pool had an acceptable outcome, with a 57% incidence of osteonecrosis. As suggested in the algorithms, a medial dye pool greater than 7 mm on arthrography is a potential indication to proceed with open reduction. One limitation of this method is that magnification of imaging can affect the size of the dye pool; therefore, it is important to rely on clinical judgment as well.

The "safe zone" is the range between maximum passive hip abduction and the angle of abduction at which the femoral head becomes unstable. Adductor tenotomy, performed with either an open or a percutaneous technique, can decrease the adduction contracture and thus widen the safe zone by increasing abduction.

Salter and others have cautioned against immobilization in a position of extreme hip abduction, as this may be associated with the development of osteonecrosis.[11,19] After closed reduction, a spica cast is applied in the "human position" of about 100 degrees of flexion and controlled abduction. In a study of 68 dislocated hips treated by closed reduction, the development of osteonecrosis was statistically associated with hip-abduction angles

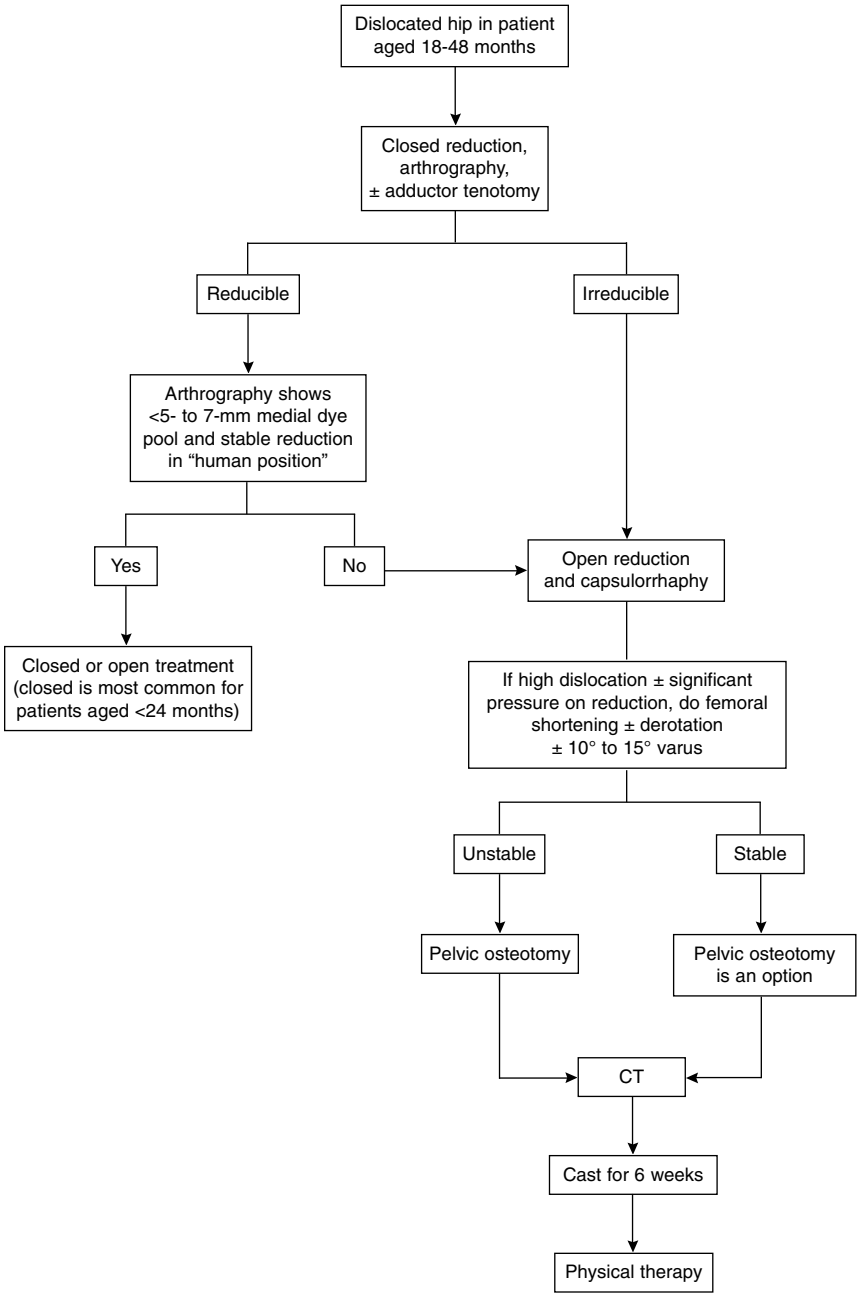

Figure 4 Algorithm for treatment of DDH in children aged 18 to 48 months.

greater than 55 degrees.[19] Technical points that merit consideration include use of a greater-trochanter mold (Fig. 5, B) and maintenance of 90 to 100 degrees of hip flexion, despite the tendency of the hip to extend as padding and casting material are placed over the anterior hip crease. Closed reduction and casting is as technically demanding as open reduction, and should be performed only with adequate anesthesia and assistance.

Reduction of the hip is confirmed by using a limited computed tomographic (CT) or magnetic resonance imaging study. A line drawn parallel to either of the pubic rami on a CT scan should intersect the proximal femoral metaphysis (Fig. 5, B).[20] In a series of 68 hips treated by closed reduction, 6 of the 53 patients demonstrated a proximal femoral metaphysis below this line. Of these 6 patients, 4 had dislocated hips, and the other 2 eventually required further surgery.[19] A reduced hip tends to sit posteriorly within the acetabulum (Fig. 5, B), in contrast to a dislocated hip, which is usually unequivocally posterior to the acetabulum (Fig. 5, A).

The length of postreduction cast immobilization is variable and should be adjusted for the individual child. Currently, the spica cast is utilized for 3 months without changing if it remains clean and is not too tight, regardless of the age of the child. After 3 months, an abduction orthosis is applied for full-time wear for 4 weeks, followed by 4 weeks of nighttime-only use. There is little evidence to support a weaning period from the brace.

Acetabular development occurs most rapidly in the first 6 months after a closed reduction, and continues at a slower pace over the next year (Fig. 2).[10] Assessment of hip-joint maturation is generally accomplished with serial radiographs. It has been suggested that if the acetabular angle has not decreased at least 4 degrees during the first 6 months after reduction, abandonment of closed treatment should be considered.[18] However, strict reliance on the acetabular index for assessment of acetabular maturation is problematic due to the variability of measurement. The 95% confidence interval for intraobserver readings is 12 degrees in dysplastic hips. Fortunately, the acetabular index shows the least intraobserver variability (95% CI, 5 degrees) in the situation in which it is most useful—after a closed reduction of a dysplastic hip.[8]

Many authors have reported that a significant proportion of children will eventually require an additional procedure after closed reduction. Zionts and MacEwen[21] reported on 42 children between 1 and 3 years of age who underwent a closed reduction and adductor tenotomy. Arthrography was not routinely used. An open reduction was required for 25% of patients. Of the hips successfully reduced by closed reduction, 66% required a secondary procedure a mean of 5 years after the reduction. Of the patients older than 18 months at the time of reduction, 74% required a secondary procedure (most commonly, femoral osteotomy).

Schoenecker et al[22] reported that 12 (52%) of 23 hips in which closed reduction at 18 months of age was successful required a femoral or pelvic osteotomy because of failure to remodel. They also reported that 15 (79%) of 19 hips in children aged 18 to 21 months were successfully

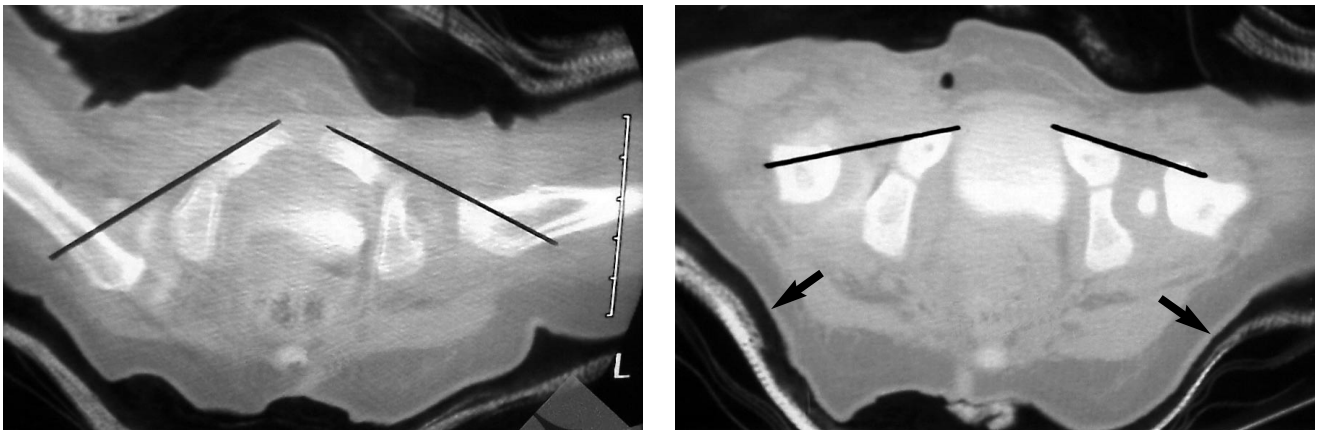

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Figure 5 **A,** CT scan obtained after attempted closed reduction of a dislocated right hip. Line drawn parallel to the right pubic ramus misses the proximal metaphysis. The hip was not reduced, and the patient was immediately taken back to the operating room. **B,** CT scan obtained after open reduction. Note concentric reduction and well-molded cast (arrows). The small amount of posterior "sag" of the femoral head is acceptable. Lines drawn along the pubic rami are now continuous with the proximal metaphyses on both sides.

reduced, compared with only 8 (42%) of 19 hips in children aged 22 months or older. They concluded that children under the age of 22 months have a higher likelihood of a successful closed reduction.

Open Reduction

Although most often considered for children older than 18 months, an open reduction is indicated for any hip in which a concentric, stable reduction cannot be achieved by closed means. A variety of approaches may be used; the location of the skin incision is of less importance than the elements of the procedure relevant to the acetabulum.

The modified Smith-Petersen anterolateral approach, performed via a "bikini" incision, is the most utilitarian approach and is used when there is the possibility of a concomitant pelvic osteotomy. This approach is particularly well suited to open reduction in patients in whom there may be a high-riding femur with a lax capsule adherent to a false acetabulum—structures that are not as well visualized through a medial approach.

Inability to perform a pelvic osteotomy or capsulorrhaphy via a medial approach generally limits its use to patients less than 12 to 18 months of age. However, a medial approach requires minimal dissection, avoids splitting the iliac apophysis, and allows direct access to the medial structures.

There are several medially based approaches. The true medial approach, as originally described by Ludloff, utilizes the interval between the pectineus and the adductor longus and brevis. Ferguson[23] popularized the use of this approach in the United States and modified it to pass between the adductor longus and brevis anteriorly and the adductor magnus and gracilis posteriorly. Weinstein and Ponseti[24] have described an anteromedial approach that passes between the neurovascular bundle and the pectineus muscle.

A medial approach potentially endangers the blood supply to the femoral head, and several authors have noted an association between use of the medial approach and increased rates of osteonecrosis. Although the incidence of osteonecrosis has been reported to be as high as 43% at a mean follow-up interval of nearly 10 years, this has not been substantiated.[25] Nevertheless, concern regarding increased rates of osteonecrosis has contributed to the decreased popularity of this approach.

More important, the completeness of the removal of obstacles to reduction affects the outcome. A common finding in a "redislocated" hip following an open reduction is an intact transverse acetabular ligament that was not fully released at the initial procedure. It is necessary to perform a complete release of the hypertrophied transverse acetabular ligament across the horseshoe-shaped acetabular notch at the base of the acetabulum until a finger can be easily pushed past the inferior-medial rim. The acetabular origin of the ligamentum teres is just superior to the transverse acetabular ligament and can serve as a guide for its identification.

Following open reduction and capsulorrhaphy, a spica cast is used for approximately 6 weeks with immobilization in about 30 degrees of abduction, 30 degrees of flexion, and 30 degrees of internal rotation. After cast removal, physical therapy is often prescribed for hip mobilization and muscle strengthening, especially in the older child.

Femoral Osteotomy

Femoral shortening is thought to facilitate reduction and decrease the rate of osteonecrosis by taking the tension off the contracted soft tissues around the hip. Schoenecker and Strecker[26] compared preoperative skeletal traction with femoral shortening in children over age 3 who underwent open reduction of a developmentally dislocated hip. The incidence of osteonecrosis was 54% in the 26 hips treated with traction, compared with 0% in the 13 hips treated with femoral shortening. Femoral shortening should be utilized whenever hip reduction is difficult or when it appears that undue force is being produced by reduction of the hip. The amount of shortening is determined on the basis of the amount of overlap of the femoral segments after osteotomy with the hip reduced, and is most often in the range of 1 to 2 cm in this age group.

Femoral osteotomy is primarily indicated for shortening, but it also presents an opportunity to correct excessive femoral anteversion. However, derotational osteotomy should be performed cautiously when combined with an anteriorly directed pelvic osteotomy, as excessive derotation may result in iatrogenic posterior instability. Some authors question whether derotational osteotomy of the femur truly changes the relationship of the femur to the acetabulum or simply externally rotates the leg on the femur. However, many others believe that proximal femoral osteotomy redirects the femoral head into the acetabulum and is likely to stimulate remodeling in children who have acetabular remodeling potential (generally those who are 4 years of age or younger). Femoral varus-producing osteotomies have a role in the treatment of children with neuromuscular diseases, including cerebral palsy. However, varus osteotomy combined with open reduction has little or no role in the treatment of DDH.

Pelvic Osteotomy

A pelvic osteotomy directly addresses the insufficiency of ace-

tabular coverage and may be indicated for persistence of acetabular dysplasia or hip instability. There is considerable variability in clinical practice with regard to pelvic osteotomy in this age group. Some reserve pelvic osteotomy for cases in which open reduction and/or femoral osteotomy has failed, whereas others commonly use pelvic osteotomy in combination with open reduction as part of the initial procedure. For example, Salter and Dubos[11] have advocated pelvic osteotomy as an index procedure for all patients with persistent dysplasia who are older than 18 months. Others recommend a pelvic osteotomy as the initial procedure only if there is residual instability after reduction in children less than 2 to 3 years of age.

The choice between femoral osteotomy and pelvic osteotomy and among the various types of pelvic osteotomies may be based more on the surgeon's training and experience than on data comparing patient outcomes. Overall, the innominate osteotomy of Salter remains the most commonly used pelvic osteotomy for patients in this age group.[11] This is a complete transverse osteotomy from the sciatic notch to the ilium just above the anterior inferior iliac spine. It relies on rotation through the pubic symphysis in young patients and effectively redirects the acetabulum anterolaterally. In a review of 325 hips treated between 1958 and 1968, Salter and Dubos[11] reported 93.6% excellent or good results in patients aged 18 months to 4 years at an average follow-up interval of 5.5 years.

Incomplete osteotomies, such as those described by Pemberton and Dega (Fig. 6), hinge through the open triradiate cartilage, and are also commonly used in skeletally immature patients with DDH. A useful comparison of the various reviews and a detailed discussion of the techniques of pelvic osteotomies for DDH was published in 1999 by Gillingham et al.[7]

Our preference is to use a Dega osteotomy in children over age 18 months with a steep acetabulum as well as in children who exhibit instability after open or closed reduction. It is also frequently used in children with neuromuscular conditions because it improves posterior acetabular coverage by cutting through the sciatic notch and leaving the medial ilium intact as a hinge. When the Dega osteotomy is used to treat DDH, the cortex at the sciatic notch is left intact as a hinge, thus providing lateral and anterior coverage.[27] An advantage of the Dega osteotomy is the intrinsic stability, which obviates the need for internal fixation with hardware, as well as the need for a second operation for hardware removal (Fig. 7). A spica cast is not routinely necessary for postoperative immobilization, unless the Dega osteotomy is combined with open reduction.

In a thought-provoking article, Lejman et al[28] questioned the need for capsulorrhaphy in open reductions with osteotomies. In this prospective, randomized study of 39 DDH patients aged 2 to 3 years, the authors evaluated the results after open reductions combined with femoral and pelvic osteotomies with or without capsulorrhaphy. In the 16 patients who underwent capsulorrhaphy, there were three postoperative dislocations and one instance of osteonecrosis. In 23 patients who underwent capsulectomy, the hip capsule was opened in a T fashion, with excision of the two triangles of capsule formed by the T. Patients with capsulectomies had no postoperative dislocations or osteonecrosis. The authors stated that a tight anterior hip capsule may push the femoral head toward posterior dislocation.

Secondary Procedures

One of the most difficult decisions in the treatment of children with DDH is whether a secondary

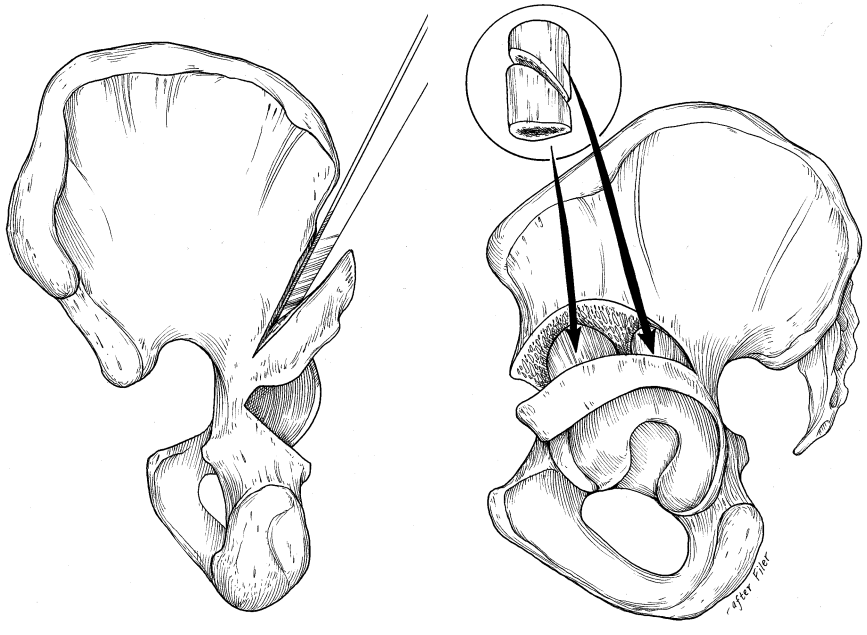

Figure 6 Dega osteotomy for DDH, which leaves the sciatic notch intact.

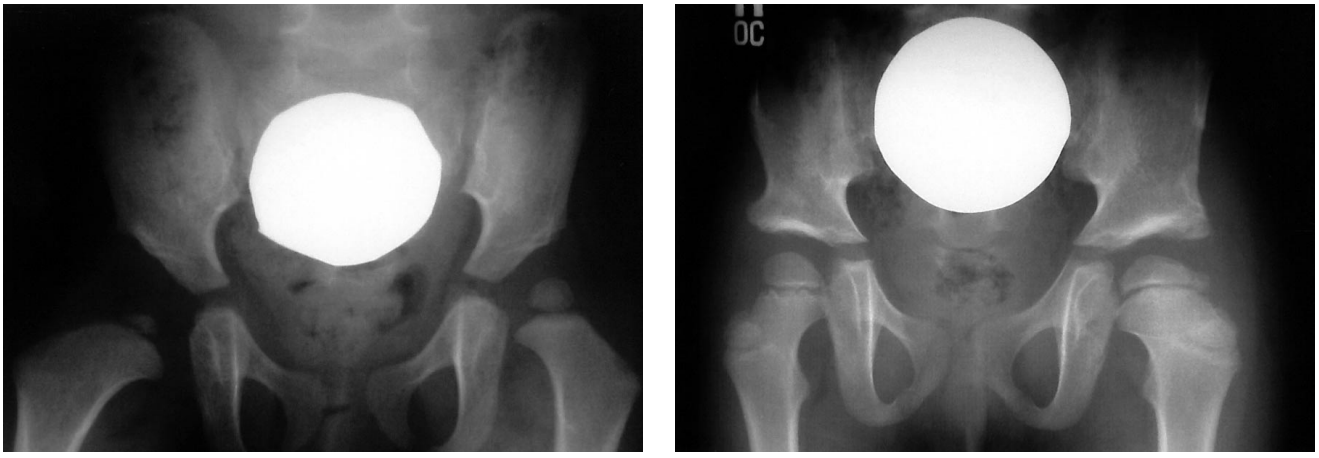

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Figure 7 **A,** Preoperative radiograph of a 2-year-old girl with bilateral DDH. **B,** Postoperative radiograph obtained 1 year after bilateral Dega osteotomy. Both osteotomies were done at one sitting.

procedure is indicated (and if so, when). With the onset of walking, hips that appeared to have been maturing appropriately after reduction may begin to lateralize or dislocate; this is a definite indication for a secondary procedure. Arthrography is helpful in this setting to determine whether a second open reduction, combined with a pelvic or femoral osteotomy, is necessary. Race and Herring[18] recommend that if the acetabular index has not decreased at least 4 degrees or if the joint remains unstable 6 months after reduction, abandonment of closed treatment should be considered after assessment by arthrography.

Functional Results

In a 30-year follow-up study of 119 DDH patients, the average Iowa hip rating was 91 of 100 points, even though 60% had a growth disturbance of the proximal end of the femur, and 43% had radiographic evidence of degenerative joint disease.[9] Patients who did not have such a growth disturbance functioned well for many years despite poor radiographic results. Overall, function deteriorated with time even in the absence of a growth disturbance of the proximal end of the femur.

Despite encouraging intermediate-term functional results, numerous studies of the natural history have established a strong link between persistent dysplasia and early degenerative joint disease.[2-4] Appreciation of the predictably negative natural history of hip dysplasia has been a driving force in the increasingly aggressive management of this condition. However, the risk of the natural history of this disease process must be carefully balanced against the possibility of iatrogenic complications, particularly osteonecrosis.

Complications

The most devastating and, unfortunately, most common complication of treatment of DDH is osteonecrosis of the femoral head, which has also been referred to as a primary growth disturbance of the proximal femoral physis. This growth disturbance is not part of the natural history of DDH, but is an iatrogenic complication observed with every form of treatment, including the Pavlik harness. Although not completely understood, the cause of osteonecrosis is believed to involve an interruption of the blood supply to the femoral head. This may be caused by compression or stretch of vessels from excessive hip abduction, direct injury to the vessels supplying the femoral head, or excessive mechanical pressure on the head after reduction.

The relationship between hip abduction and blood-flow velocity in the femoral head has been established with Doppler ultrasound. In normal volunteers with their hips in neutral position, mean flow was 13 cm/sec; at 30 degrees of abduction, it was 10.3 cm/sec; and at 45 degrees, 3.8 cm/sec.[29] Clinical studies have clearly shown the protective effect of femoral shortening on decreasing joint pressure. Some authors[30] have posited that the presence of the ossific nucleus confers a protective effect on the otherwise malleable femoral head, and may

thus lead to lower rates of osteonecrosis, but this has been refuted by others.[31] Nevertheless, most pediatric orthopaedists would argue that the best overall results for DDH are associated with as early a reduction as possible.

Rates of osteonecrosis vary widely from study to study. Thomas et al[32] have pointed out that the marked variation in reported rates of osteonecrosis reflects not only differences in patient populations but also differences in the definition of this entity. Several systems of classification of osteonecrosis have been developed that encompass the range of disease, from temporary irregular ossification to total head involvement with growth disturbance. Studies have shown that osteonecrosis may first become apparent years after treatment, emphasizing the need for long-term follow-up of studies dealing with treatment of DDH.

The development of osteonecrosis leads to a poor outcome. Although some acetabular remodeling may occur over time, the extent of remodeling is often even less than that seen with osteonecrosis, which is due to a number of factors. Physical therapy may be used in an attempt to maintain motion. Although multiple treatment options exist, they uniformly offer less than satisfactory results when the head is severely involved.

Summary

Despite rigorous efforts to identify and treat all cases of DDH in infancy, some patients will present with DDH later in childhood. In an attempt to avoid a poor result, there has been a gradual evolution toward earlier and more aggressive treatment of DDH. Concentric reduction as early as possible is essential. Successful treatment of DDH in the older child demands an appreciation of the pathoanatomy, the age-dependent potential for acetabular remodeling, the relative merits and pitfalls of various treatment options, and recognition that iatrogenic osteonecrosis may occur. Early closed or open reduction, recognition of the safe zone of immobilization, femoral redirection and shortening, and well-conceived pelvic osteotomies all play an important role in improving the outcomes of older children with DDH.

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