CHAPTER 24

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Legg-Calvé-Perthes Syndrome

SURGICAL PROCEDURE INDEX

Legg-Calvé-Perthes disease remains one of the most controversial topics in all of pediatric orthopaedic surgery. The debate about its etiology and pathogenesis continues, and there is no unanimity regarding treatment. This chapter reviews what is known about the condition, points out where controversies exist, and highlights the problems in decision making regarding treatment.

EARLY HISTORY

Legg-Calvé-Perthes syndrome is a disorder of the hip in young children. The condition was described independently in 1910 by Legg (1), Calvé (2), Perthes (3), and Waldenstrom (4, 5). In the late 19th century, however, Thomas (6), Baker (7), and Wright (8) described patients with supposed hip joint infections that resolved without surgery, whose histories were consistent with Legg-Calvé-Perthes disease. Maydl (9), in 1897, reported this condition and thought it was related to congenital dislocation of the hip (10). Recent findings, discussed in this chapter's section on pathogenesis, suggest that Legg-Calvé-Perthes "disease" may more appropriately be called a syndrome.

In 1909, Arthur Legg presented a paper on five children who were limping after injury. This paper was published in 1910. He called this condition an "obscure affectation of the hip" and postulated that pressure secondary to injury caused flattening of the femoral head (1). In that same year, Calvé reported 10 cases of a noninflammatory self-limiting condition that healed with flattening of the weight-bearing surface. He postulated that the cause of this condition was an abnormal or delayed osteogenesis. He reported coxa vara and increased femoral head size in these patients; on physical examination, all of the patients had decreased abduction (2). Perthes simultaneously reported six cases of what he termed "arthritis deformans juveniles." He postulated that this was an inflammatory condition (3). In his description of the condition, Waldenstrom postulated that the disease was a form of tuberculosis (4, 5).

Perthes was the first investigator to describe the pathologic and histologic features of the disorder (11). He reported on a 9-year-old boy who had experienced symptoms for 2 years. Examination of a portion of the excised head revealed numerous cartilage islands throughout and "strings" connecting the cartilage of the joint and the physeal plate. Perthes noted that the marrow spaces were widened, with fatty infiltration; he saw no evidence of inflammation. He believed that the cartilage islands were new and that this was an osteochondritis and not a tubercular process (11). Schwartz (12), an associate of Perthes, described the pathologic changes in a 7-year-old boy with a 2-year history of symptoms and reported similar findings. Waldenstrom (13) suggested the use of the term *coxa plana* to make the description of the disease consistent with that of other hip deformities, such as coxa vara and coxa valga. Sundt (14, 15) published the first monograph on Legg-Calvé-Perthes syndrome, reporting on 66 cases and the pathology of the condition. The essential feature in all of his cases was the cartilaginous islands in the epiphysis. Sundt attributed the disease to an "osteodystrophy due to dysendocrinia of a hereditary disposition." He believed that individuals so predisposed would get Legg-Perthes disease after they sustained an injury (i.e., infection or trauma) to the hip. Sundt was the first to introduce the modern concept of the "susceptible child."

Phemister (16), reporting on the curettage findings in a 10-year-old child with an 8-month history of symptoms, described areas of bone necrosis, granulation tissue, old bone

with new bone formation, and osteoclasts. He interpreted these findings as an inflammatory and infectious process. In 1922, Riedel (17) reported on two cases and presented the histology. He described the thickening of the articular cartilage and noted that the junction between the bone and the articular cartilage was filled with blood. He also noted that the physeal plate was destroyed and that there were many cartilage rests. Dead bone was surrounded by a rich granulation tissue, and many giant cells were present. He also noted that farther away from the main disease process, the marrow was fibrotic with inflammatory infiltrates. Riedel was the first investigator to notice that there were blastic and clastic changes working at the same time on the same bone trabeculae. In his second specimen, he found regeneration of the cartilage in the subchondral area, cell atrophy, and some inflammatory cells. That same year, Waldenstrom (18) proposed the first radiographic classification of the disease process on the basis of the data from 22 patients who were followed up until the completion of their growth. Since then, most of the orthopaedic literature has centered on the etiologic, epidemiologic, and prognostic factors in Legg-Calvé-Perthes disease and follow-up of various treatment modalities (19–23).

EPIDEMIOLOGY AND ETIOLOGY

Legg-Calvé-Perthes syndrome occurs most commonly in the age range of 4 to 8 years (24), but cases have been reported in children from 2 years of age to the late teenage years. It is more common in boys than in girls by a ratio of 4 or 5 to 1 (25). The incidence of bilaterality has been reported as 10% to 12% (24, 26). Although the incidence of a positive family history in patients with Legg-Calvé-Perthes syndrome ranges from 1.6% to 20% (10, 24, 27–33), there is currently no evidence that this syndrome is an inherited condition (34, 35).

Wynne-Davies and Gormley (24) reported on a series of 310 index patients with Legg-Calvé-Perthes syndrome. They noted that, of the children of index patients with the syndrome, only 2% had Legg-Calvé-Perthes syndrome. All twins in this series were discordant, including one monozygotic pair. Eleven percent had abnormal birth presentations, including breech and transverse, compared with the 2% to 4% incidence that would be expected in the general population. There is a higher incidence of Legg-Calvé-Perthes syndrome in later-born children, particularly the third to the sixth child, and a higher percentage in lower socioeconomic groups (36, 37). Parents of the children with the syndrome also tend to be older than those in the general population (24, 33, 38).

Legg-Calvé-Perthes syndrome is more common in certain geographic areas, particularly in urban rather than rural communities, giving rise to the suspicion of a nutritional cause, possibly a trace element deficiency (36–44). There is also a reported strong association (33% of patients with the syndrome) of Legg-Calvé-Perthes disease with the psychological profile associated with attention-deficit hyperactivity disorder (45). Malloy and MacMahon (46, 47) as well as Lappin et al. (48) noted that birth weight was lower in children with the syndrome. Harrison et al. (49) reported that children with Legg-Calvé-Perthes syndrome lagged behind their chronologic age, and 89% of the involved individuals had delayed bone age. Ralston (50) and others (51, 52) demonstrated that this delay in skeletal maturation averages 21 months but that during the healing stages of the disease, there was recovery of height and weight through increased growth velocity (35, 50, 52). Race may also be a factor in the frequency of incidence of this condition. There is a higher frequency of occurrence of Legg-Calvé-Perthes syndrome among the Japanese, other Asians, Eskimos, and Central Europeans, and a lower frequency of occurrence among native Australians, Americans, Indians, Polynesians, and persons of African origin (10, 41, 53, 54).

There is considerable evidence of anthropometric abnormalities in children with Legg-Calvé-Perthes syndrome. Cameron and Izatt (55) reported that boys with the syndrome were 1 in. shorter and girls with the syndrome were 3 in. shorter compared with healthy children. Burwell et al. (56–58) and others (37, 59, 60) demonstrated that children with the syndrome are smaller in all dimensions, except for head circumference, and shorter in the distal portions of the extremities as opposed to the proximal portions. Loder et al. (61), in a more recent study, demonstrated that bone age of the pelvis in boys was less delayed than that of the hand and wrist. In patients who have the disorder at a young age, the shortness in stature tends to correct during adolescence, whereas patients who have the disorder at an older age tend to be small throughout life (33). Eckerwall et al. (62) followed up 110 children with the disorder in a longitudinal study and showed that these children were shorter at birth, remained short during the entire growth period, and their growth velocity never changed. Burwell et al. (56) demonstrated an abnormality of growth hormone–dependent somatomedin in boys with Legg-Calvé-Perthes syndrome, whereas Tanaka et al. (63), Fisher (27), and Kitsugi et al. (64) reported contrary results.

Growth hormone regulates postnatal skeletal development. The effects of growth hormone on postnatal skeletal development are mediated, in part, by the somatomedins [insulin-like growth factors (IGFs)] (65). Somatomedin C insulin-like growth factor-1 (IGF1) is the principal somatomedin responsible for postnatal skeletal bone maturation (65). Plasma IGF1 levels have been reported to be significantly reduced in children with the disorder during the first 2 years after the diagnosis of Perthes disease. These alterations were accompanied by a tendency toward growth arrest and impaired weight gain. An acceleration in growth and weight gain is believed to accompany the healing stages of the disease, although a recent report by Kealey et al. disputes this growth acceleration following the active stages of the disease (66).

In plasma, nearly all IGF1 is bound to specific binding proteins. However, levels of the major binding protein, insulin-like growth factor–binding protein 3 (IGFBP3), are normal during the first 2 years after the diagnosis of Perthes disease (67, 68). Low levels of circulating IGF1 and failure of IGF1 to increase normally during the prepubertal years in patients with Perthes disease, in conjunction with reportedly normal growth hormone levels, raise the possibility of decreased responsiveness of growth-plate chondrocytes and hepatocytes (65). The combination of moderately reduced IGF1 levels with normal IGFBP3 has been reported in normal-variant short-statured children. The skeletal maturation delay and retarded bone age reported in patients with Perthes disease, in conjunction with the findings described in the preceding text, could be considered to be a retention of the infantile hormone pattern (66).

Malnutrition is one factor that leads to low IGF levels, and this could be related to the reportedly higher incidence of Perthes disease in low-income families (43). The disproportionate skeletal development affecting the distal portions of the body reflects a tendency toward infantile body proportions. This correlates with the reduced IGF1 levels in the presence of normal levels of binding proteins (69). Controversy still exists in that a study by another group of investigators reported results opposite to those reported by Neidel et al. (68), with serum levels of IGF1 being normal and those of IGFBP3 being lower in children with Perthes disease, compared with controls (70). Another recent study, although confirming the skeletal maturation delay in children with Perthes disease, demonstrated no difference in IGF1 (measured with IGF2-blocked binding sites) and IGFBP3 serum concentrations with respect to bone age (71). This group disputed the claims of disturbance of the hypothalamic–pituitary–somatomedin axis in patients with Perthes disease. The reported differences in the various studies, in some cases, may be partly attributable to the methods used for measuring IGF1. There is an increased incidence of hernia in patients with Legg-Calvé-Perthes syndrome and their first-degree relatives. There is also an increased incidence of minor congenital abnormalities in patients with the syndrome (29, 72–74).

The cause of Legg-Calvé-Perthes syndrome remains unknown. Many etiologic theories have been proposed. In the early part of the 20th century, most investigators thought that it was a disease of an inflammatory or infectious nature (3–5, 75–77). Phemister (16, 78) believed that the disease was an infectious process, although tissue cultures were negative. Axhausen (75) believed that it was caused by bacillary embolism in which the infection either was not manifested or was too weak and healed quickly. As late as 1975, Matsoukas (79) demonstrated an association between Legg-Calvé-Perthes syndrome and prenatal rubella.

Until the 1950s, trauma was considered by many investigators to be the cause, or a significant contributing factor, of Perthes disease (1, 80–86). As with most childhood orthopaedic conditions, a significant number of patients may relate an episode of trauma to the onset of symptoms.

Many investigators, particularly those from Eastern Europe, thought that Legg-Calvé-Perthes syndrome was of congenital origin, and that there was a relationship between this disease and congenitally dislocated hips (84–91). Glimcher (92) proposed that cytotoxic agents of external or endogenous origin may be responsible for bone cell death (93). A recent report showed the association of Perthes with delayed ossification of the proximal femoral epiphysis (94). At one time, Perthes disease was believed to be related to hypothyroidism (95–97); this has since been disproved (89, 90). Recent reports demonstrate moderately increased plasma concentrations of free thyroxin and free triiodothyronine in patients with Perthes disease, compared with controls (69). It has yet to be conclusively determined whether the aforementioned factors contribute to causing Perthes disease, and whether IGF1 is at reduced levels in the early disease stages as reported. These findings do, however, provide additional evidence that growth-related systemic abnormalities exist in patients with Legg-Calvé-Perthes syndrome (69).

Transient synovitis has been thought, by many investigators, to be a precursor to the condition. Gershuni (98) reported that 25% of children with benign transient synovitis developed Legg-Calvé-Perthes disease, whereas Jacobs (99) reported three cases of Legg-Calvé-Perthes disease among 25 patients with acute transient synovitis. Although all hips with Perthes disease have synovitis, especially early in the course of the disease, and many have persistent synovitis for years (100–104), a review of the literature reveals that an average of 1% to 3% of patients with a history of transient synovitis later develop Legg-Calvé-Perthes syndrome (105–110). Chuinard (111, 112) and Craig et al. (82, 83) have proposed that excessive femoral neck anteversion is a causative factor in the development of Legg-Calvé-Perthes syndrome.

Most current etiologic theories involve vascular embarrassment. An insufficient blood supply to the proximal femur has been elucidated by many authors. The terminology used in the literature varies. However, there are three main sources of blood to the proximal femur: an extracapsular arterial ring, the ascending cervical (retinacular branches) vessels, and the artery of the ligamentum teres (113) (Fig. 24-1). The extracapsular ring is formed mostly by the medial and lateral femoral circumflex vessels. This ring gives rise to the ascending cervical branches, which are extracapsular, and these in turn give rise to the metaphyseal and epiphyseal branches. The anterior portion of the extracapsular ring is formed primarily by the lateral femoral circumflex artery. The posterior, lateral, and medial aspects of the ring are formed by the medial femoral circumflex artery. Chung (113) found that the greatest volume of blood flow to the femoral head comes through the lateral ascending cervical vessel (the termination of the medial femoral circumflex artery), which crosses the capsule in the posterior trochanteric fossa. Trueta and Pinto de Lima (114, 115) and Chung (113) demonstrated that the anterior vascular anastomotic network (Fig. 24-1) is much less extensive than the

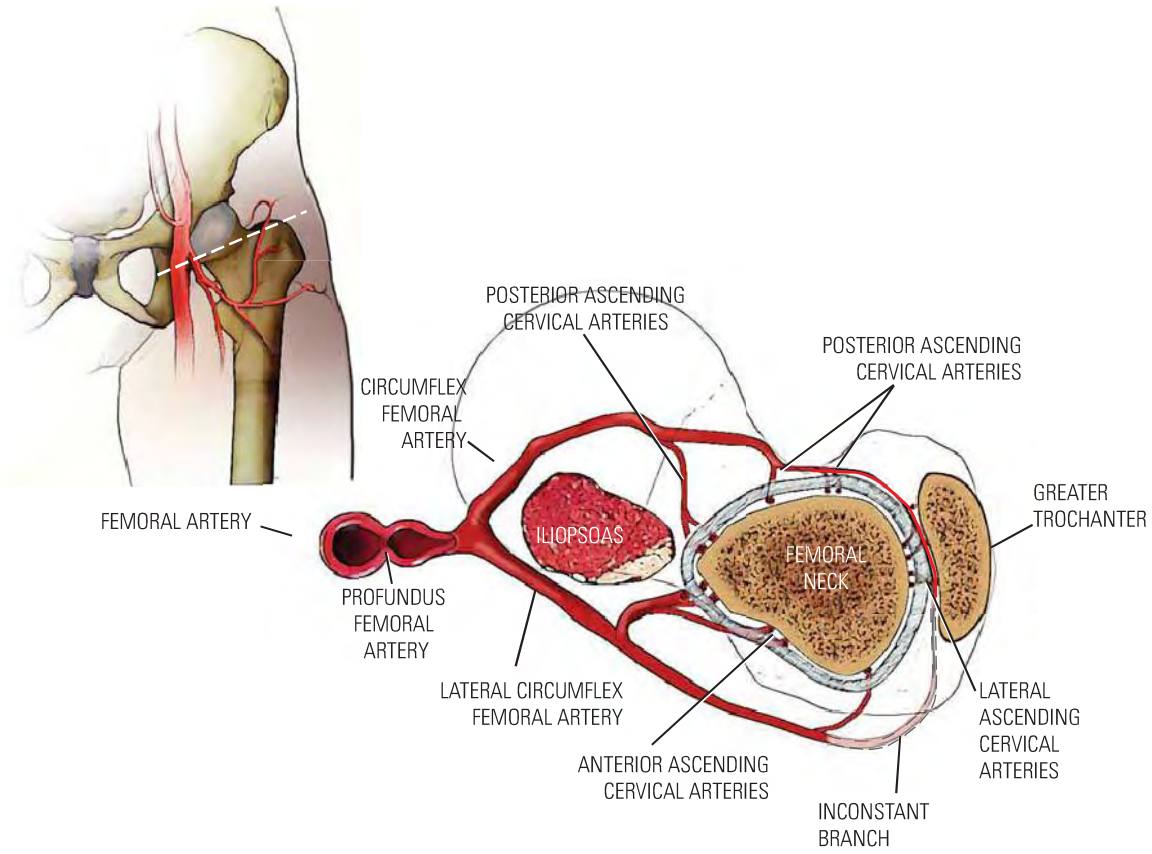


FIGURE 24-1. The blood supply to the normal proximal femur in a child. (From Chung SMK. The arterial supply of the developing proximal end of the human femur. *J Bone Joint Surg Am* 1976;58:961.)

posterior anastomotic network, particularly in specimens taken from patients 3 to 10 years of age, which correlates with the age range of Legg-Calvé-Perthes syndrome. Chung (113) also demonstrated that the anterior anastomotic network was incomplete more often in boys, which correlates with the male predominance found in Legg-Calvé-Perthes syndrome. Ogden (116) reported the presence of vessels crossing the physeal plate in some of his specimens, but Chung disagreed, suggesting instead that the vessels do not actually cross the plate, but pass through the peripheral perichondral fibrocartilaginous complex.

Interruption of the blood supply to the femoral head in Perthes disease was first demonstrated in 1926, when Konjetzny (77) showed obliterative vascular thickening in a pathologic specimen. Theron (117) used selective angiograms to demonstrate obstruction of the superior retinacular artery in patients with Legg-Calvé-Perthes syndrome. In a recent angiographic study, Atsumi et al. (118) showed that 68% of subjects with Perthes disease had interruption of the lateral epiphyseal arteries at their origin. In 1973, Sanchis et al. (119) proposed the second infarction theory. They experimentally infarcted the femoral head of animals labeled with tetracycline. They were unable to produce a typical histologic picture of Legg-Calvé-Perthes syndrome with only a single infarction. With a second infarction, however, they were able to show a more characteristic histologic picture of Legg-Calvé-Perthes syndrome. Inoue et al. (120, 121) later correlated this double-infarction theory with human histologic material. Clinical correlation for this theory is provided by reports of recurrent Perthes disease (122, 123) (Fig. 24-2). Salter and Thompson (124, 125) proposed that Legg-Calvé-Perthes syndrome is a complication of aseptic necrosis, and that a fracture manifested radiographically by a subchondral radiolucent zone initiates the resorptive phase. Kleinman and Bleck (126) demonstrated increased blood viscosity in a group of patients with Legg-Calvé-Perthes syndrome, possibly leading to decreased blood flow to the femoral epiphysis. Vascular embarrassment, caused by intraosseous venous hypertension and venous obstruction, has been demonstrated by several authors (34, 127, 128).

Recently, attention has been centered on reports of protein C and S deficiencies in patients with Perthes syndrome (129–137). Thrombophilia induced by low levels of protein C or protein S, or by resistance to activated protein C, has been associated with the development of osteonecrosis and with arterial thrombosis (129, 130, 133–137). These investigators have suggested routine screening of the levels of protein C, protein S, and lipoprotein(s); plasminogen activator inhibitor activity; and stimulated tissue plasminogen activator activity in patients with Perthes syndrome (130). They believe that routine coagulation screening of children with Legg-Perthes disease has an additional advantage because of the familial nature of the autosomal dominant coagulopathies. These disorders are associated with thrombotic events in 60% of adult

family members. The authors believe that the diagnosis of a coagulation disorder in a child with Legg-Perthes disease can and should lead to studies in first-degree relatives, with the goal of preventing thrombotic events in families. More recent literature has refuted the role of thrombophilia in causing Perthes disease (138–142).

PATHOGENESIS

The histologic changes seen in Legg-Calvé-Perthes syndrome should be put in perspective. Few human specimens have been studied, and each such specimen represents only one stage in the disease process. Most specimens are from curettage or core

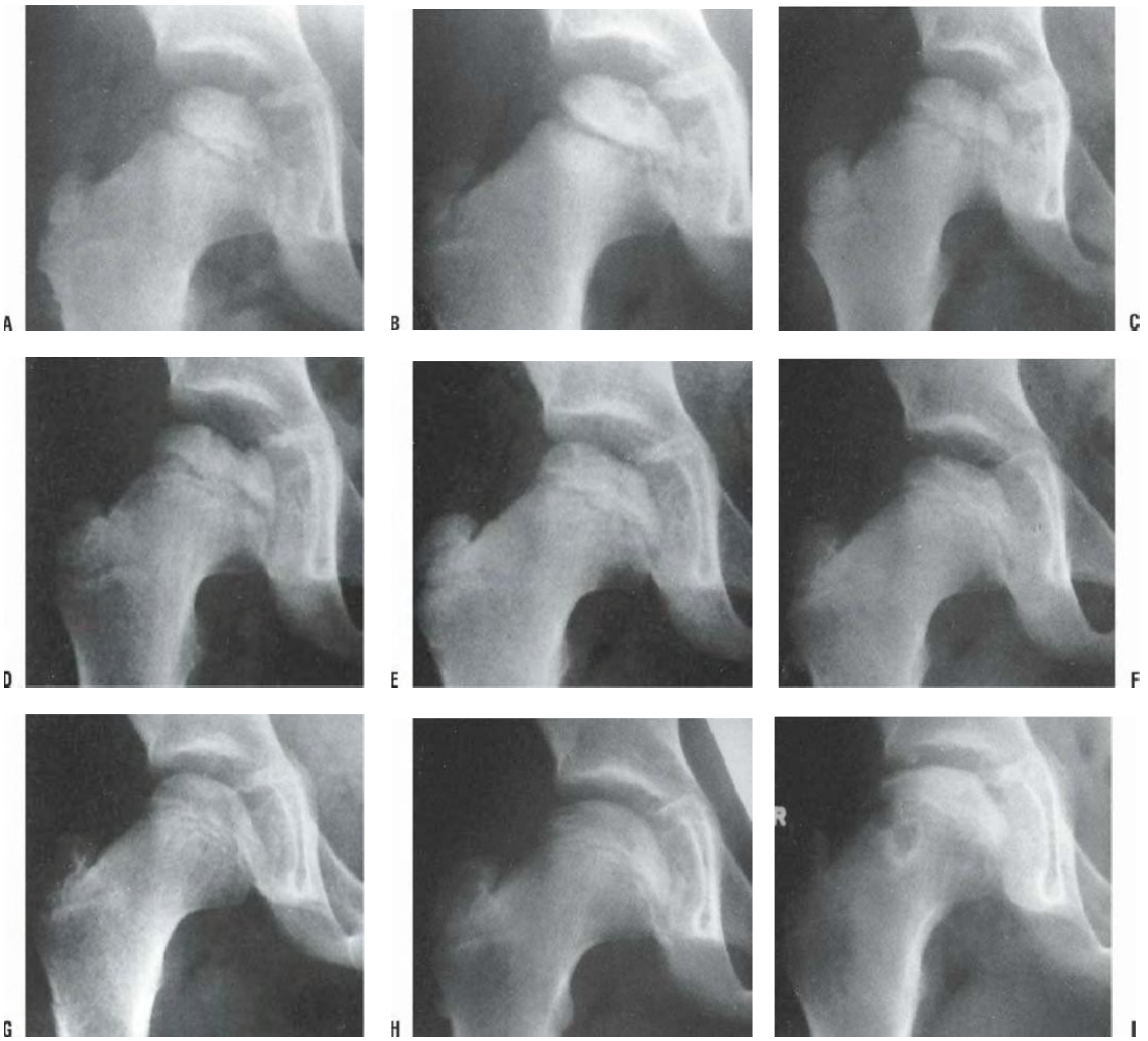


FIGURE 24-2. A girl, 4 years and 8 months of age, was treated for left hip Perthes disease (late fragmentation phase) beginning in January 1983. AP (right, **A–I**) and Lauenstein views of the right hip at different stages, January 1983 to December 1987. **A:** View of the right hip at the time of initial presentation with no signs of involvement (January 1983). **B:** Early involvement, patient still asymptomatic (September 1983). Progressive healing of the right femoral epiphysis at May 1984 **(C)**, August 1984 **(D)**, May 1985 **(E)**, and November 1985 **(F)**. **G:** Femoral head was completely healed by December 1986. **H:** Recurrent changes in the density of the femoral head and a subchondral fracture that involves <50% of the head (Catterall group 2) was seen in June 1987. **I:** Complete involvement of the ossific nucleus (Catterall group 4) with diffuse metaphyseal reaction and cysts in December 1987. (From Martinez AG, Weinstein SL. Recurrent Legg-Calvé-Perthes' disease: case report and review of the literature. *J Bone Joint Surg Am* 1991;73:1081.) (*Continued on next page*)

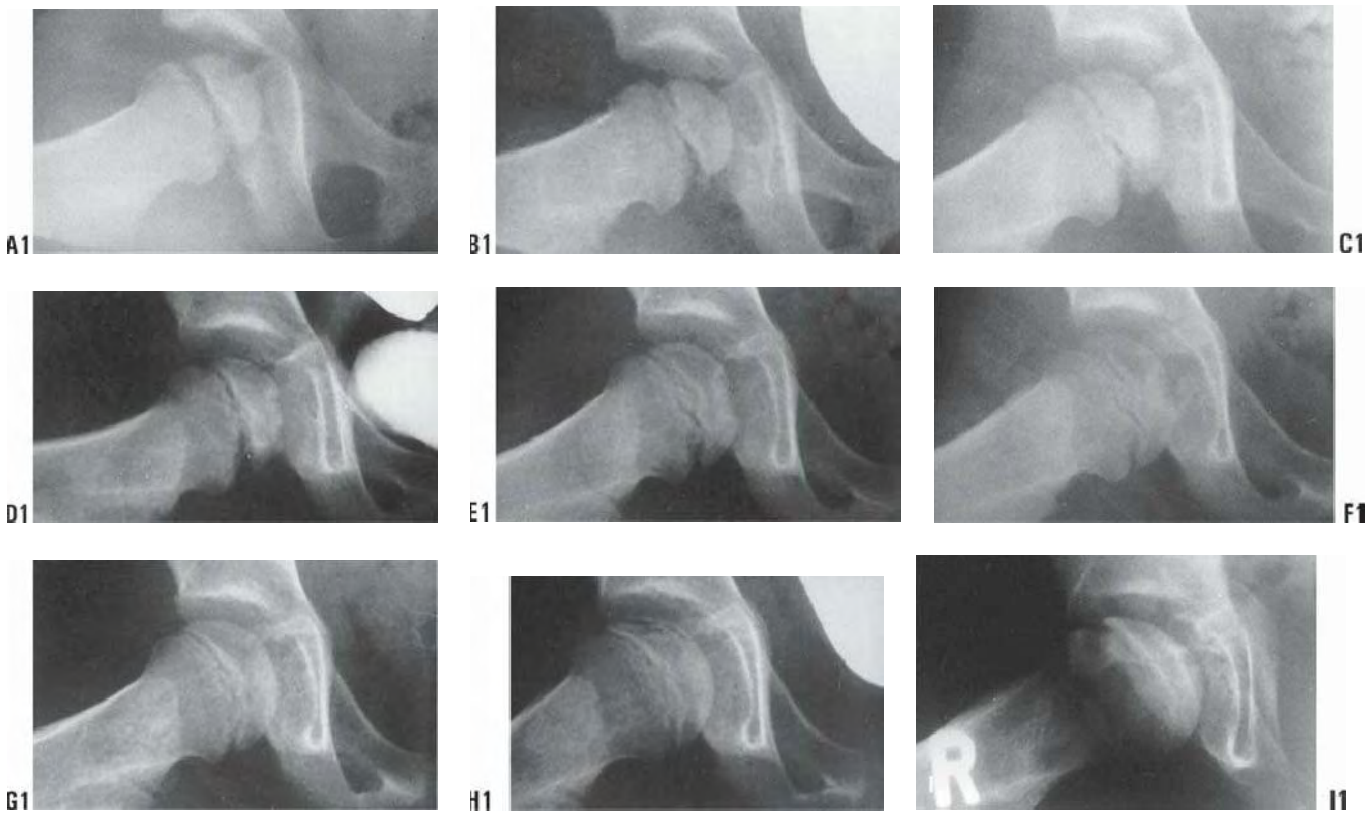


FIGURE 24-2. (*continued*)

biopsies, which show only one portion of the involved head at a time.

In the developing normal human femoral head, the secondary center of ossification is covered by cartilage comprising three zones (Fig. 24-3). The superficial zone has the morphologic properties of adult articular cartilage. Beneath this zone is the zone of epiphyseal cartilage, which is histochemically different. The zone becomes thinner as the skeleton matures and the epiphyseal bone enlarges in size. Underneath the epiphyseal cartilage is a thin zone formed by small clusters of cartilage cells that hypertrophy and degenerate. Capillaries penetrate this zone from below, and bone forms at a much slower rate than in the metaphysis (143).

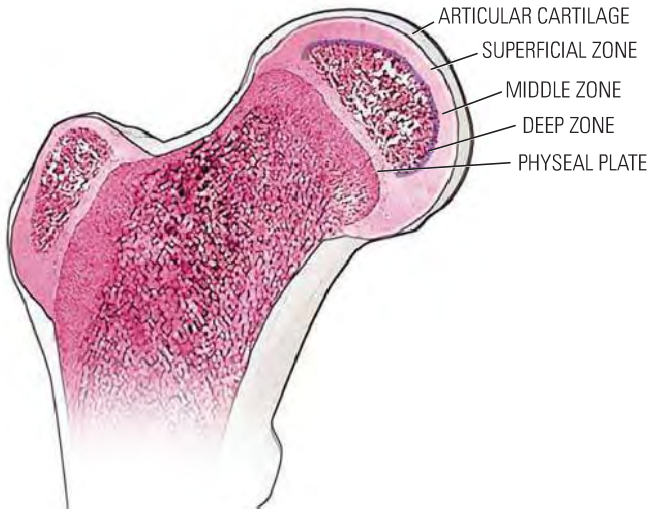


FIGURE 24-3. Proximal femur in a child.

Histologic changes of the epiphyseal and physeal cartilage of patients with Legg-Calvé-Perthes syndrome (Figs. 24-4 and 24-5) were described as early as 1913. These and current studies demonstrate that the superficial zone of the epiphyseal cartilage covering the affected femoral head is normal but thickened. In the middle layer of the epiphyseal cartilage, however, two types of abnormalities are seen: areas of extreme hypercellularity, with the cells varying in size and shape and often arranged in clusters, and areas containing a loose fibrocartilage-like matrix. These abnormal areas in the epiphyseal cartilage have histochemical and ultrastructural properties that are different from normal cartilage and fibrocartilage. Areas of small secondary ossification centers are evident, with bony trabeculae of uneven thickness forming directly on the abnormal cartilage matrix (143–148). The superficial and middle layers of epiphyseal cartilage are nourished by synovial fluid and continue to proliferate, whereas only the deepest layer of the epiphyseal cartilage is dependent on the epiphyseal blood supply and is affected by the ischemic process (143, 146, 149–157).

The physeal plate also is abnormal in Legg-Calvé-Perthes syndrome. It shows evidence of cleft formation with amorphous debris and extravasation of blood. In the metaphyseal region, endochondral ossification is normal in some areas, but

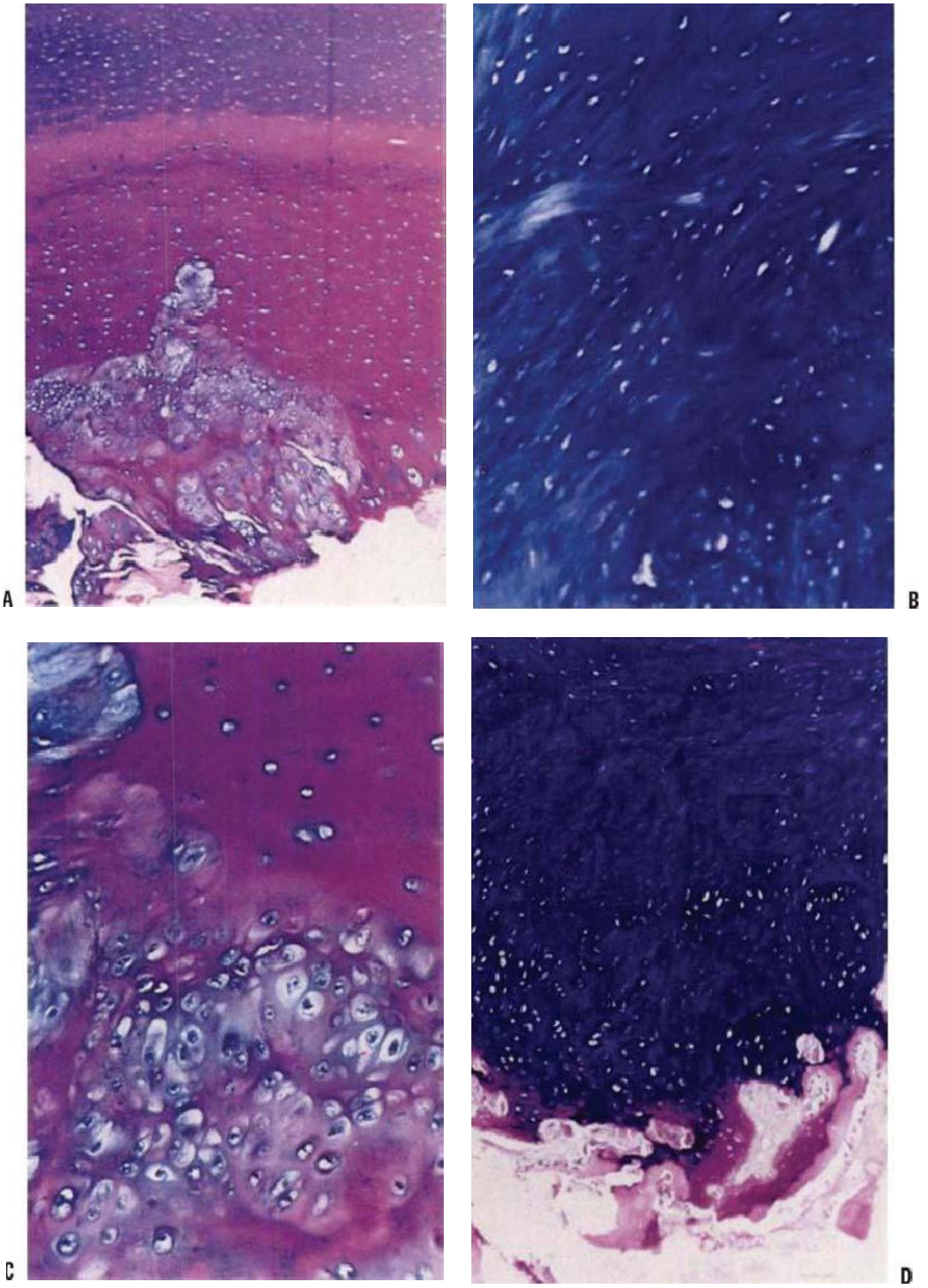


FIGURE 24-4. **A:** Superficial zone cartilage and epiphyseal cartilage of the femoral head. The superficial zone cartilage is normal and is Alcian blue positive. The epiphyseal cartilage stains with periodic acid–Schiff, but only the perilacunar rims stain with Alcian blue. In the epiphyseal cartilage, there is an area of disorganized abnormal Alcian blue-positive cartilage. (Alcian blue with 0.6 mol per L magnesium chloride; original magnification, ×25.) **B:** Abnormal area of epiphyseal cartilage. The matrix has a fibrillated appearance and is strongly Alcian blue positive. (Alcian blue with 0.6 mol per L magnesium chloride; original magnification, ×100.) **C:** Junction between the normal and abnormal epiphyseal cartilage. Normal cartilage is periodic acid–Schiff positive, whereas the abnormal cartilage is very cellular and retains Alcian blue positivity at high concentrations of magnesium chloride. (Alcian blue with 0.7 mol per L magnesium chloride; original magnification, ×165.) **D:** Extensive area of abnormal epiphyseal cartilage in the femoral head. Bone seems to form directly on the abnormal cartilage. Abnormal cartilage retains intense Alcian blue positivity at a high concentration of magnesium chloride, but loses that positivity and becomes strongly positive to periodic acid–Schiff at the bone–cartilage junction. (Alcian blue with 0.7 mol per L magnesium chloride, periodic acid–Schiff, and Weigert hematoxylin stains; original magnification, ×40.) (From Ponseti IV, Maynard JA, Weinstein SL. Legg-Calvé-Perthes' disease: histochemical and ultrastructural observations of the epiphyseal cartilage and the physis. *J Bone Joint Surg Am* 1983;65:797.)

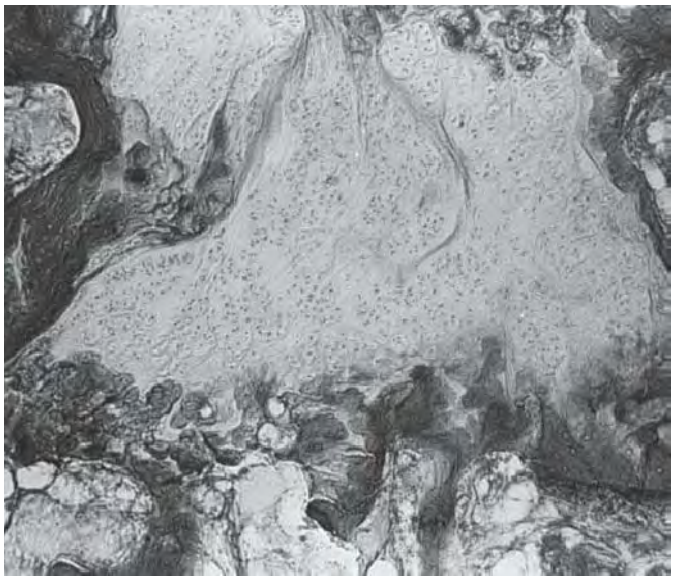


FIGURE 24-5. Photomicrograph showing a large area of cartilage between the bone trabeculae of the femoral neck. (Original magnification, ×80.) (From Ponseti IV. Legg-Perthes' disease. *J Bone Joint Surg Am* 1956;38:739.)

in others the proliferating cells are separated by a fibrillated cartilaginous matrix that does not calcify (Fig. 24-5). The cells in these areas do not degenerate but continue to proliferate without endochondral ossification, leading to tongues of cartilage extending into the metaphysis as bone growth proceeds in the adjoining areas (143, 144, 148, 158–160).

Catterall et al. (158) have demonstrated thickening, abnormal staining, sporadic calcification, and diminished evidence of ossification in the deep zone of the articular cartilage of the unaffected hip. They also demonstrated that the physeal plate in these unaffected hips is thinner than normal, with irregular cell columns and cartilage masses remaining unossified in the primary spongiosa.

Some of these cartilage changes have been seen in other epiphyseal plates, such as the greater trochanter and the acetabulum (161). In the human specimens described by Ponseti (144), the physeal plate lesions were longstanding, as shown by the fact that there was only necrotic bone in the femoral head and no evidence of repair. Catterall et al. reported similar cartilaginous lesions in a patient with Catterall group 1 disease, in which there is no sequestrum formation (146, 148) (Fig. 24-6). The various reported physeal plate and epiphyseal plate lesions resemble the lesions that Ponseti and Shepard (162) produced in rats by administering aminonitrils. These epiphyseal and physeal plate changes, in conjunction with the unusual and precarious blood supply to the proximal femur, make the femoral head vulnerable to the effects of physeal plate disruption.

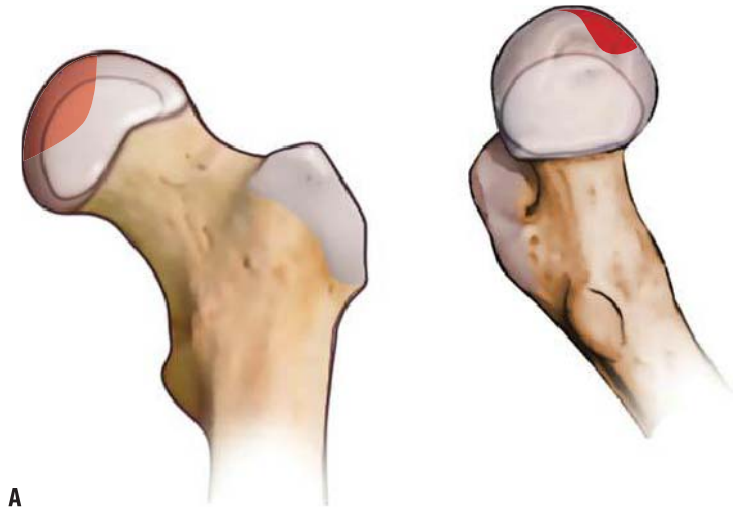
Surveys of patients with Legg-Calvé-Perthes syndrome confirm that the histologic abnormalities are accompanied by irregularities of ossification in other epiphyses, especially Kohler disease of the navicular (73, 144, 163). Harrison and Blakemore (164), studying 153 consecutive patients with unilateral Legg-Calvé-Perthes disease, found that 48% had contour irregularities in the contralateral normal capital epiphysis compared with 10% of the matched controls. Kandzierski et al. (152) reported that 35% of patients with Perthes disease showed changes in the unaffected proximal femur in the first radiograph. Aire et al. (165) demonstrated that the unaffected hip showed anterior and lateral flattening at the time of diagnosis of the affected hip. These data suggest that Legg-Calvé-Perthes disease is a generalized process affecting other epiphyses and therefore should not be referred to as a disease but should be called *Legg-Calvé-Perthes syndrome*.

Disorganization of the physeal plate, together with minimal trauma, may interrupt the continuity of retinacular vessels, causing necrosis (143, 144). This finding, in conjunction with the aforementioned epidemiologic, histologic, and radiologic data, supports the belief that Legg-Calvé-Perthes syndrome may be a localized manifestation of a generalized disorder of epiphyseal cartilage in the susceptible child (10, 34, 52, 59, 72, 143, 151, 166, 167).

Radiographic Stages. Radiographically, Legg-Calvé-Perthes syndrome can be classified into four stages: initial, fragmentation, reossification, and healed. These stages are important in the formulation of treatment decisions that will be discussed later in this chapter. In the initial stage (18, 168), one of the first signs of this condition is failure of the femoral ossific nucleus to increase in size because of a lack of blood supply (Fig. 24-7). The affected femoral head appears smaller than the opposite, unaffected ossific nucleus. Widening of the medial joint space, as initially described by Waldenstrom (18, 169) (Fig. 24-7), is another early radiographic finding. Some researchers have theorized that widening is caused by synovitis. Others have proposed that this finding is secondary to decreased head volume caused by necrosis and collapse and a secondary increase in blood flow to the soft-tissue parts, such as the ligamentum teres and pulvinar, causing the head to displace laterally (168, 170). Synovitis is indeed present in patients with Perthes disease to varying degrees (101–104, 171, 172), but the medial joint space widening is probably most often an apparent radiographic phenomenon secondary to epiphyseal cartilage hypertrophy (Fig. 24-8).

In the initial stage, the physeal plate is irregular and the metaphysis is blurry and radiolucent (87) (Fig. 24-9). The femoral ossific nucleus appears radiodense (173). This relative increase in radiodensity may be caused by osteopenia of the surrounding bone (174, 175) or an increase in the mass of bone per unit area.

The second radiographic stage is called the *fragmentation phase* (18, 168). Radiographically, the repair aspects of the disease become more prominent (Fig. 24-9). The bony epiphysis begins to fragment, and there are areas of increased radiolucency and increased radiodensity. Increased radiodensity at this stage may be caused by new bone forming on old bone (176–180) and thickening of existing trabeculae (178). The subchondral radiolucent zone (i.e., crescent sign) first described by Waldenstrom (169, 181), and later brought to wider attention by Caffey (182), is one of the very early signs



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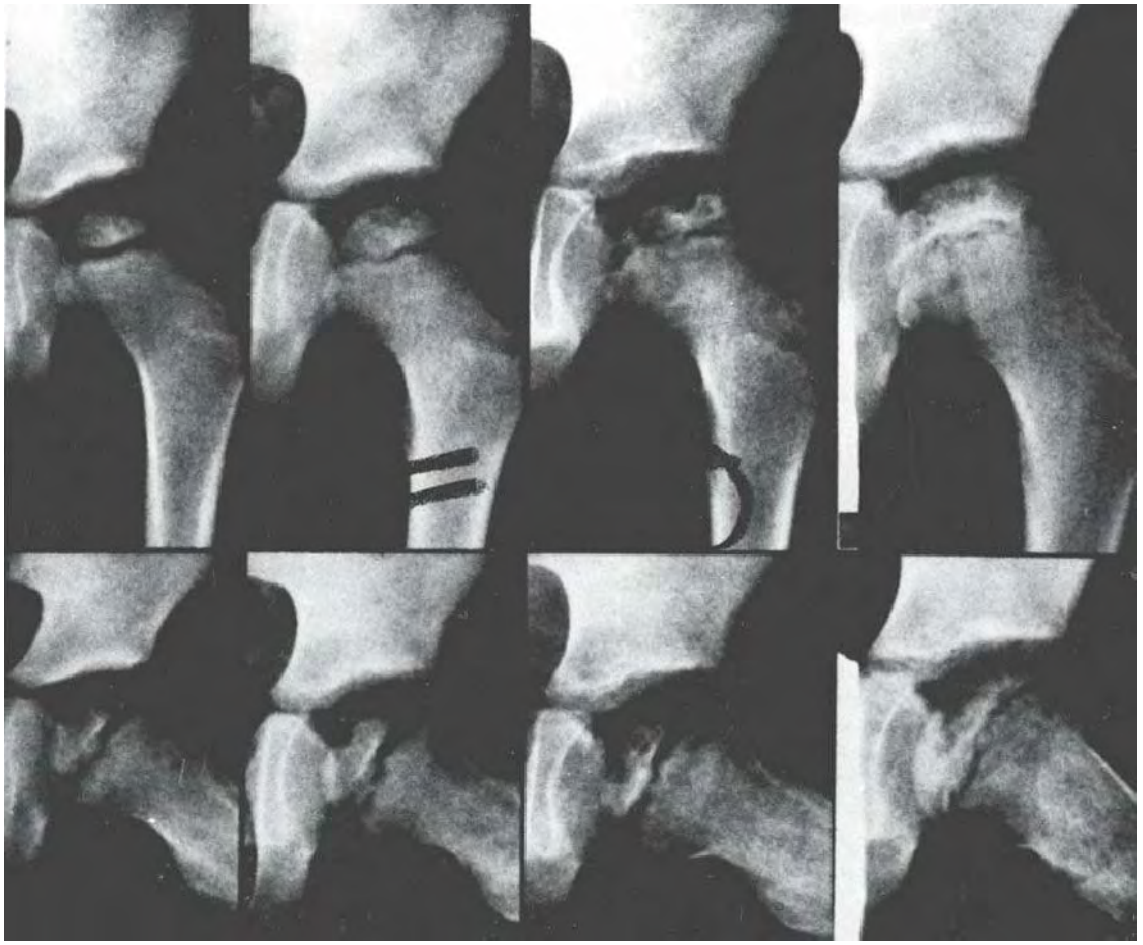


B

FIGURE 24-6. **A:** Catterall group 1 disease shows anterior femoral head involvement with no evidence of sequestrum, subchondral fracture line, or metaphyseal abnormalities. **B:** Catterall group 1 disease 1 week to 5 years after onset of symptoms.

of Legg-Calvé-Perthes syndrome in the fragmentation stage (Figs. 24-2 and 24-10). According to Salter and Thompson (125) and Salter and Bell (183), this radiographic finding results from a subchondral stress fracture, and the extent of this zone determines the extent of the necrotic fragment.

The third radiographic stage is the reparative or reossification phase (18, 168). Radiographically normal bone density returns, with radiodensities appearing in areas that were formerly radiolucent. Alterations in the shape of the femoral head and neck become apparent (Fig. 24-9).

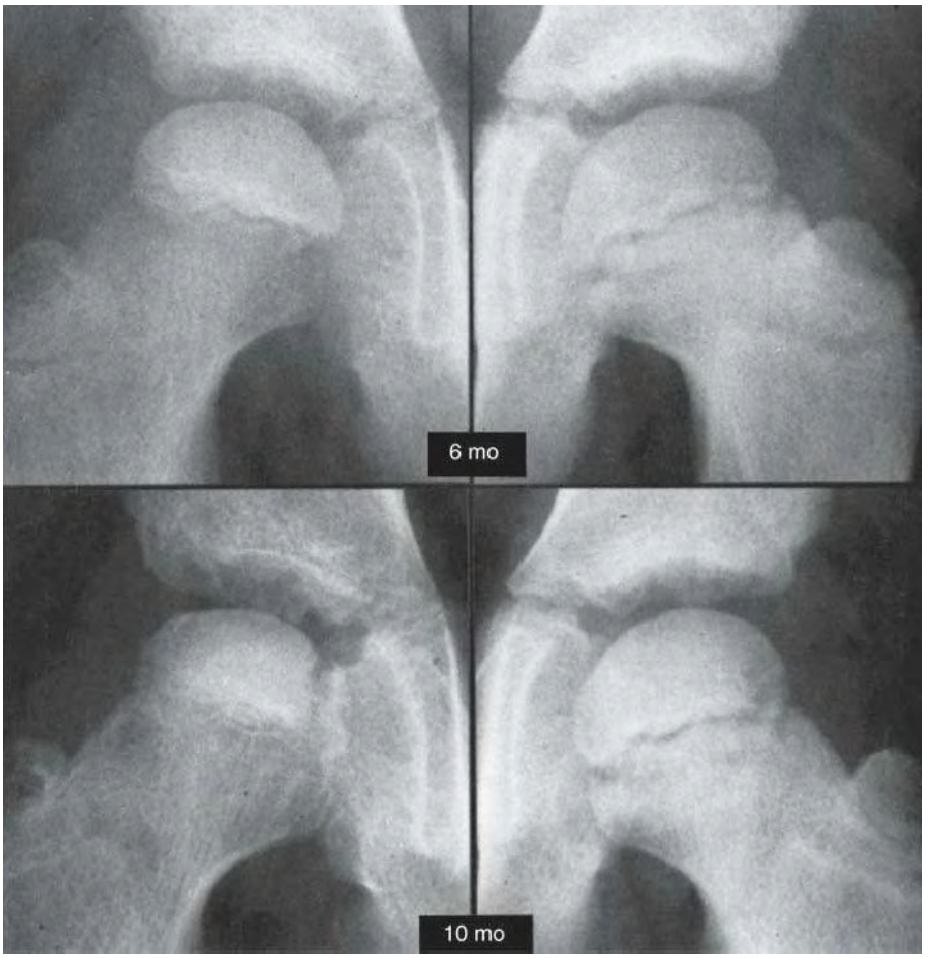


FIGURE 24-7. AP radiogram of a hip in a patient who developed Legg-Calvé-Perthes disease. On the initial film, taken 6 months after the onset of symptoms, the right ossific nucleus is smaller than the left, and the medial joint space is widened. Note also the retained density of the ossific nucleus compared with the normal hip and the relative osteopenia of the viable bone of the proximal femur and pelvis. Ten months after the onset of symptoms, the evolution of the radiographic changes is seen. (From McKibbin B, ed. *Recent advances in Perthes' disease*. Edinburgh, UK: Churchill Livingstone, 1975.)

The final stage is the healed phase. In this stage, the proximal femur may have residual deformity from the disease and the repair process (Fig. 24-9).

In the young child, Legg-Calvé-Perthes syndrome cannot be compared with aseptic necrosis after fracture of the neck of the femur or traumatic dislocations of the hip. In these

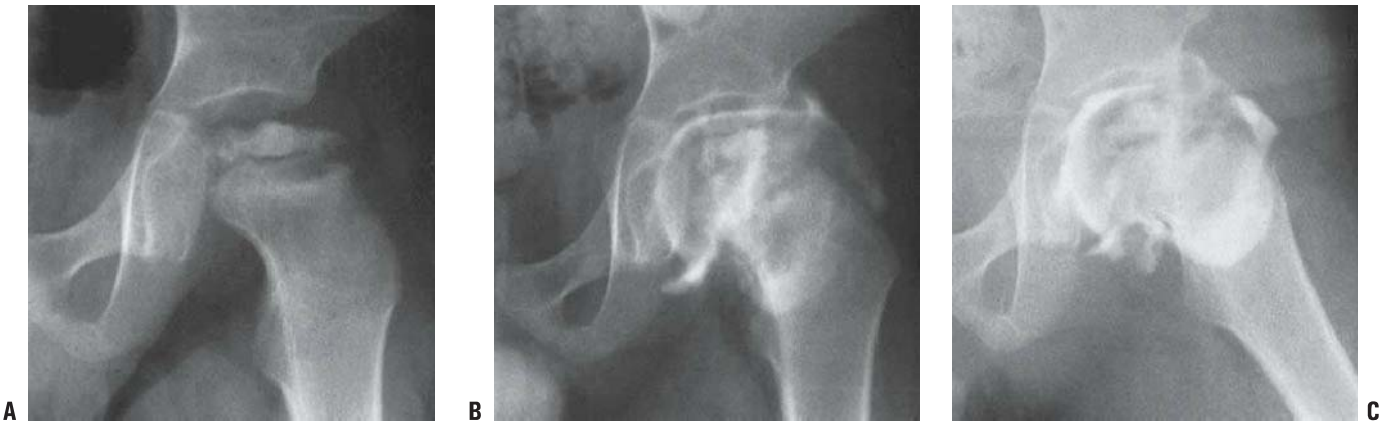
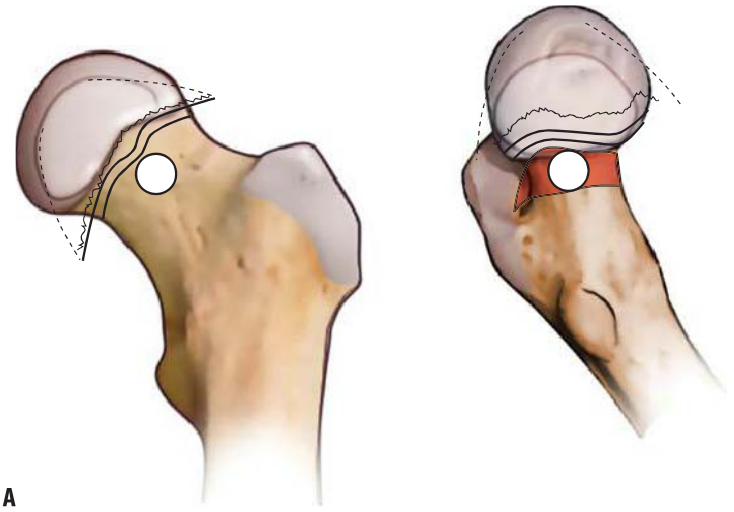
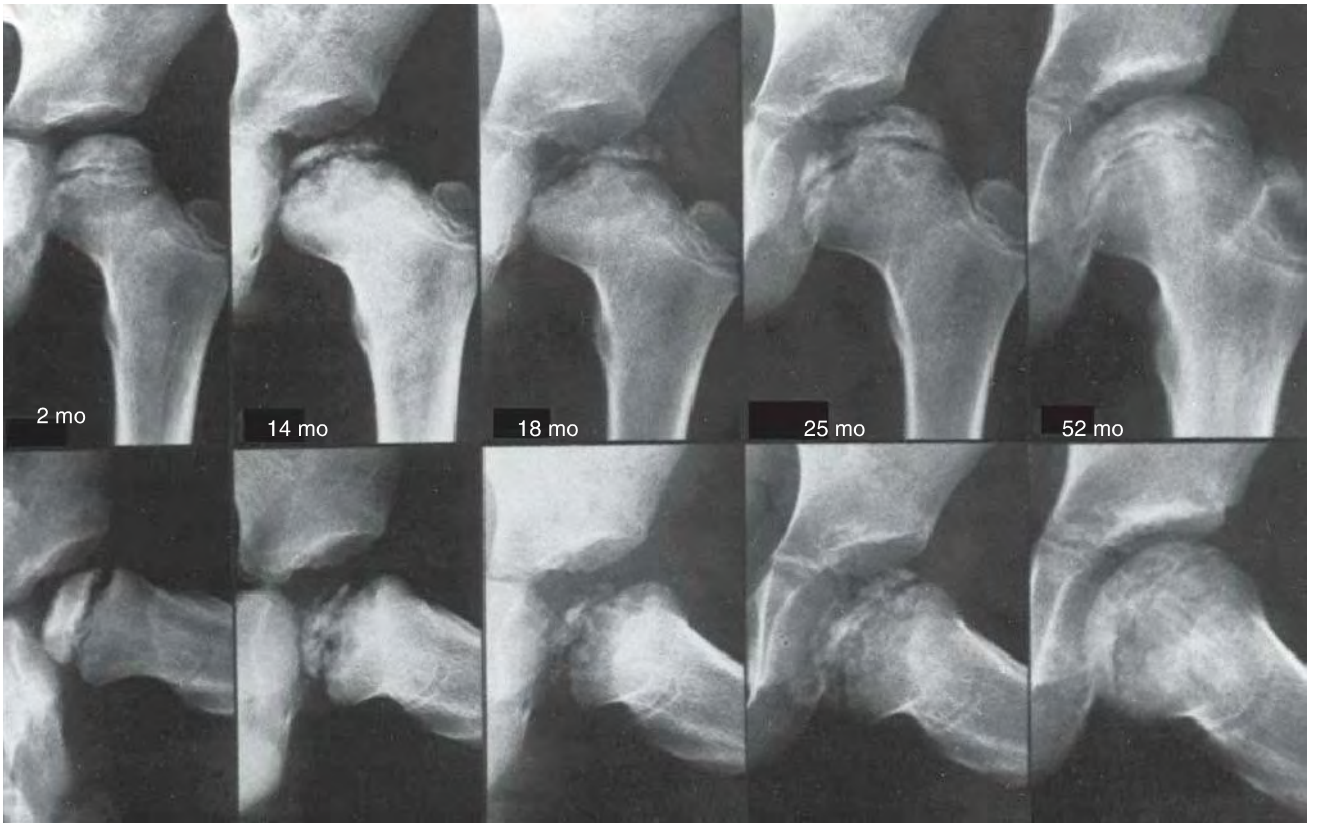


FIGURE 24-8. A boy, 4 years and 9 months of age, with Catterall group 4 disease and at-risk status. **A:** Plain radiograph. **B:** Arthrogram in neutral abduction, adduction, and rotation. There is enlargement and flattening of the cartilaginous femoral head, and the lateral margin of the acetabulum is deformed by the femoral head. **C:** Arthrogram in abduction and slight external rotation. The femoral head hinges on the lateral edge of the acetabulum, further deforming the lateral acetabulum. Slight pooling of dye is seen medially. Note that the widened joint space is an apparent widening, not a real widening, and that it is secondary to continued growth of the superficial zone of cartilage in the absence of growth of the ossific nucleus.



A



B

FIGURE 24-9. **A:** Catterall group 4 disease shows involvement of the whole head of the femur, with either diffuse or central metaphyseal lesions and with posterior remodeling of the epiphysis. **B:** Catterall group 4 disease, 2 to 52 months after onset of symptoms. Note the stages: 14 months, fragmentation; 18 months, early reossification; 25 months, late reossification; 52 months, healed. Note also the growth-arrest line and evidence of reactivation of the growth plate along the femoral neck.

situations, the vascular insult to the femoral head usually heals rapidly without going through the prolonged stages of fragmentation and repair that are seen in children with Legg-Calvé-Perthes syndrome (143, 184, 185).

Pathogenesis of Deformity. The deformities of the femoral head that occur in Legg-Calvé-Perthes syndrome come about in many ways. First, there is growth disturbance in the epiphyseal and physeal plates. In the physeal plate, this may result in premature closure with resultant deformity, such as central physeal arrest, causing shortening of the neck of the femur and trochanteric overgrowth (186, 187) (Fig. 24-11). The repair process itself may cause physical compaction resulting from structural failure and displacement of tissue elements (92). During the healing process, the femoral head will deform according to the asymmetric repair process and the

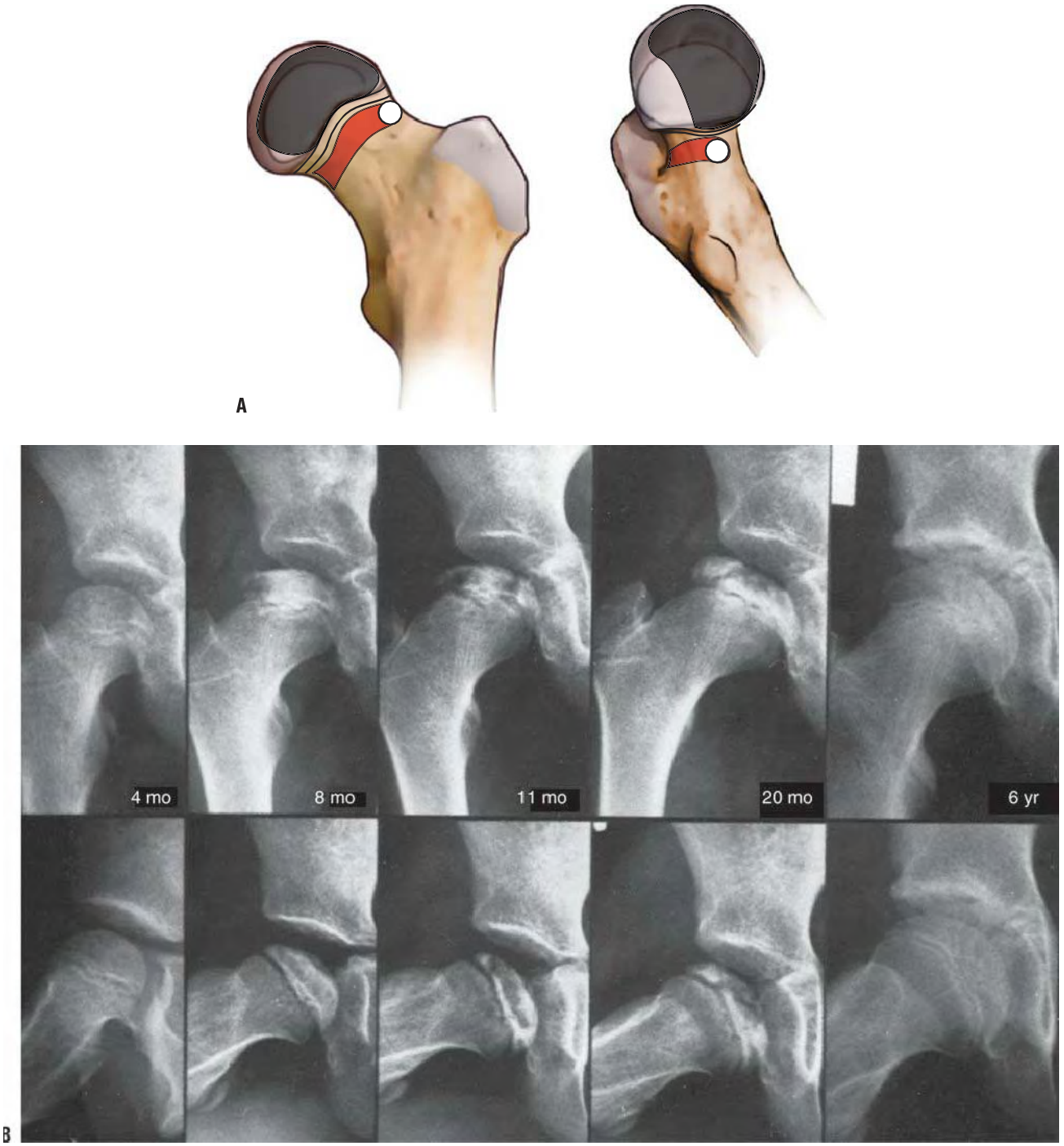


FIGURE 24-10. **A:** Catterall group 3 disease shows large sequestrum involving three-fourths of the femoral head. The junction between the involved and the uninvolved portions is sclerotic. Metaphyseal lesions are diffuse, particularly anterolaterally, and the subchondral fracture line extends to the posterior half of the epiphysis. The lateral column is involved. **B:** Catterall group 3 disease, 4 months to 6 years after symptom onset. Note the involvement of the lateral pillar, as well as the subchondral radiolucent zone on the radiograph taken 8 months after onset of symptoms.

applied stresses. The molding action of the acetabulum during new bone formation may also play a role in this process (188, 189). With deformity of the femoral head, the acetabulum, particularly its lateral aspect, is deformed secondarily.

The articular cartilage of the femoral head shows changes in shape secondary to the disease process itself. The deepest layer of the articular cartilage is nourished by the subchondral blood supply. This layer is often devitalized in Legg-Calvé-Perthes syndrome (146, 149, 150, 152–154, 156). The superficial layers that are nourished by synovial fluid continue to proliferate, causing an increase in the thickness of the articular cartilage. With trabecular collapse and fracture and articular cartilage overgrowth, significant femoral head deformities develop that are manifested clinically as loss of abduction and rotation (Fig. 24-8).

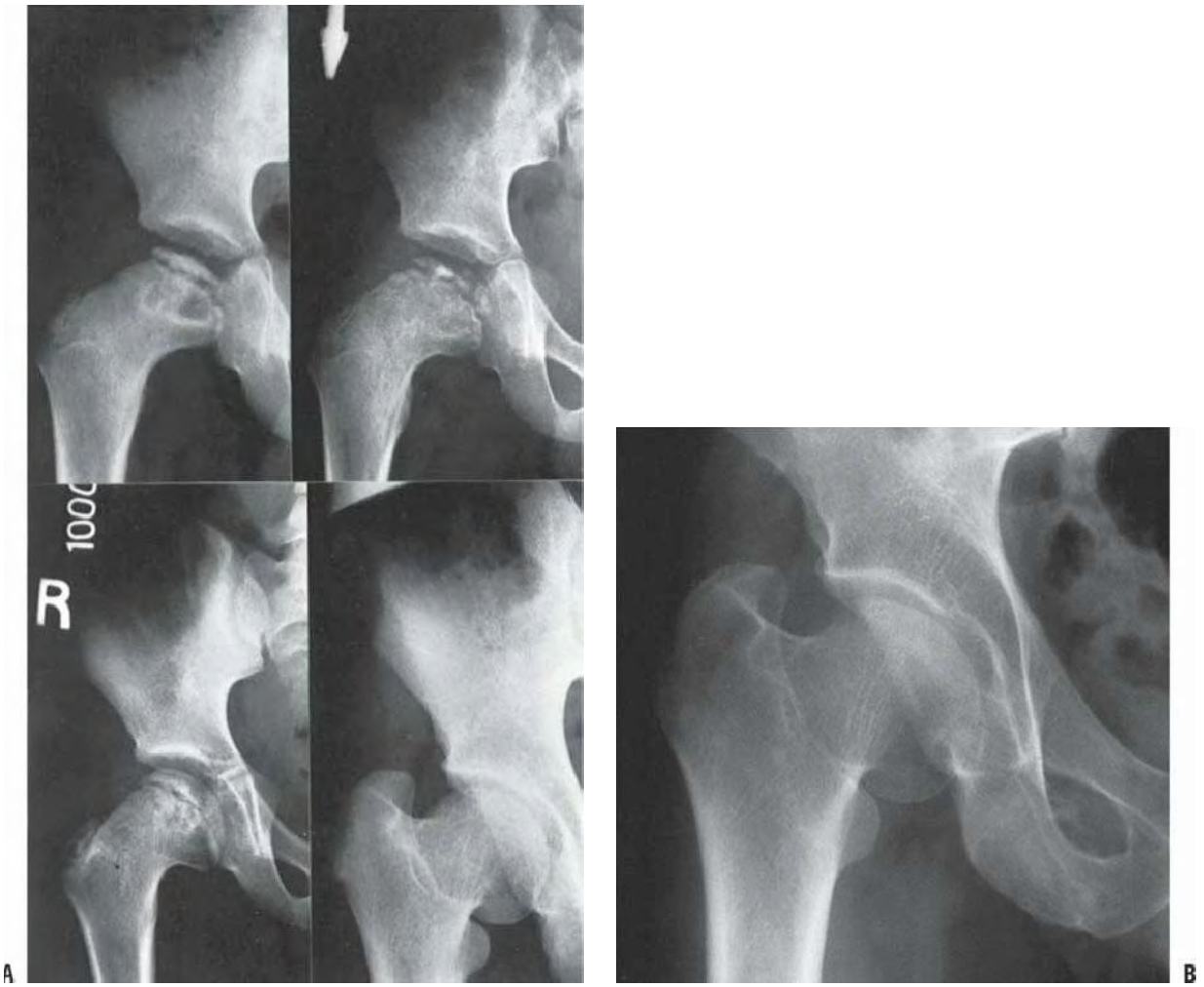


FIGURE 24-11. **A:** A 6-year-old boy with Catterall group 4 disease. At 6 years and 2 months of age, fragmentation stage **(upper left)**. At 6 years and 9 months of age, early reossification stage **(upper right)**. At 8 years and 9 months of age, healed **(lower left)**. At 16 years and 2 months of age, skeletally mature **(lower right)**. The patient's hip healed with a central physeal arrest pattern. **B:** A 51-year-old patient at 45-year follow-up. He was asymptomatic and had a full range of motion (Iowa Hip Rating, 95 of 100 points). At maximal fragmentation, the hip is classified as showing Catterall group 4, Salter-Thompson type B, and lateral pillar type C disease.

The source of vessel ingrowth is under debate. Many investigators (149, 150, 190) have demonstrated that the new blood vessels arise from the metaphysis and the metaphyseal periosteum and penetrate between the epiphysis and the joint cartilage into the epiphysis. Other investigators have shown metaphyseal vessels penetrating the physeal plate into the epiphysis (112, 116). When the blood supply of the subchondral area is restored, it generally comes from the periphery and moves to the center, first restoring endochondral ossification at the periphery and causing asymmetric growth (156, 191) (Fig. 24-12). In addition, there is abnormal ossification of the disorganized matrix of the epiphyseal cartilage. Finally, there is periosteal bone growth and reactivation of the physeal plate along the femoral neck, with abnormally long cartilage columns leading to coxa magna and a widened femoral neck (143, 144).

The actual deformity that develops is profoundly influenced by the duration of the disease. This, in turn, is proportional to the extent of the epiphyseal involvement, the age of the patient at the time of onset of the disease, the remodeling potential of the patient, and the stage of disease when treatment is initiated. An additional factor is the type of treatment chosen (192–195).

Patterns of Deformity. Four basic patterns of residual deformity result from Legg-Calvé-Perthes syndrome: coxa magna, premature physeal arrest patterns, irregular femoral head formation, and osteochondritis dissecans (187, 196). Coxa magna (Fig. 24-9) develops with ossification of the hypertrophied articular cartilage and also from reactivation of the physeal plate along the femoral neck. This also occurs in conjunction with periosteal new bone formation along the femoral neck.

Premature physeal plate closure generally leads to one of two patterns of arrest: central or lateral. In the central arrest pattern, the femoral neck is short and the epiphysis is relatively round (Fig. 24-11). There is trochanteric overgrowth and mild

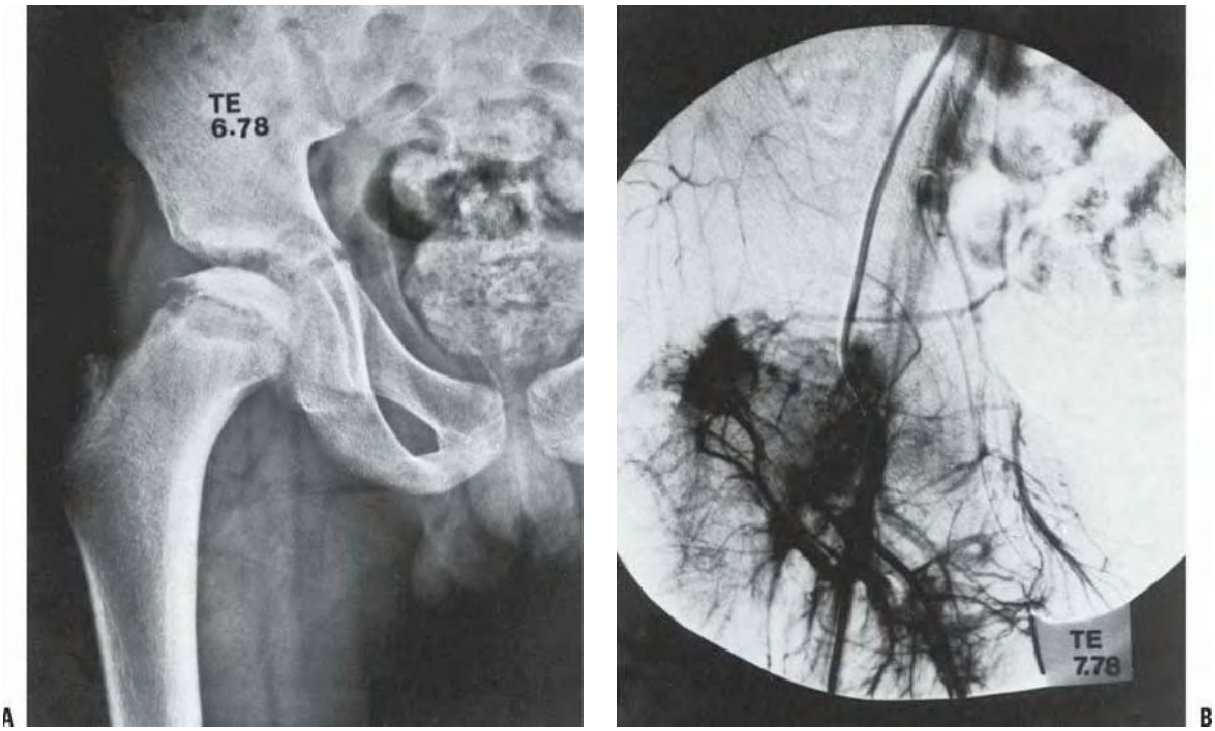


FIGURE 24-12. **A:** A 12-year-old boy with total femoral head involvement in the early fragmentation stage of the disease. **B:** Subtraction arteriogram demonstrating the avascularity of the central portion of the femoral head, with increased vascularity at the periphery. (Courtesy of J. G. Pous, MD, Montpellier, France.)

acetabular deformity. In the lateral arrest pattern, the femoral head is tilted externally (Fig. 24-13). There is also trochanteric overgrowth. The epiphysis is oval, with a corresponding acetabular deformity (187, 196).

The irregular femoral head may occur as a consequence of certain patterns of physeal arrest, or it may be an iatrogenic deformity from attempts at "containment" of a noncontainable head (Fig. 24-14). After the femoral head becomes deformed and is no longer containable within the acetabulum, the only motion that is allowed is in the flexion and extension plane, with abduction leading to hinging on the lateral edge of the acetabulum. This hinge abduction causes acetabular deformity, leading to femoral head deformity (197–199).

The fourth and least common (3% incidence) residual deformity that occurs in Legg-Calvé-Perthes syndrome is osteochondritis dissecans (Fig. 24-15). This usually occurs when there is late onset of disease, and with prolonged, ineffectual repair (187, 196, 200–202).

NATURAL HISTORY

The formulation of disease treatment requires that the treating physician knows what would happen to the patient in the absence of treatment (natural history) and what factors prognosticate an adverse outcome. The treating physician must determine which of these adverse prognostic factors can be affected by treatment. A treatment plan is then initiated, and long-term follow-up determines whether treatment favorably alters the course of the disease over the long term. The fundamental problem in developing treatment plans for patients with Legg-Calvé-Perthes syndrome is the paucity of natural history data (72, 203–206).

Catterall (203) compared 46 untreated hips of Murley and Lloyd-Roberts with a matched control group of 51 hips treated with a weight-relieving caliper. The average age at diagnosis was 4 years and 6 months, and the average follow-up was 10 years and 5 months, with a range of 4 to 18 years. The patients were evaluated according to the grading system of Sundt (121), which requires some subjective assessments. The 10-year average follow-up in this series was too short to determine the outcomes for patients and thus the natural history of the disease, because most patients with childhood hip disease do well regardless of the radiographic appearance in their early years (207–210). In addition, no data are presented on the interobserver or intraobserver reliability of the outcome criteria.

Catterall (203) also reported on 97 untreated patients from around the British Isles (203). The average follow-up in this series was only 6 years, and the results were graded according to the aforementioned system of Sundt (121). The outcomes in this group of patients (Table 24-1) are widely quoted in the literature as a comparison for outcomes of various treatment modalities. Unfortunately, very few articles in the literature use the same grading system for outcomes, and the follow-up of this group is too short to be defined as natural history.

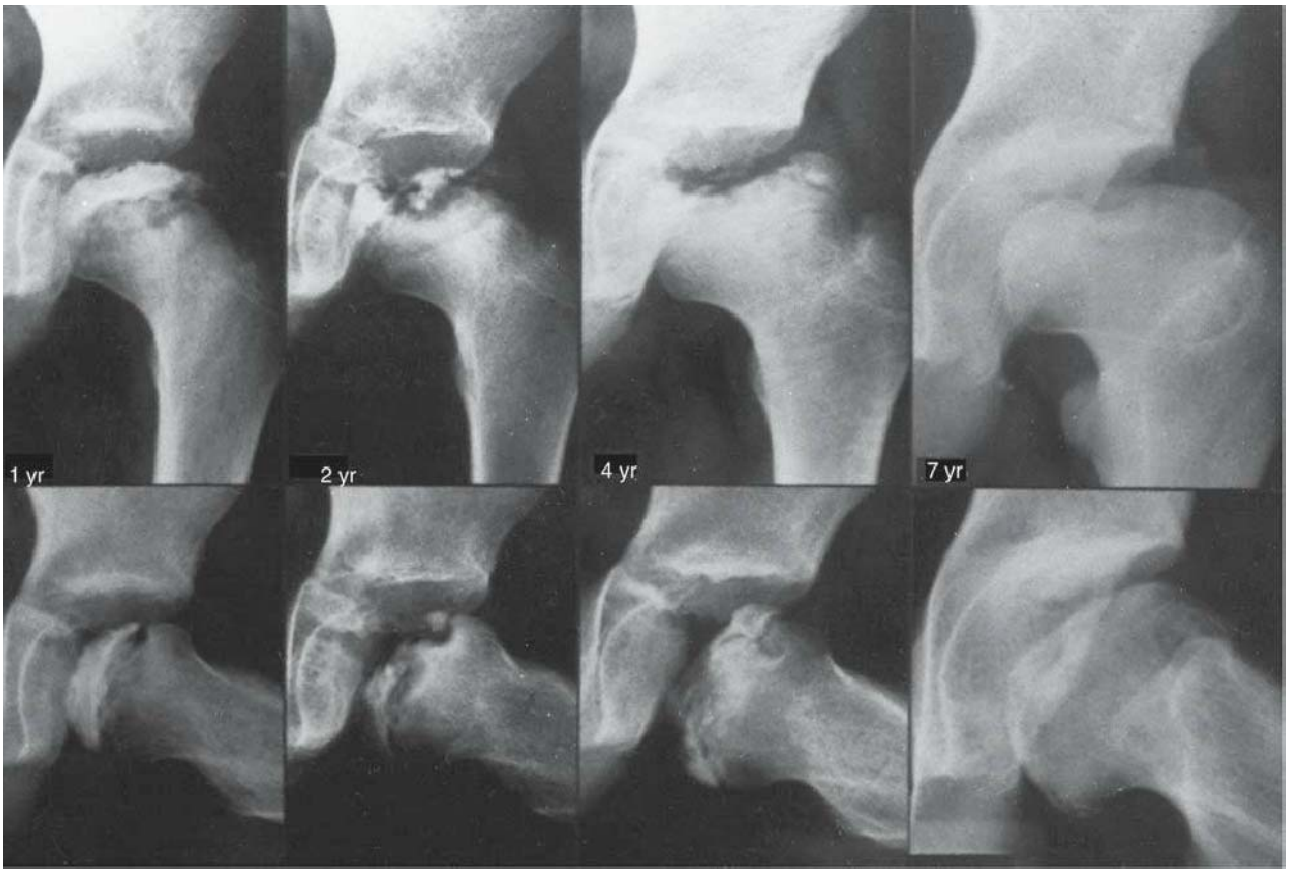


FIGURE 24-13. A 7-year follow-up from presentation in a patient with Catterall group 4 disease, who had a lateral growth-arrest pattern. At maximal fragmentation, the radiographic classification would be Salter-Thompson type B and lateral pillar type C disease. (From Weinstein SL. Perthes' disease: an overview. *Curr Orthop* 1988;2:181.)

The only other article labeled "natural history" in the literature (206) is not a natural history study but a study of patients from three centers treated by different methods. This study attempted both to establish a relation between residual deformity and degenerative joint disease and to identify clinical and radiographic factors in the active phase of disease that would be predictive of hip deformity and degenerative joint disease. Therefore, as will be further discussed later in the chapter, decision making with reference to treatment is difficult because of the lack of true long-term natural history data.

Long-Term Follow-Up Results. Although there is little information available on natural history, there are many long-term follow-up studies of patients with Legg-Calvé-Perthes syndrome. The long-term studies that are available suffer from the faults of retrospective long-term reviews in that most series contain only small numbers of patients, with many of the original patients not traced; original radiographs often are not available. Many of the longer series contain patients diagnosed in the years 1910 to 1940, when little was known about the disease, prognostic factors, and radiographic classifications. In most series, patients are combined regardless of what are now known to be prognostic factors: the extent of epiphyseal involvement, age at onset of the disease, age at the beginning of treatment, and stage of the disease at treatment initiation. Various treatment modalities are combined in many series, and control groups are generally absent. Because of these inherent problems, and the fact that different grading systems are used in judging clinical and radiographic end results, all of which lack interobserver and intraobserver reliability data, it is difficult to compare and contrast the various reported series. Despite these shortcomings, a great deal has been learned about the prognosis in Legg-Calvé-Perthes syndrome.

In reviewing long-term follow-up studies, it is apparent that results can improve with time, because remodeling potential continues until the end of growth (72, 211) (Figs. 24-9 and 24-10). Mose wrote that, "for a precise prognosis, conclusions from any measurements ought not be made before the patient reaches the age of 16, when growth stops" (209). Reviews of the outcomes of treatment modalities before skeletal maturity must be viewed as preliminary reports.

Twenty to forty years after the onset of symptoms, most (70% to 90%) patients with Legg-Calvé-Perthes syndrome are active and free of pain. Most patients maintain a good range of motion, despite the fact that few have normal-appearing radiographs. Clinical deterioration and symptoms of increasing pain, decreasing range of motion, and loss of function

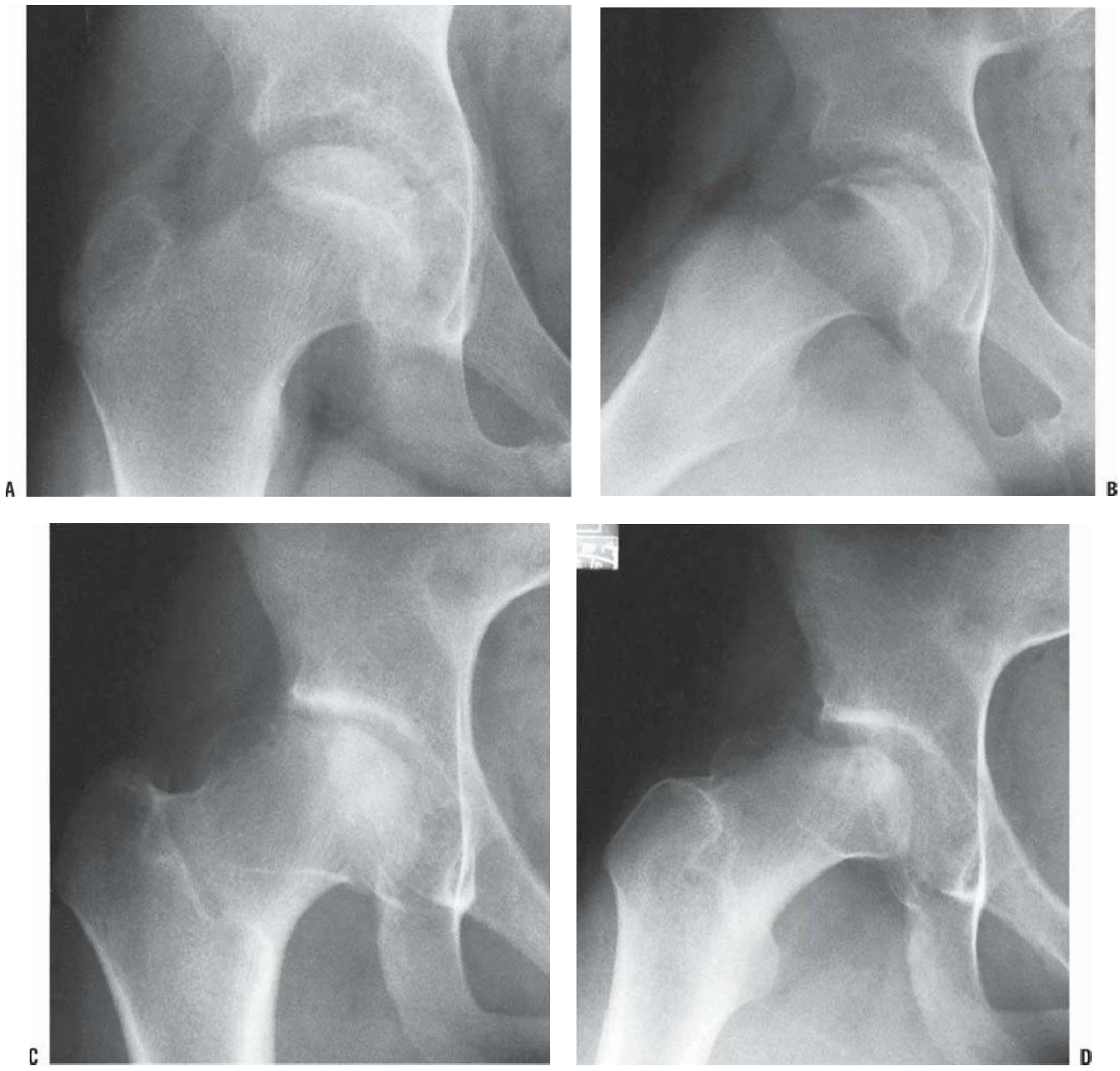


FIGURE 24-14. A girl, 11 years and 3 months of age, with Catterall group 3 disease had a noncontainable femoral head, yet was treated for a long time in an abduction brace. AP radiograph in the early fragmentation stage **(A)** and Lauenstein radiograph in the early fragmentation stage **(B)**. At age 14 years, the patient was skeletally mature and had an irregular femoral head. AP radiograph **(C)** and Lauenstein radiograph **(D)**. (From Weinstein SL. Perthes' disease: an overview. *Curr Orthop* 1988;2:181.)

are observed only in patients with flattened irregular heads at the time of primary healing, and in patients with premature physeal closure, as indicated by femoral neck shortening, femoral head deformity, and trochanteric overgrowth (193) (Fig. 24-13).

Danielsson and Hernborg (212) reported a 33-year follow-up of 35 patients. Twenty-eight of the thirty-five patients were free of pain, with 34 of 35 functioning without restrictions. In a 34-year follow-up, Hall (213) reported satisfactory results in 71% of 209 cases. Perpich et al. (214) reported a 30-year follow-up of 37 patients. The average Iowa Hip Rating was 93 of a possible 100 points. Eighty-five percent of the patients had good clinical results, despite the fact that only 33% had spherical femoral heads, as rated by the Mose Sphericity Scale (209) (Fig. 24-16). Forty-three percent of the patients had poor Mose ratings; however, of these patients, 76% had good clinical results.

Ratliff (215) followed 34 patients for an average of 30 years and noted that 80% were fully active and free of pain, whereas only 40% were radiographically normal. He

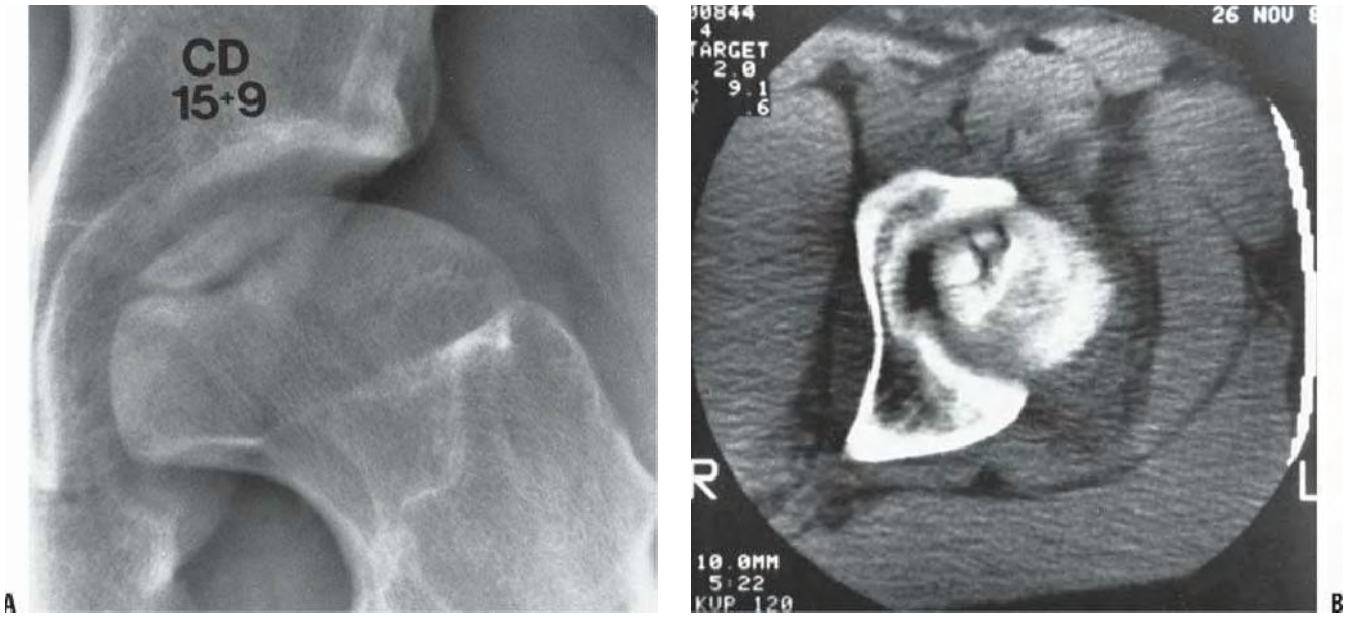


FIGURE 24-15. **A:** A 15-year-old boy, whose disease started at 8 years and 6 months of age, returned to the physician with pain and synovitis. AP radiograph demonstrates osteochondritis of the femoral head. **B:** Computed tomographic scan shows multiple fragments that appear as one on the radiograph.

followed 16 of these patients for an additional 11 years (216) and noted that, despite the fact that only one-third of them had good anatomic results, "deterioration rarely occurred and many patients had no pain and (maintained) normal activity."

Yrjonen (210) followed 96 patients (106 hips), all of whom had noncontainment treatment, for an average of 35 years. At maturity, 61% had poor results by the Mose criteria. In a final follow-up, 48% had evidence of degenerative joint disease. However, at an average 35-year follow-up, only 4% had undergone total hip arthroplasty, with an additional 13% having clinical symptoms significant enough to warrant arthroplasty. Ippolito et al. (217) reported on 61 patients with an average follow-up of 25 years. Only 19% of their patients had poor results, as measured by the Iowa Hip Rating, at final follow-up. W.J. Cumming (personal communication, 1997) reported on 82 patients with 95 involved hips treated by prolonged frame recumbency, with an average follow-up of 38 years. Only 10% of the patients had required arthroplasty at follow-up, with an additional 10% having symptoms significant enough to warrant arthroplasty.

Gower and Johnston (218) reported on 30 nonoperated hips with an average 36-year follow-up. This series is representative of other 20- to 40-year long-term series reported in the literature. The average Iowa Hip Rating for these 30 patients was 91 points. The typical patient had minimal shortening, absent or mild hip pain, and minimal or no functional impairment with respect to their jobs and activities of daily living. Ninety-two percent of the patients had Iowa Hip Ratings higher than 80 points, and only 8% of them had undergone arthroplasty.

In follow-up studies beyond 40 years, hip function begins to deteriorate. In another study of the Iowa group of patients at 48-year follow-up, McAndrew and Weinstein (208) reported that only 40% of patients maintained an Iowa Hip Rating of better than 80 points. Forty percent of the patients had undergone arthroplasty, and an additional 10% had disabling osteoarthritis symptoms but had not yet undergone arthroplasty (Fig. 24-17). Further, at 48-year follow-up, 50% of the patients had disabling osteoarthritis and pain, and an additional 10% had Iowa Hip Ratings of <80 points. The prevalence of osteoarthritis in this group of patients was ten times that found in the general population in the same age range (193). Mose followed a group of patients into the seventh decade of life. All of the patients with irregular femoral

TABLE 24-1 Results for 97 Untreated Hips

Catterall Group	Good	Fair	Poor
Group 1	27	1	0
	92%		
Group 2	25	6	2
Group 3	4	7	11
			91%
Group 4	0	4	10
Total	56 (57%)	18 (19%)	23 (24%)

Results graded by the system of Sundt (121).
From Catterall A. *Legg-Calvé-Perthes' disease.* Edinburgh, UK: Churchill Livingstone, 1982.

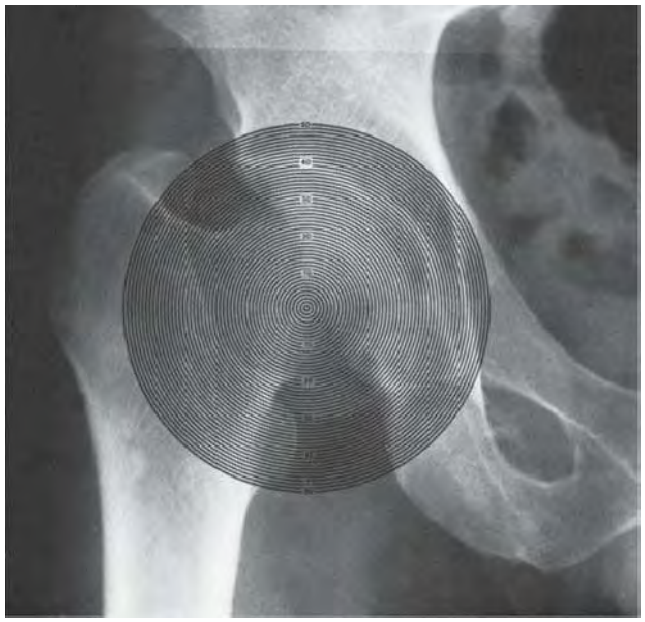


FIGURE 24-16. Mose Sphericity Scale.

heads had degenerative arthritis. Of those patients with femoral heads that Mose classified as "normal, ball shaped," no patient had degenerative joint disease by the middle of the fourth decade, but 67% had severe degenerative arthritis by the middle of the seventh decade (209). Therefore, the follow-up studies beyond 40 years demonstrate marked reduction of function, with most of the patients developing degenerative joint disease by the sixth and seventh decades (187, 206–209).

Prognostic Factors. In reviews of long-term series of patients with Legg-Calvé-Perthes syndrome, certain clinical and radiographic features have been identified that have prognostic value (193, 197, 210, 219–223) (Table 24-2). The most important prognostic factor in determining the outcome is the residual deformity of the femoral head, coupled with hip joint incongruity (224–226). Femoral head deformity and joint incongruity are multifactorial problems. They are interrelated with all of the other prognostic factors. It must be kept in mind that Legg-Calvé-Perthes syndrome represents a growth disturbance of the proximal femur; the epiphyseal and physeal cartilage is abnormal. Other key factors involved in the development of deformity include the extent of epiphyseal involvement and the varying degrees and patterns of premature physeal closure associated with this condition (227).

Stulberg et al. (206) established a relation between residual deformity and degenerative joint disease. This was accomplished by retrospectively examining the long-term outcomes of patients from three different centers treated by various methods (e.g., bed rest, spica cast, ischial weight bearing, brace, crutches, cork shoe lift on the normal side, combination of methods). They attempted to identify clinical and radiographic factors in the active phase of the disease that were predictive of the development of hip deformity. They proposed a radiographic classification of deformity relating to long-term outcome (Table 24-3). The more deformity there was at maturity (i.e., the higher the Stulberg classification), the worse the long-term outcome. However, as noted from long-term follow-up studies, it is the class 5 hips that deteriorate the earliest; they usually have significant symptoms by the end of the fourth decade (207–210). Patients with aspherical congruency (Stulberg class 3 and 4 disease) may have satisfactory outcomes for many years, with most patients undergoing significant functional deterioration in the fifth and sixth decades of life (207–210). This classification scheme, which attempts to

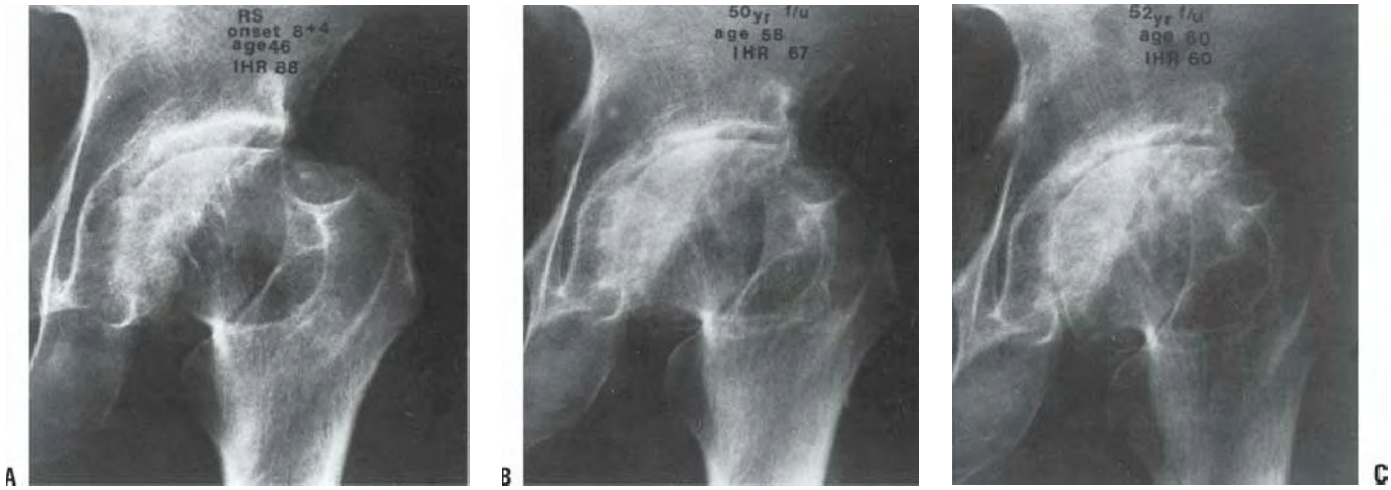


FIGURE 24-17. This patient had disease onset at 8 years and 3 months of age. At 46 years of age (38-year follow-up), the Iowa Hip Rating was 88 points **(A)**. At 58 years of age (50-year follow-up), there was a loss of 21 points on the Iowa Hip Rating, to 67 **(B)**. At 60 years of age, just before arthroplasty, the Iowa Hip Rating was 60 points **(C)**. (From Weinstein SL. Legg-Calvé-Perthes' disease: results of long-term follow-up. In: Fitzgerald RH Jr, ed. *The Hip: Proceedings of the Thirteenth Open Scientific Meeting of the Hip Society*. St. Louis, MO: Mosby, 1985:28.)

TABLE 24-2 Prognostic Factors

Deformity of the femoral head
Hip joint incongruity
Age at onset of disease
Extent of epiphyseal involvement
Growth disturbance secondary to premature physeal closure
Protracted disease course
Remodeling potential
Type of treatment
Stage at treatment initiation

classify a three-dimensional deformity using two-dimensional parameters, has been shown to have poor interobserver and intraobserver reliability (228). A newer modification of this classification may prove more reliable (229). The general principles expressed by Stulberg et al. (206), however, have been shown to have validity with reference to long-term outcome studies. That is, the more out of round the femoral head is, and the greater the discrepancy between the shape of the femoral head and the shape of the acetabulum, the greater the chance of development of early degenerative joint disease.

O'Garra (230), Salter and Thompson (124, 125), and others (72, 144, 197, 203, 231, 232) have confirmed Waldenstrom's original finding that partial or anterior femoral head involvement leads to a more favorable prognosis than whole-head involvement. Catterall (72, 145, 197) demonstrated the importance of the extent of epiphyseal involvement with regard to prognosis, and he proposed 4 groups on the basis of the presence or absence of 7 radiographic signs observed in 97 untreated hips (Figs. 24-6, 24-9, 24-10, and 24-18). He compared the final radiograph with the initial radiograph, using the clinical grading of Sundt (121); 90% of the patients who had good results were in group 1 or 2, whereas 90% of those who had poor results were in group 3 or 4. This commonly used classification has been criticized as being difficult to use in that there may be a great deal of interobserver error (219, 233–235). It also has been criticized as being insufficiently prospective, because it may take up to 8 months for the hip to be far enough into the fragmentation phase to show the extent of epiphyseal involvement (236, 237). Furthermore, it also has been noted that the classification may change when radiographs taken during the initial phase are compared with those taken at maximal fragmentation (236, 238).

Salter and Thompson (125) described a simplified two-group classification based on prognosis and determined by the extent of the subchondral fracture line, which appears early in the course of the disease: in group A, less than half of the head is involved (Catterall groups 1 and 2), and in group B, more than half of the head is involved (Catterall groups 3 and 4). The major distinguishing factor between groups A and B is the presence or absence of a viable lateral column of the epiphysis. This intact lateral column (i.e., Catterall group 2, Salter-Thompson type A) may shield the epiphysis from collapse and subsequent deformity (Fig. 24-18).

Maintenance of the integrity of the lateral column and the height of the femoral head has been described as important by several investigators (72, 213, 219, 229, 239–241). Hall (213) reported on the long-term follow-up (34 years) of 209 hips. He considered loss of femoral head height, as seen on the initial radiograph, to be an important prognostic sign. All of his patients in whom there had been a loss of 2 mm or more of height of the femoral head in the affected hip, compared with the unaffected hip, had unsatisfactory results in adult life. Patients in whom the height of the femoral head was within 2 mm of that of the unaffected hip on the initial radiograph had good results in all but six cases.

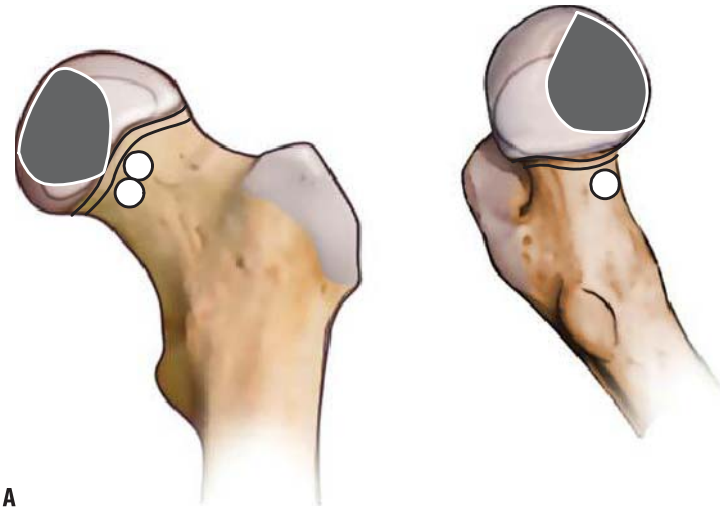
Herring et al. (219) proposed a radiographic classification based on the radiolucency of the lateral pillar of the femoral head on anteroposterior (AP) films during the fragmentation phase of the disease (Table 24-4) (Figs. 24-11, 24-13, and 24-19). The lateral pillar occupies the lateral 15% to 30% of the femoral head width on an AP radiograph. The central pillar occupies approximately 50% of the head width, and the medial pillar occupies 20% to 35% of the medial aspect of the head width on an AP radiograph.

Herring et al. (219) reported on the outcomes of 93 hips in 86 patients with radiographic follow-up to maturity. Intraobserver reliability was reported to be 0.78, with a good correlation of outcome, as measured by the classification of

TABLE 24-3 Stulberg Classification

Class	Radiographic Features	Congruency
1	Normal hip	Spherical
2 (Figs. 24-9 and 24-18)	Spherical femoral head, same concentric circle on AP and frog-leg lateral views, but with one or more of the following: coxa magna, shorter-than-normal neck, abnormally steep acetabulum	Spherical
3 (Figs. 24-11 and 24-17)	Ovoid, mushroom-shaped (but not flat) head, coxa magna, shorter-than-normal neck, abnormally steep acetabulum	Aspherical
4 (Fig. 24-13)	Flat femoral head and abnormalities of the head, neck, and acetabulum	Aspherical
5 (Fig. 24-14)	Flat head, normal neck, and acetabulum	Aspherical incongruency

From Stulberg SD, Cooperman DR, Wallensten R. The natural history of Legg-Calvé-Perthes' disease. *J Bone Joint Surg Am* 1981;63:1095.



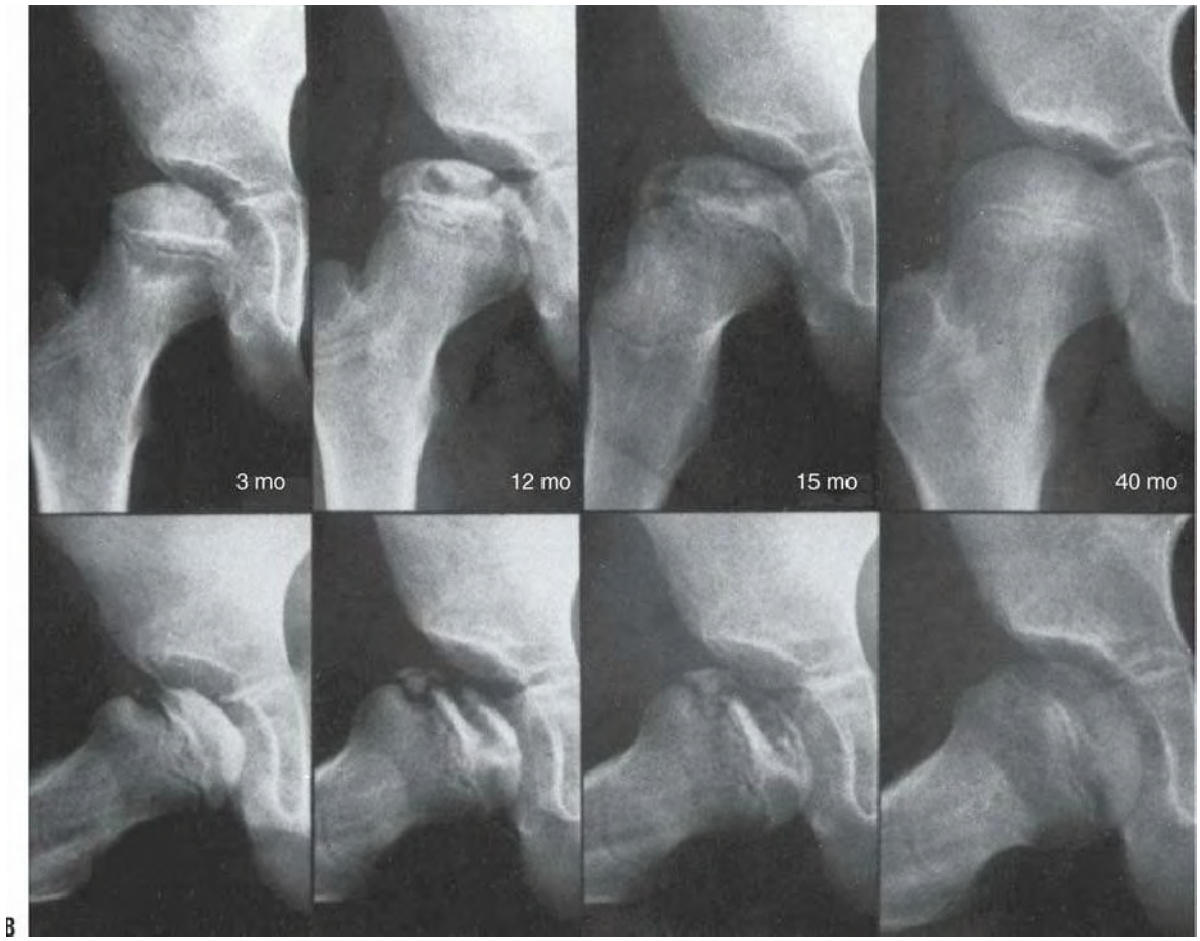


FIGURE 24-18. **A:** Catterall group 2 disease showing anterolateral involvement, sequestrum formation, and a clear junction between the involved and uninvolved areas. There are anterolateral metaphyseal lesions, and the subchondral fracture line is in the anterior half of the head. The lateral column is intact. **B:** Catterall group 2 disease. Three to forty months after onset of symptoms, the lateral pillar is still intact.

Stulberg et al. (206). Herring et al. (229) recently refined the lateral pillar classification by adding a new B/C Border group (Table 24-5; Fig. 24-19). The importance of the integrity of the lateral column is seen in other classifications, with patients in Salter-Thompson type A and Catterall groups 1 and 2 having intact lateral columns. The results of treatment in long-term outcome studies show this to be an important prognostic factor (207, 219, 238, 242, 243) (Fig. 24-20). The reliability of this classification and its utility in Perthes disease will require further study (229, 234, 239, 244).

TABLE 24-4 Original Lateral Pillar Classification

Type A	No involvement of the lateral pillar; lateral pillar is radiographically normal; possible lucency and collapse in the central and medial pillars, but full height of the lateral pillar is maintained
Type B	Greater than 50% of the lateral pillar height is maintained; lateral pillar has some radiolucency, with maintenance of bone density at a height between 50% and 100% of the original height of the lateral head
Type C	Less than 50% of lateral pillar height is maintained; lateral pillar becomes more radiolucent than in type B, and any preserved bone is at a height of <50% of the original height of the lateral pillar

From Herring JA, Neustadt JB, Williams JJ, et al. The lateral pillar classification of Legg-Calvé-Perthes' disease. *J Pediatr Orthop* 1992;12:143.

TABLE 24-5 B/C Border Group

Very narrow lateral pillar (2–3 mm wide) >50% original height
Lateral pillar with little ossification but at least 50% original height
Lateral pillar that is exactly 50% of original height but depressed relative to central pillar

In analyzing the unexpectedly poor results in each category, Catterall (72, 197, 203, 245, 246) identified certain radiographic signs, known as *at-risk signs*, that were associated with poor results (Fig. 24-21). Results in untreated patients show that there were no poor results in patients who did not have two or more of the radiographic at-risk signs during the active stage of the disease. Radiographic at-risk signs include the Gage sign (a radiolucency in the lateral epiphysis and metaphysis) and calcification lateral to the epiphysis. These two signs are indicative of early ossification in the enlarged epiphysis. They are present only when the head is deformed. These signs are present when the changes are reversible with treatment (72, 247). A third at-risk sign is metaphyseal lesions. These metaphyseal radiolucencies may herald the potential for a growth disturbance of the physeal plate (160, 248, 249). The final two at-risk signs are lateral subluxation and a horizontal growth plate (250). Lateral subluxation is indicative of a widened head. A horizontal growth plate (adducted hip) is indicative of a developing femoral head deformity that, if left untreated, will lead to fixed deformity, hinge abduction, and subsequent further deformity. These radiographic at-risk signs are manifested clinically as loss of motion and adduction contracture. Catterall reported no poor results in patients who did not manifest at-risk signs. The validity of the Catterall classification and the at-risk signs has been confirmed by several series (236, 251–258), but questioned by others (207, 219, 238, 259).

Stulberg et al. (206) identified lateral and superior subluxation, which are indicative of significant growth disturbance and flattening of the femoral head, as the key factors associated with the development of class 3 and class 4 hips and poor long-term outcome (i.e., after 40 years). Disease onset after the age

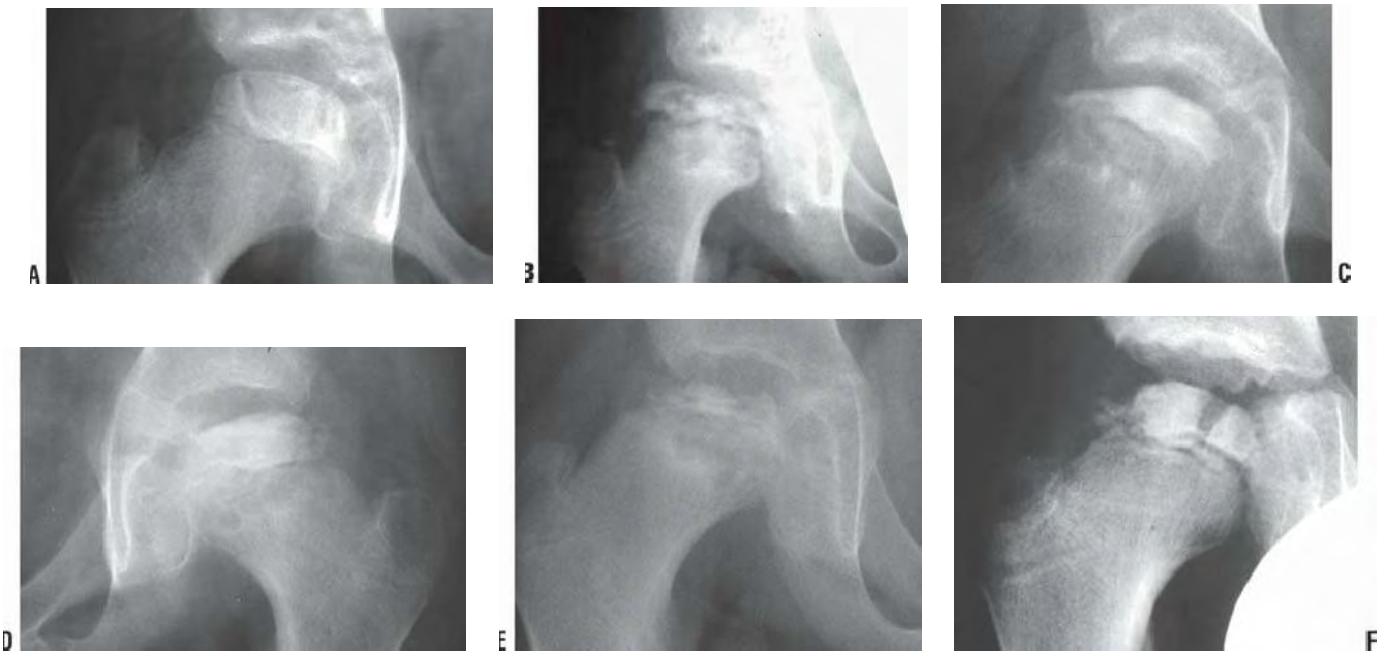


FIGURE 24-19. The lateral pillar classification. **A:** Lateral pillar A; **B:** Lateral pillar B; **C:** Lateral pillar C; **D–F:** B/C Boarder examples. (Reprinted from Herring JA, Kim HT, Browne R. Legg-Calvé-Perthes disease: part I: classification of radiographs with use of the modified lateral pillar and Stulberg classifications. *J Bone Joint Surg Am.* 2004;86(10):2103–2120, with permission.)

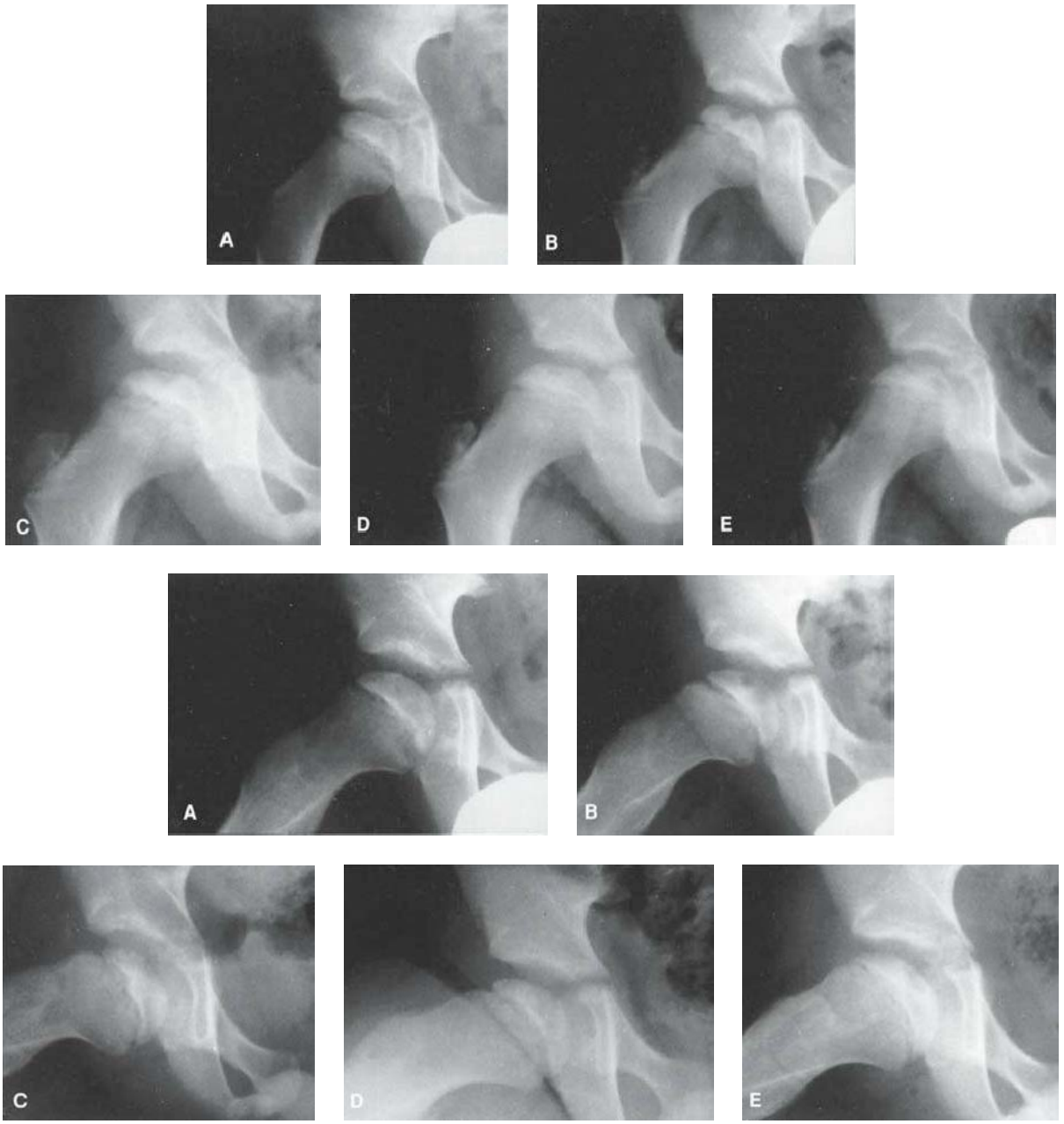


FIGURE 24-20. AP **(top, A–E)** and lateral **(bottom, A–E)** views of a 7-year-old boy who presented with hip pain and a limp. **A:** At presentation, the patient was in the initial radiographic stage of the disease; his prognosis was indeterminate. **B:** Six months after presentation, he had minimal loss of height of the lateral pillar and some radiolucency in that region, as well as significant bone resorption centrally. Note how the lateral pillar maintains its height throughout the course of the disease. One year **(C)**, 18 months **(D)**, and 3 years **(E)** after onset of disease. The patient had only mild symptoms on occasion and maintained good range of motion throughout the course of the disease. Only symptomatic treatment was provided.

of 9 years and partial femoral head involvement, particularly anterosuperior quadrant involvement, were associated with the development of a class 5 hip and the early onset of degenerative joint disease (i.e., third to fifth decade of life).

The duration of the disease is related to the extent of epiphyseal involvement. In general, the greater the extent of epiphyseal involvement, the longer the duration and course of the disease. End results are worse with prolonged disease duration (211, 219, 260, 261). The extent of epiphyseal involvement is also related to the sex of the patient in that girls affected by Legg-Calvé-Perthes syndrome have a poorer prognosis than boys (262, 263). This may be explained by the fact that there are more girls (who tend to be more skeletally mature than comparably aged boys, and hence have

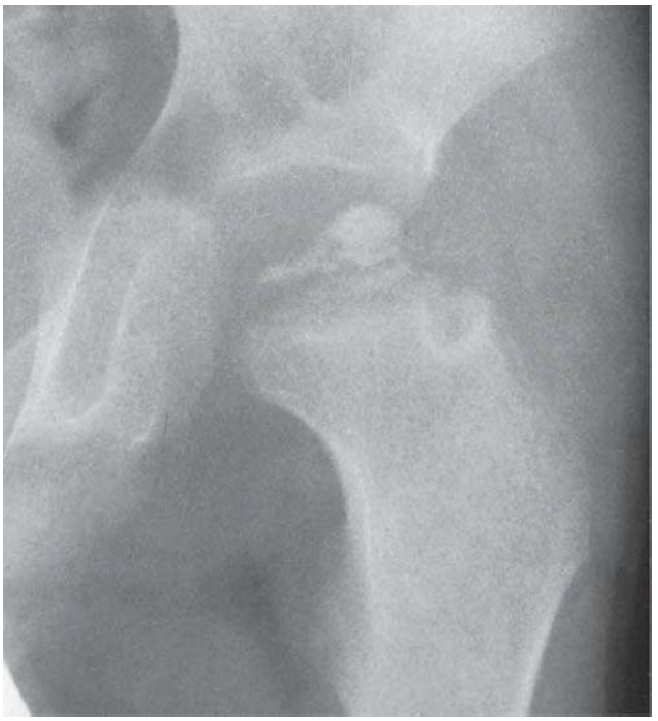


FIGURE 24-21. A boy, 6 years and 5 months of age, with Catterall group 4 disease demonstrates all of the at-risk signs: Gage sign, calcification lateral to the epiphysis, metaphyseal lesions, lateral subluxation, and horizontal growth plate.

less remodeling potential) with Catterall group 3 or group 4 disease, which are the groups associated with a less favorable prognosis (166, 264).

Age at onset of the disease is the second most significant factor related to outcome; only deformity is more significant. Eight years seems to be the watershed age in most long-term series (71, 193, 208, 264–267); however, some authors believe that the prognosis is markedly worse for long-term outcome in patients older than 6 years at the onset of the disease (217, 264). W.J. Cumming (personal communication, 1997) estimated that 45% of patients with onset of Perthes disease after the age of 6 years have undergone arthroplasty by age 60 years. Patients older than 11 or 12 years, even with Catterall group 2 or Salter-Thompson type A disease, may have poor anatomic and clinical results, even with treatment (268). Age at healing, however, is probably a more important factor (Fig. 24-11). The overall skeletal maturation delay (50) in patients with Legg-Calvé-Perthes syndrome, and the usual compensation for this delay during the pubertal growth spurt (52), contribute to the favorable prognosis in the young patient. The more immature the patient at the time of entering the reossification stage, the greater the potential for remodeling. At-risk signs are also less likely to occur in younger patients, particularly those younger than 5 years.

The key factor relating to outcomes, and therefore to the prognosis, is the shape of the femoral head and its relationships to acetabular shape (congruency) and joint motion. The shape of the acetabulum depends on the geometric pattern within it during growth (188, 269, 270). In addition, the acetabulum continues to have significant potential for development until the patient is 8 or 9 years of age (86, 88, 271). If a young patient develops a deformity of the proximal femur because of Perthes disease, the immature acetabulum conforms to the altered shape of the femoral head. This may lead to the development of an aspherical congruency (Stulberg classes 3 and 4) that may be compatible with normal function for many years. In older patients (whether "older" means older than 6 years or older than 8 years is subject to debate), the acetabulum cannot conform to the shape of a deformed femoral head; there is thus a greater chance of the development of an incongruous relation between the two, leading to early degenerative joint disease (206, 208–210, 217, 270, 272).

The importance of premature physeal arrest secondary to the disease process cannot be overemphasized. Keret et al. (189), in a study of 80 patients with Legg-Calvé-Perthes syndrome, showed interference with physeal growth in 90% of them, with 25% having premature physeal closure. They demonstrated a direct correlation between the severity of physeal involvement and deformity of the femoral head. Clarke and Harrison (273) reported that 47% of 31 patients who presented with painful hips after Legg-Calvé-Perthes syndrome, at an average age of 27 years, showed evidence of premature physeal closure.

Various methods have been used to measure the sphericity of the femoral head and congruency at healing. Goff (10, 53, 274) used a transparent protractor with concentric circles drawn at 2 mm of radial difference to evaluate the shape of the femoral head. Mose further developed Goff's method and applied it clinically. This is the most commonly used method of measuring sphericity (106, 275–277) (Fig. 24-16). It is not clear from the criteria of Mose whether the measurement under consideration is the difference between the outline of the femoral head on the AP and lateral radiographs, or the deviation from a given circle, measured in millimeters, on either the AP or the lateral radiograph, or a combination of these two parameters. This variability in the application of the method of Mose et al. is evident in the literature on Legg-Calvé-Perthes syndrome (253, 254, 278–283).

In general, the template with concentric circles is superimposed on the AP and lateral radiograms. In the author's practice, if the outline of the femoral head is a perfect circle in both projections, it is rated good; <2 mm of deviation is rated fair; and more than 2 mm of deviation from a circle, in the AP or lateral projection, is rated poor. Regardless of the measurements used, it is important to realize that, with growth and remodeling of the femoral head and acetabulum, the various parameters used for measuring head deformity and congruency may change.

The shape of the femoral head and its congruency, as measured at skeletal maturity, are probably the most reliable indicators of prognosis and the development of degenerative joint disease. Catterall (72) showed, in a follow-up of untreated patients, that 33% of the patients improved in anatomic grade. Twenty percent of these patients improved two anatomic grades; all of these patients were younger

than 5 years at the time of onset of the disease. However, it must also be remembered that the various deformities of the femoral head and anomalies in acetabular congruency are three-dimensional parameters that cannot be measured adequately on two-dimensional radiographs. Thus far, the only existing radiographic parameter that correlates with good clinical outcome is a perfectly spherical femoral head. Loss of sphericity by itself, however, does not necessarily lead to a poor long-term result (193, 195, 224).

Thompson and Westin (284) confirmed the work of Ferguson and Howorth (76), which demonstrated that after the femoral head is in the reossification stage of the disease, it will not deform further. If a treatment for femoral head deformity is to be successful, it must be instituted early in the course of the disease, that is, in the initial or fragmentation stage, hence the importance of radiographic staging of patients.

CLINICAL PRESENTATION

Patients with Legg-Calvé-Perthes syndrome most commonly present with a history of an insidious onset of a limp. Most patients do not complain of much discomfort, unless specifically questioned about this aspect. Pain, when present, is usually activity related and relieved by rest. Because of the mild nature of the symptoms, most patients do not present for medical attention until weeks or months after the clinical onset of disease. The pain is generally localized to the groin, or referred to the anteromedial thigh or knee region. Failure to recognize that the thigh or knee pain in the child may be secondary to hip pathology may cause further delay in the diagnosis. Some children present with more acute onset of symptoms. Seventeen percent of patients with Legg-Calvé-Perthes syndrome may have a history of related trauma (24, 27, 285).

PHYSICAL EXAMINATION

The child with Legg-Calvé-Perthes syndrome usually presents with limited hip motion, particularly abduction and medial rotation. Early in the course of the disease, the limited abduction is secondary to synovitis and muscle spasm in the adductor group; however, with time and the subsequent emergence of deformities, the limitation of abduction may become permanent. Longstanding adductor spasm occasionally leads to adductor contracture. The Trendelenburg test in patients with Legg-Calvé-Perthes syndrome is often positive. These children most commonly have evidence of thigh, calf, and buttock atrophy from disuse secondary to pain. This is additional evidence of the longstanding nature of the condition before detection (1–5, 274, 286). Limb length should be measured; inequality is indicative of significant collapse of the femoral head and a poor prognosis. Evaluation of the patient's overall height, weight, and bone age may be helpful in ruling out skeletal dysplasias or growth disorders in the differential diagnosis and may provide confirmatory evidence of the disorder. Laboratory studies are generally not helpful in Legg-Calvé-Perthes syndrome, although they may be necessary for ruling out other conditions (see section on differential diagnosis).

IMAGING

In Legg-Calvé-Perthes syndrome, plain radiographs taken in the AP and frog-leg lateral positions are used in making the initial diagnosis, and also for assessing the subsequent clinical course. These radiographs are generally sufficient for the assessment of the patient and subsequent follow-up evaluations. From the plain radiographs, the extent of epiphyseal involvement (e.g., Catterall groups 1 to 4; Salter-Thompson type A or B; lateral pillar type A, B, B/C Border, or C) and the stage of the disease (initial, fragmentation, or reossification) can be determined. According to Salter and Thompson (125), if appropriate radiographs are taken within 4 months of the clinical onset of the disease, the subchondral radiolucent zone will be detectable. Catterall, however, states that this sign is helpful in only 25% of the cases, because it is present only transiently in the early phases of the disease (72, 120). It is most important, while following the course of the disease, to view all radiographs sequentially and compare them with previous radiographs, so as to assess the stage of the reparative process and determine the constancy of the extent of epiphyseal involvement. Additional radiographic or imaging studies are rarely necessary but may be helpful in the initial assessment and also in the follow-up of the condition (287–289).

Radionuclide bone scanning with technetium and pinhole columnation (Fig. 24-22) may be helpful in the early stages of the disease, when the diagnosis is in question, particularly if the differential diagnosis is between transient synovitis and Perthes disease. Some investigators consider scintigraphy to be helpful in determining the extent of epiphyseal involvement and the prognosis (281, 290–299).

Magnetic resonance imaging appears to be sensitive in detecting infarction, but cannot yet accurately portray the stages of healing. Its role in the management of Perthes syndrome has yet to be defined. In the future, magnetic resonance imaging not only may help the clinician in the diagnosis but also may shed additional light on the underlying pathology of the condition (102, 295, 300–303) (Fig. 24-23).

Arthrography is useful primarily in demonstrating any flattening of the femoral head that may not be seen on plain radiographs (Fig. 24-24). It can be used to demonstrate the hinge abduction (Figs. 24-8, 24-25, and 24-26) phenomenon with abduction of the leg (170, 197, 198, 224, 304, 305). Arthrography, in conjunction with plain radiography or computed tomography, also may be useful in the diagnosis of osteochondritis dissecans secondary to Perthes disease. Arthrography is most useful for assessing the shape of the femoral head and its relation to the acetabulum, both of which are necessary for treatment decisions (Figs. 24-25 to 24-27). Where there is severe flattening of the femoral head, arthrography is helpful in determining containability before any treatment is started, whether it is Petrie casts or surgery. It is also useful in determining the best position of containment

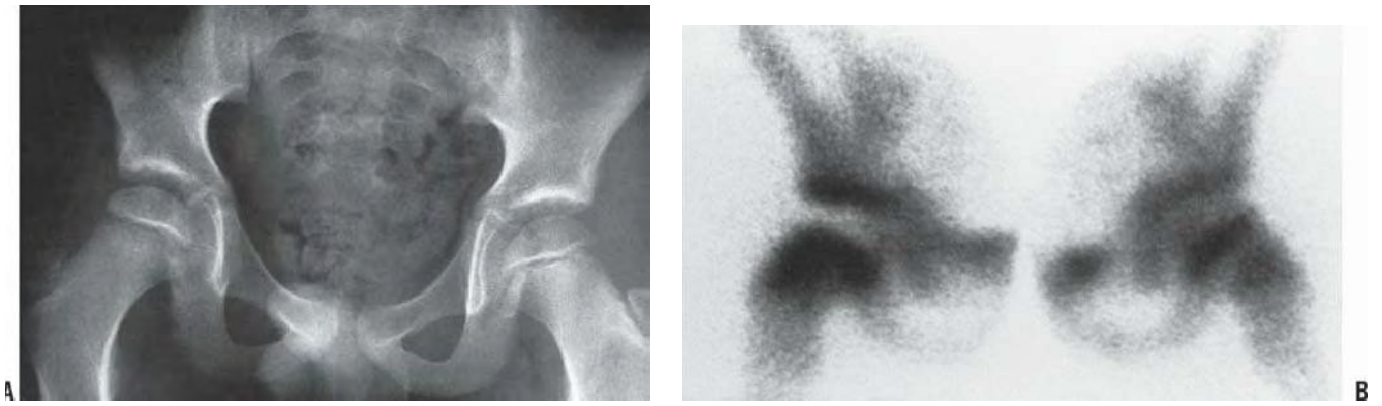


FIGURE 24-22. An 8-year-old boy with right hip pain. **A:** AP radiograph demonstrates a slight increase in width and medial joint space; the femoral ossific nucleus is slightly smaller than the one on the opposite side. **B:** Technetium 99 radionuclide scan demonstrates decreased uptake in the entire right femoral head, with increased vascularity in the neck.

(e.g., internal or external rotation and abduction or adduction) if surgical management is considered.

DIFFERENTIAL DIAGNOSIS

The history of the patient, physical examination, and plain radiographs are usually sufficient for making a diagnosis of Legg-Calvé-Perthes syndrome (Table 24-6). Diagnosis early in the initial phase of the disease requires that it be differentiated from conditions such as septic arthritis, whether primary or secondary to proximal femoral osteomyelitis, and toxic synovitis (306–308). A complete blood count including white cell differential, erythrocyte sedimentation rate, C-reactive protein, and hip joint aspiration and analysis of the fluid may be necessary in order to rule out infection. In patients with Legg-Calvé-Perthes syndrome, all laboratory results are usually normal except the erythrocyte sedimentation rate, which may be slightly elevated. In early cases, if all of the laboratory and plain radiographic studies are normal, but doubt regarding

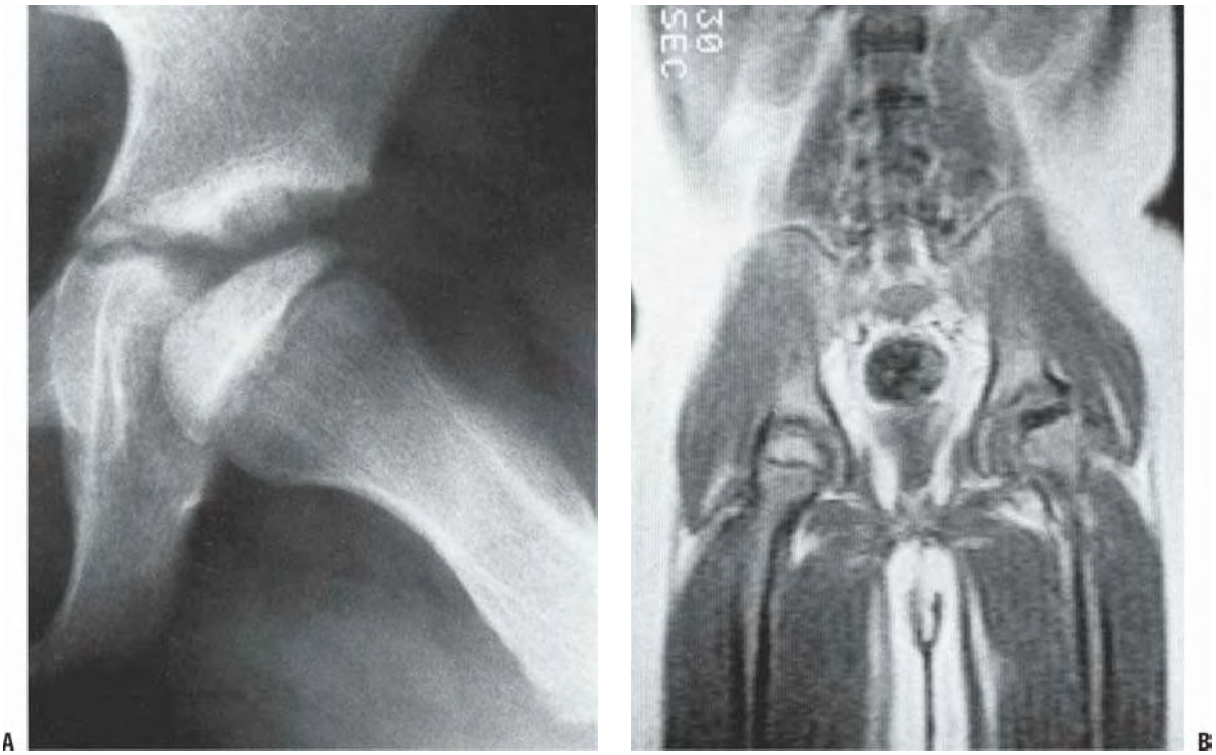


FIGURE 24-23. A 6-year-old boy with Catterall group 3 disease in the early fragmentation stage. **A:** Plain radiograph shows apparent sparing of the posterior head. **B:** Magnetic resonance image demonstrates a complete absence of signal on the affected side. (Courtesy of Peter Scoles, MD, Case Western Reserve Medical School, Cleveland, Ohio.)

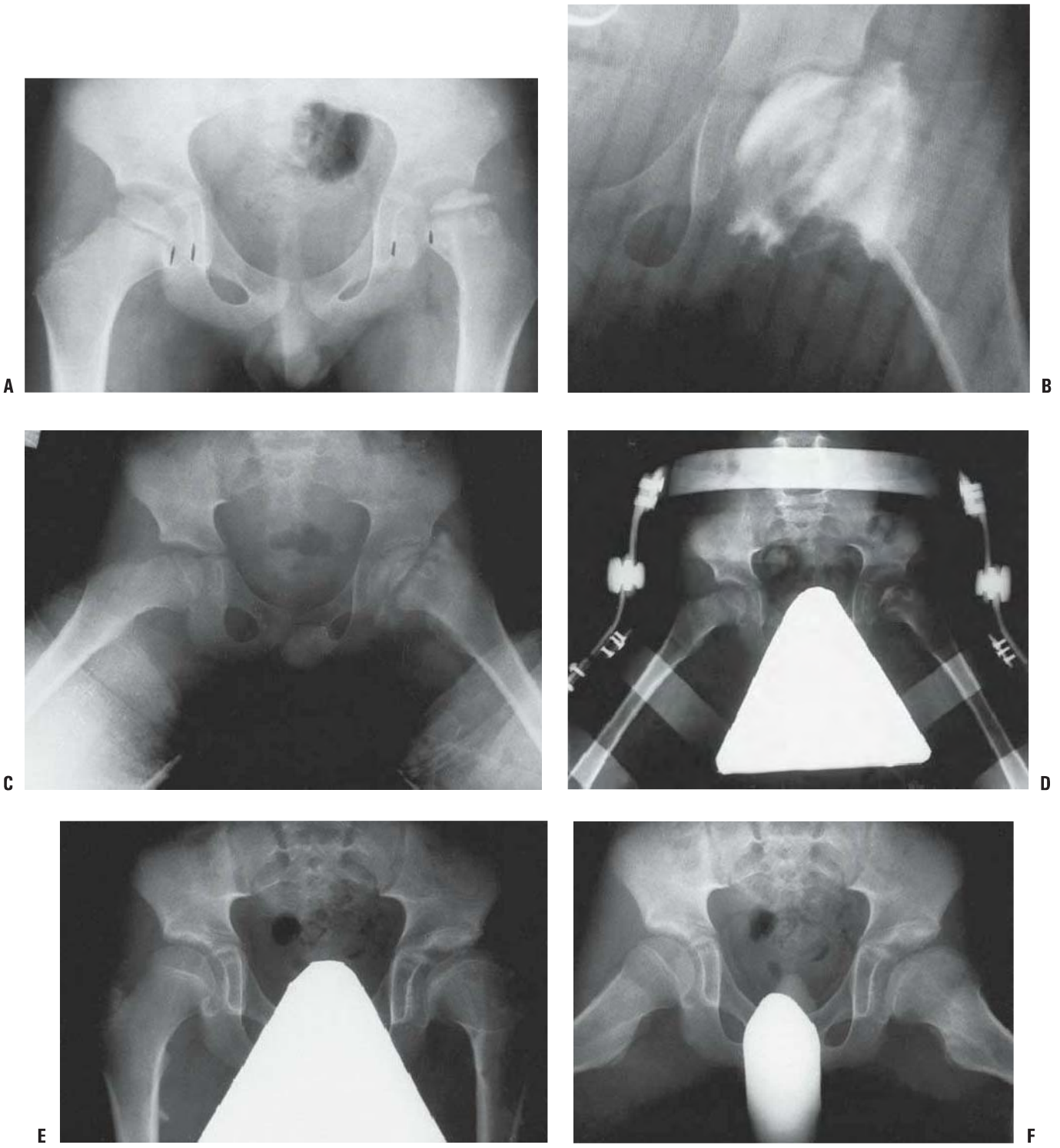


FIGURE 24-24. A 5-year-old boy with Catterall group 4 disease and at-risk status. **A:** AP radiograph on presentation. **B:** AP arthrogram, in the same position as in C, after 10 days of traction. Note the relation between the lateral acetabular margin and the lateral margin of the cartilaginous femoral head, as well as the severe flattening of the femoral head. **C:** AP radiogram in Petrie broomstick abduction plasters. The patient was maintained in casts for 6 weeks. **D:** AP radiograph with pelvis abduction orthosis (weight bearing). **E:** AP radiograph at age 13 years. Note residual deformity. **F:** Lauenstein radiograph at age 13 years.

the diagnosis persists, radionuclide scanning or magnetic resonance imaging may be helpful.

In patients with bilateral hip involvement, generalized disorders such as hypothyroidism and multiple epiphyseal dysplasia must be considered (309–311). In patients with bilateral involvement, particularly those with atypical radiographic features, care should be taken to obtain a detailed family history, measurements of height and weight should be recorded, and a bone survey should be done in order to rule out a metabolic or genetic condition (see Chapters 2 and 6). The possibility of Meyer dysplasia, a benign self-resolving condition, must be considered in children younger than 4 years of age (312, 313).

TREATMENT

For the past 80 years, many investigators (14, 15, 121, 184, 206, 314) have expressed a nihilistic attitude toward the role of therapy in this disease. Sundt (121) believed that treatment could not prevent degenerative joint disease. Because there is a paucity of long-term natural history data available, the question must be raised whether the outcome of Legg-Calvé-Perthes syndrome can be altered by any particular treatment. Although surgical management has become very popular today, long-term series of patients with uniform treatment, and matched for age, gender, stage, and extent of epiphyseal involvement, are necessary in order to determine the most effective treatment of Perthes syndrome.

Most patients (60%) with Legg-Calvé-Perthes syndrome do not need treatment (72, 125, 203, 237, 247, 315). Treatment must be considered only for those patients who have an otherwise known poor prognosis based on prognostic factors gleaned from long-term follow-up. It is difficult to formulate specific treatments for patients because the natural history of the condition is not well known. Also, most studies of current treatment methods lack interobserver and intraobserver reliability as regards classifications of the extent of epiphyseal involvement and outcome measures, and all the studies lack control groups. These factors, and other variables that exist in most series, make it difficult to support a "best" method of treatment.

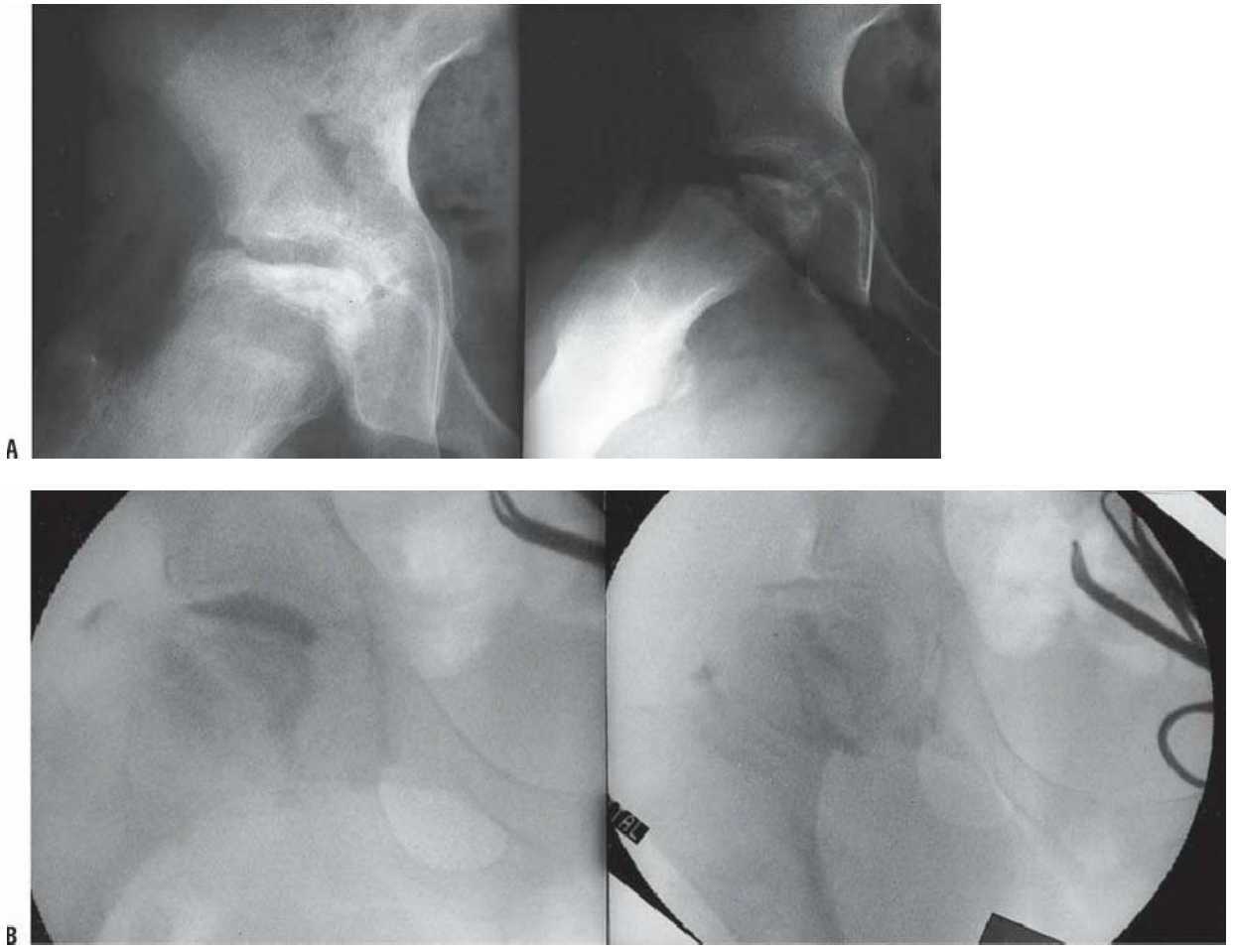


FIGURE 24-25. An 11-year-old girl with Catterall group 4 Perthes disease. The range of motion of the hip showed marked restriction of abduction (20 degrees) and rotation (10 degrees internal and external). All movement was painful. **A:** Preoperative AP **(left)** and Lauenstein **(right)** views. **B:** Intraoperative arthrograms demonstrating hinging on the lateral aspect of the acetabulum in abduction **(left)** with good congruity in adduction **(right).** *(Continued on next page)*

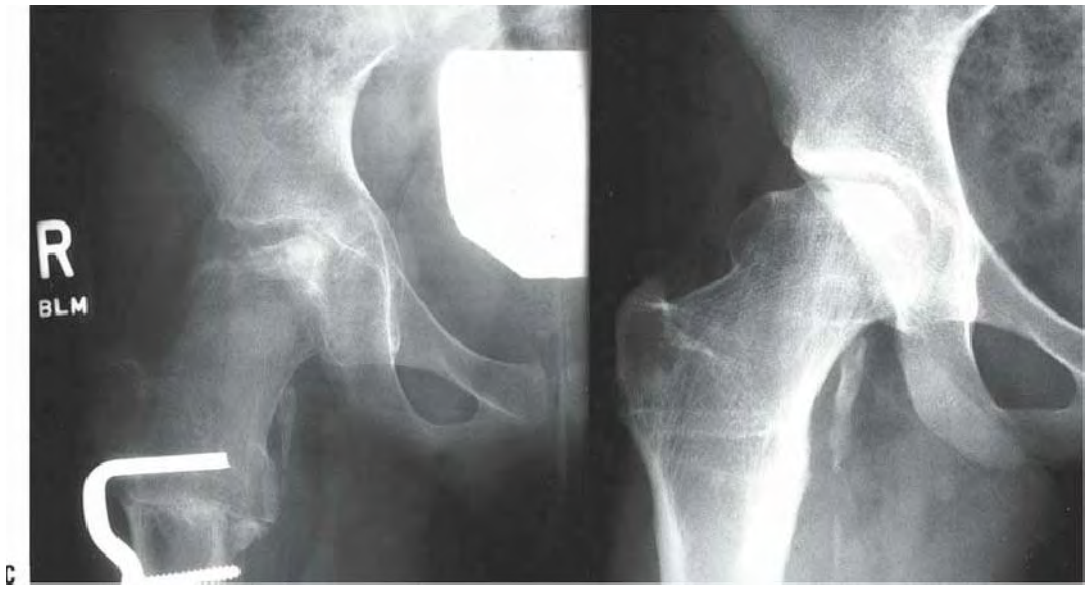


FIGURE 24-25. (*continued*) **C:** Six-month **(left)** and 7-year **(right)** follow-ups after abduction osteotomy. At 7-year follow-up, the patient was free of pain, with 40 degrees of abduction, 20 degrees of adduction, flexion to 130 degrees, and 20 degrees of internal and external rotation. She has been pain free since her surgery.

Standard treatment algorithms are based on radiographic features of the various disease classification schemes. Under these protocols, no treatment is warranted in patients with a good prognosis (i.e., those with Catterall group 1, Salter-Thompson type A, or lateral pillar type A disease) (Table 24-7). Patients with a poor prognosis should be considered for treatment. These would include patients with Catterall groups 3 and 4 disease, Salter-Thompson type B disease, and lateral pillar type C disease. There is another large group of patients whose prognosis is indeterminate; these patients require careful follow-up, because they may need treatment at a later date. This group includes patients with Catterall group 2 disease (good prognosis in 90% of cases), patients with lateral pillar type B disease, and some B/C border patients. Because we have learned that the two major prognostic factors in outcome are deformity of the femoral head and age of the patient, these two factors must be taken into account in the decision-making process. Patients with deformity (arthrographically and/or clinically documented by persistent loss of motion, particularly abduction) younger than 8 years should be considered for treatment. Patients older than 8 years, especially girls, should be considered for treatment even in the absence of deformity. In the absence of treatment, such patients have a poor prognosis (71, 267, 316) because their growth potential is insufficient for any deformity of the proximal femur to be compensated for by a corresponding change in the shape of the acetabulum.

All patients should be treated if they manifest clinical at-risk signs (i.e., if they lose range of motion and have pain), or if they demonstrate several of the radiographic at-risk signs regardless of the extent of epiphyseal involvement. If the patient is already in the reossification or healing stage of the disease, little further deformity ensues, and no treatment is indicated unless the patient has symptoms (see the section *Treatment Options in the Noncontainable Hip and the Late-presenting Patient with Deformity* later in this chapter).

The earliest treatment methods used weight relief until the femoral head was reossified. These methods were based on the premise that weight relief would prevent the mechanical deformation of the head and early degenerative joint disease (89, 317–319). These modalities included prolonged, strict bed rest, often in the hospital, and bed rest with or without various periods of traction on special frames or in spica casts. These methods of treatment were associated with disuse atrophy of muscles, osteopenia, shortening of the involved extremity, loss of thoracic kyphosis, urinary calculi, social and emotional problems, and high hospital costs (167, 215, 216, 278, 320–327).

The concept of weight relief as a treatment for Legg-Calvé-Perthes syndrome was challenged as early as 1927, when Legg stated that, "while the process suggesting weakness of bone structure is going on it is theoretically sound to allow no weight bearing but in practice relief from weight bearing in no way affects the end results" (328). In addition, prolonged immobilization and bed rest do not influence the radiographic course of the disease (237, 256, 258, 329–331). Harrison and Menon (324) pointed out, as had Pauwels and others (167, 332, 333), that even at rest or during minimal activity significant forces act on the femoral head.

The cornerstone of treatment for Legg-Calvé-Perthes syndrome is referred to as *containment*. This concept was originally described by Parker (324) and Eyre-Brook (318). The rationale for this concept has been defined further by

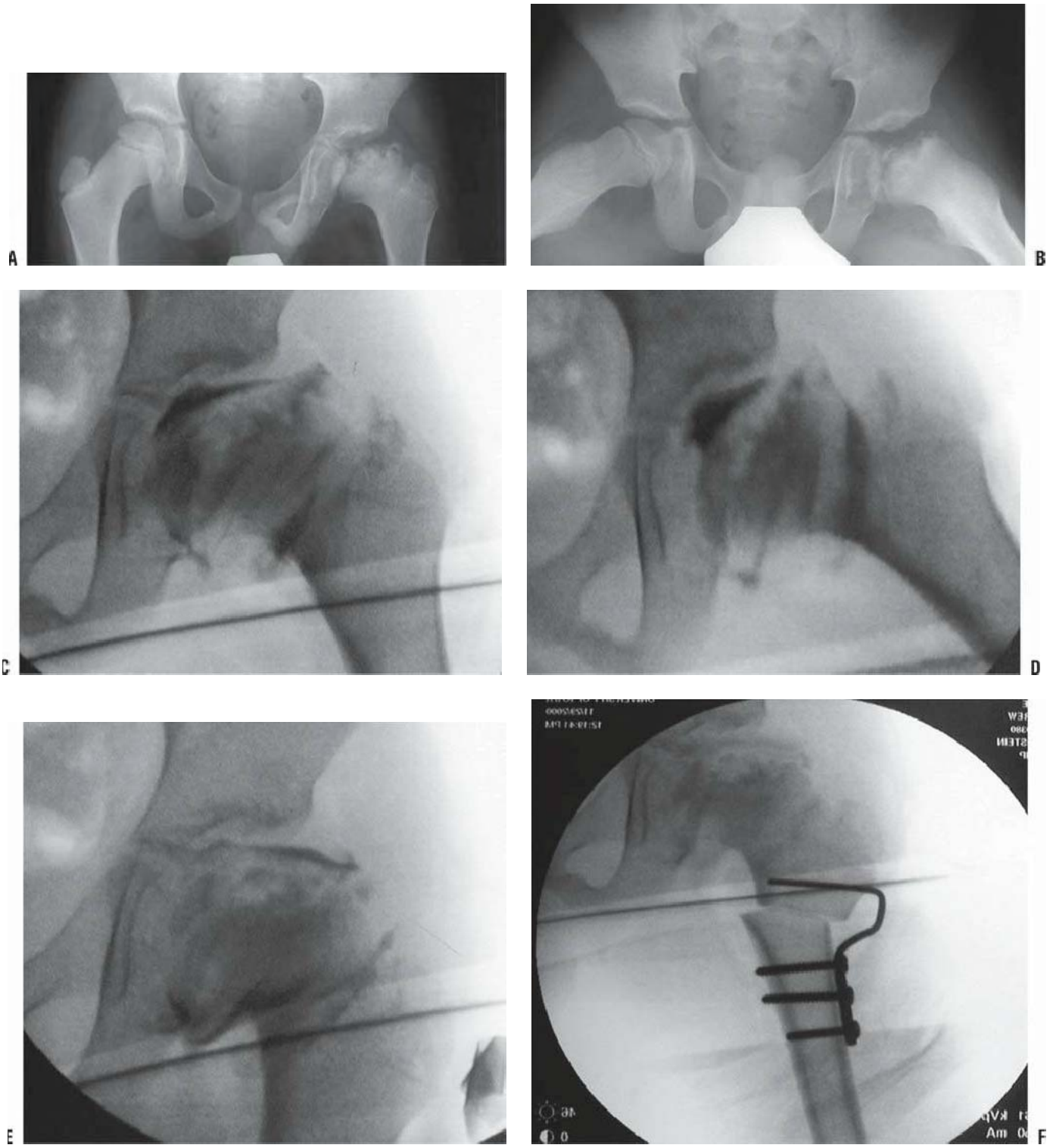


FIGURE 24-26. A 9-year-old boy presenting with hip pain, nonresponsive to nonsurgical measures. Clinical abduction is to 10 degrees; adduction is to 40 degrees with the hip in extension. **A:** Anteroposterior view of pelvis showing total femoral head involvement in reossification stage of disease. **B:** Lauenstein view. **C:** Arthrogram in neutral position showing considerable flattening of femoral head and slight impingement on lateral edge of the acetabulum. **D:** Arthrogram in abduction demonstrating hinge abduction. **E:** Arthrogram in adduction demonstrating reasonable congruity between femoral head and acetabulum; note normal contour of lateral acetabular edge. **F:** Abduction osteotomy allowing 45 degrees of abduction and 0 degree of adduction. (*Continued on next page*)

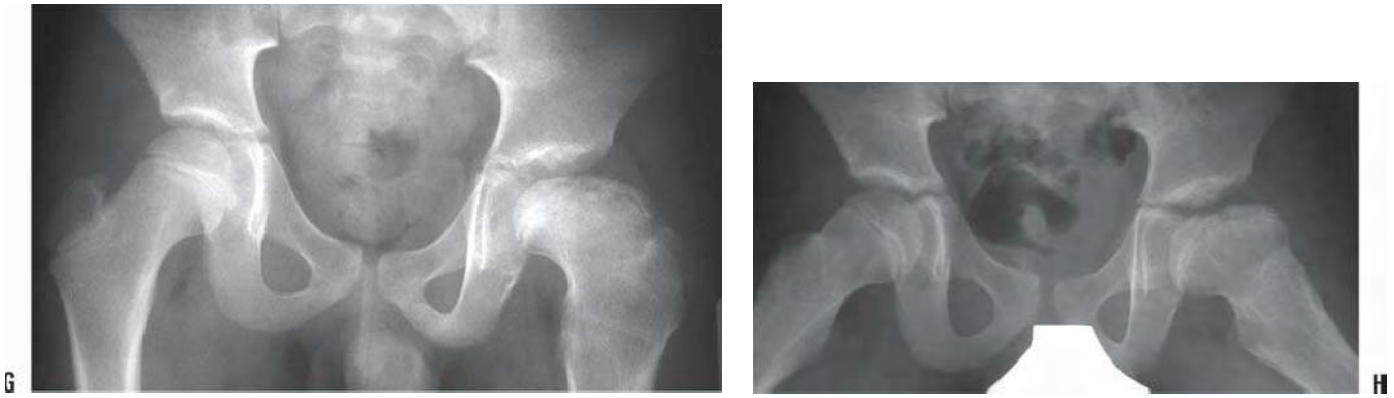


FIGURE 24-26. (*continued*) **G:** Three years postoperatively. Patient is pain free with 45 degrees of abduction, 10 degrees of adduction, and good rotation. **H:** Lauenstein view 3 years postoperatively.

Harrison and Menon (324), Petrie and Bitenc (279), Salter (124, 334), and others (335–340). The essence of containment is that, in order to prevent deformities of the diseased epiphysis, the femoral head must be contained within the depths of the acetabulum, thereby equalizing the pressure on the head and subjecting it to the molding action of the acetabulum. Containment is an attempt to reduce the forces through the hip joint by actual or relative varus positioning (341). Containment may be achieved by nonoperative or operative methods (342). The femoral head represents more than three-fourths of the sphere and the acetabulum only half of the sphere. Therefore, no method of containment can provide for a totally contained femoral head within the acetabulum during all portions of the gait cycle (156, 339, 340, 343).

Management of the Patient. The primary goals in the treatment of Legg-Calvé-Perthes syndrome are to prevent deformity (Stulberg classes 3, 4, and 5) and stop growth disturbance, thereby preventing degenerative joint disease. Attainment of these goals requires that each patient be assessed clinically and radiographically. Clinically, the patient is evaluated for clinical at-risk signs such as loss of motion, contracture of the joint, and pain. AP and frog-leg lateral radiographs are evaluated so as to determine the radiographic stage of the disease, the extent of epiphyseal involvement

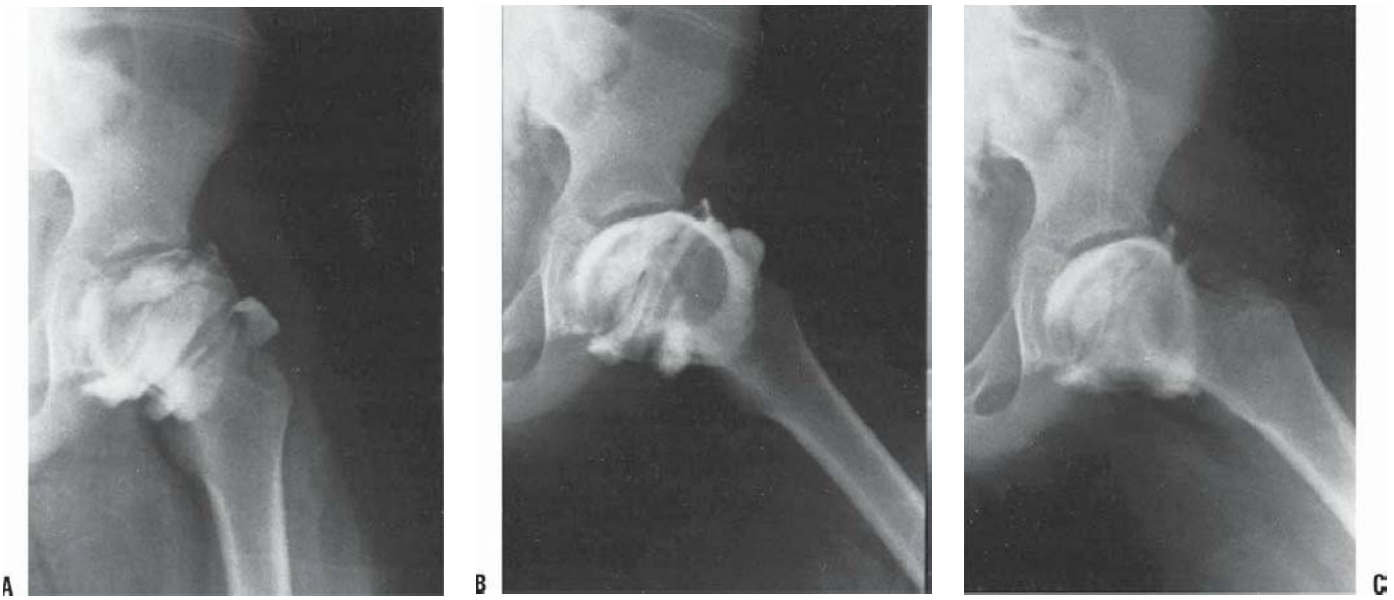


FIGURE 24-27. Arthrogram of a 6-year-old boy with Catterall group 4 disease. **A:** Neutral position. **B:** Abduction, external rotation, and slight flexion (the position that would be maintained by an abduction Scottish Rite-type orthosis). **C:** Abduction and internal rotation (the position that would be maintained by a varus derotation osteotomy or innominate osteotomy).

TABLE 24-6 Differential Diagnosis

Chondrolysis
Gaucher disease
Hemophilia
Hypothyroidism
Juvenile rheumatoid arthritis
Lymphoma
Mucopolysaccharidosis
Multiple epiphyseal dysplasia
Meyer dysplasia
Neoplasm
Old congenital dysplasia of the hip residuals
Osteomyelitis of the proximal femur
Septic arthritis
Sickle cell disease
Spondyloepiphyseal dysplasia
Toxic synovitis
Traumatic aseptic necrosis

TABLE 24-7 Treatment of Legg-Calvé-Perthes Disease

Poor prognosis group: treatment indicated
- Catterall 3 and 4
- Salter-Thompson B
- Lateral pillar C
- At risk clinically
- At risk radiographically, regardless of the disease extent
- Age <8 yr with deformity
- Age >8 yr (Catterall groups 2, 3, and 4, with or without at-risk signs; lateral pillar B and C; Salter-Thompson B), with or without head deformity

Good prognosis group: no treatment necessary
- Catterall 1 and 2 (generally good prognosis in 90% of cases)
- Salter-Thompson A
- Lateral pillar A

Indeterminate prognosis group: may require treatment
- Catterall 2
- Lateral pillar B
- B/C border

In reossification stage: may require treatment.

(Catterall group, Salter-Thompson type, or lateral pillar classifications), and the presence of radiographic at-risk signs. If treatment is to succeed in controlling subsequent deformity, it should be initiated in the initial or fragmentation phase of the disease (76, 284).

Treatment is not indicated if the child demonstrates none of the clinical or radiographic at-risk signs; if he or she has Catterall group 1 or 2, Salter-Thompson type A, or lateral pillar type A disease; or if the disease is already in the reossification stage. A child who demonstrates clinical or radiographic at-risk signs regardless of the extent of epiphyseal involvement should receive treatment (286). Even patients with Catterall group 2 disease (or lateral pillar type B disease) who are at risk may have poor results without treatment (72) (W.J. Cumming, personal communication, 1997).

The first principle of treatment regardless of the definitive method of treatment chosen is restoration of motion. Motion of the joint enhances synovial nutrition and cartilage nutrition (344, 345). This tenet of treatment cannot be overemphasized. The series that recorded the greatest success in treating patients for extensively involved femoral heads is that of Brotherton and McKibbin (335). These patients were treated with bed rest and containment. The end results in these patients were superior to those in another long-term study of patients treated with bed rest and containment on a frame (215, 216). The only difference between the two treatment regimens was that in the former series motion was always maintained. Restoration of motion can be accomplished by bed rest alone, or with skin traction and progressive abduction to relieve the muscle spasms. The author recommends bed rest at home with nonsteroidal anti-inflammatory drugs on a round-the-clock basis and then reassessment in 1 week to assure that range of motion has considerably improved (to at least 45 degrees of abduction). Occasionally, surgical release of the contracted adductors may be necessary. Restoration of motion allows abduction of the hip, which reduces the forces on the hip joint and allows positioning of the uncovered anterolateral aspect of the femoral head in the acetabulum. Mobilization of the hip joint can also be achieved by rest followed by the use of progressive abduction plasters to stretch the hip adductor muscles while allowing hip flexion and extension. A full or almost full range of motion is usually obtainable within 7 to 10 days of treatment. Because of early deformity, complete abduction and internal rotation may not always be obtainable. Persistence of an adduction contracture is always associated with a serious femoral head deformity and will not respond to bed rest or to bed rest with traction (145). Arthrography is a useful adjunct in determining whether the femoral head actually can be contained and, if so, in what position this is best accomplished (346) (Fig. 24-27). Arthrography can reveal any flattening of the femoral head that may not be seen on plain radiographs. More importantly, it can demonstrate the hinge abduction phenomenon (197, 198, 224, 304) (Figs. 24-24, 24-25, and 24-26). Demonstration of the hinge abduction phenomenon, or the inability to contain the hip, is a contraindication to any type of containment treatment. Serious damage to the femoral head and acetabulum may result from trying to contain a noncontainable head (Fig. 24-14). Arthrography should be performed under general anesthesia. This also provides an opportunity to examine whether muscle spasm, contracture, or mechanical deformity is responsible for any apparent fixed deformities.

The treatment for Legg-Calvé-Perthes syndrome remains controversial, and there is disagreement regarding whether operative or nonoperative treatment is more beneficial. Although operative treatment is becoming increasingly popular, there is considerable debate about the benefits of each operative procedure. The shortage of natural history studies for comparison of the results of different modalities of treatment is another reason for the difficulty in resolving this controversy. In addition, the variability of criteria for inclusion of patients in studies, the use of different measurements to assess outcomes of treatment, the lack of interobserver and intraobserver reliability data, and the lack of untreated control groups make comparisons difficult.

In the earlier editions of this book, considerable space was devoted to describing the use of abduction bracing in the treatment of Perthes disease. Over the years, this modality has been replaced by more promising surgical interventions and is now rarely used by pediatric orthopaedic surgeons. It is mentioned in this edition for the historical perspective of the evolution of methods of treatment. Today the most widely used methods to maintain containment are femoral osteotomy, innominate osteotomy, and the use of a procedure earlier regarded as a salvage procedure, namely, lateral shelf acetabuloplasty. There is also growing interest in combined femoral and innominate surgical procedures.

Nonoperative Treatment (Historical Review). In 1971, Petrie and Bitenc (279) reported excellent results from applying the principles of containment, using broomstick abduction with long-leg plasters (Fig. 24-24C). This series proved that weight bearing, with the femoral head contained, was not harmful. This method of treatment allows for weight bearing and maintenance of range of motion of the hip in the contained position. Successful results of this technique have been reported (347). Petrie casts are currently used by some surgeons after muscle-release procedures and capsulotomies for reducing femoral heads that are deformed and subluxated (348), or for maintaining containment after surgical treatment.

To avoid the repeated hospitalizations necessary for regaining knee and ankle motion, and to avoid the occasional flattening of the femoral condyles seen in patients treated with broomstick plasters, orthopaedists turned to the use of removal abduction orthoses, as typified by the Newington abduction brace (278), the Roberts orthosis (349), the Houston A-frame brace (350), and the Toronto Legg-Calvé-Perthes orthosis (176, 351). These devices provide containment in the abducted internal rotation position.

The most widely used abduction orthosis was the Atlanta Scottish Rite orthosis or a modification thereof (Fig. 24-28). These devices were thought to provide for containment solely by abduction without fixed internal rotation (280, 283, 352, 353). They allowed free motion of the knee and ankle. Containment was provided by the abduction of the brace and the hip flexion required for walking with the legs in abduction. These devices are less cumbersome than other braces and are well tolerated by patients. On arthrography, the position of containment that would be maintained by an abduction orthosis of this variety would be demonstrated by abduction, slight flexion, and external rotation (Fig. 24-27). Containment had to be demonstrated on a radiograph, with the patient in the weight-bearing position and in the brace (Fig. 24-24). The brace was worn on a full-time basis until the femoral head was in the reossification stage, when there was no further risk of collapse. Full-time bracing ranged from 6 to 18 months. The negative aspects of bracing included prolonged treatment times and the need for compliance on the part of the patient. Some patients did not tolerate the brace for psychological reasons (354). This type of treatment was also difficult for girls and older patients to accept (355).

Although early radiographic anatomic results were comparable with those of previously used containment weight-bearing methods (280, 353), follow-up reports of patients treated with these orthotic devices questioned the efficacy of this method of management (238, 356, 357). Martinez et al. (238) reported on 31 patients (34 hips) with severe Perthes disease (Catterall groups 3 and 4) that had been treated with weight-bearing abduction orthoses. The mean age of the patients when first seen was 6 years, and the mean duration of follow-up was 7 years. At follow-up, applying the Mose criteria, no hip had a good result, 35% had fair results, and 65% had poor results. On the basis of the classification of Stulberg et al., there were 41% class 2 results, 53% class 3 and 4 results, and 6% class 5 results. With respect to the lateral column, of the 20 hips in which collapse occurred, only 10% had Stulberg class 2 results, 35% had class 3 results, 45% had class 4 results, and 10% had class 5 results. By comparison, in the 14 hips in which collapse of the lateral column did not occur, 86% had Stulberg class 2 results and only 14% had class 3 results. Class 4 or 5 results were not found in hips in which a collapse did not occur. The authors concluded that although containment is the most widely accepted principle of treatment of Legg-Calvé-Perthes disease, little clinical information supports the contention that bracing in abduction and external rotation, as provided by the Atlanta Scottish Rite orthosis and its modifications, is effective.

Meehan et al. (356) reported on 34 patients with Catterall group 3 or 4 disease, with an average age at diagnosis of 8 years. The average follow-up duration in this series was 6 years and 9 months. At follow-up, there were no Stulberg class 1 results, 3 class 2 results, 24 class 3 results, 6 class 4 results, and 1 class 5 result. The same investigators also arrived at a similar conclusion concerning the use of this orthotic device in the treatment of Perthes disease. In both of these studies, the issue of compliance is not documented, and as with all studies of Perthes disease in the literature, control groups other than historic controls are absent. Because the radiographic outcomes in both of these studies were poor, it

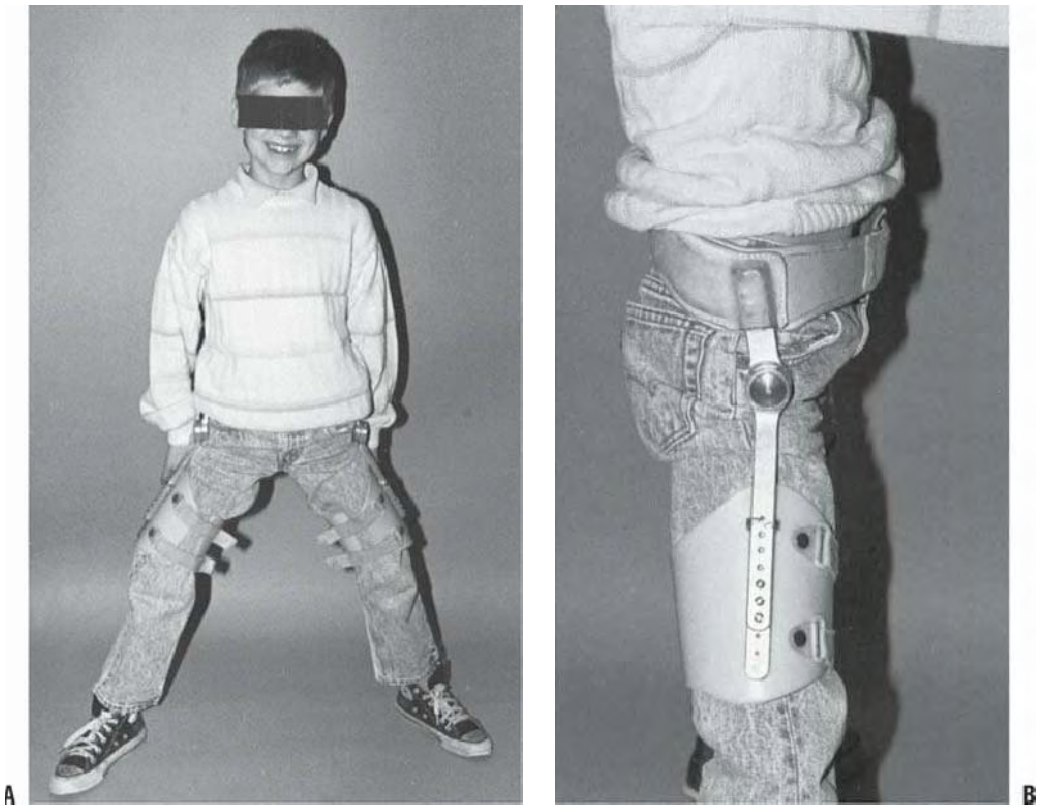


FIGURE 24-28. **A, B:** An abduction orthosis.

is questionable whether the orthosis itself adds anything to the treatment other than maintenance of range of motion. As expected, most patients with Perthes disease in both series were doing well clinically, as do most patients over the short term regardless of the extent of the deformity. The long-term prognosis for all but the Stulberg class 1 and 2 hips is guarded (358).

In the light of these results, bracing is rarely used today by pediatric orthopaedic surgeons in the treatment of Perthes disease. Because of the nihilistic attitude that many physicians share with regard to treatment for Perthes disease, they have begun treating patients with only maintenance of range-of-motion programs, including stretching exercises, nighttime abduction splinting, home traction, and other combinations. Long-term follow-up studies of these nonoperative range-of-motion regimens are needed in order to determine their efficacy.

Surgical Treatment. Surgical methods of providing or maintaining containment are advocated by many investigators. Surgical containment methods offer the advantage of early mobilization and the avoidance of prolonged bracing or cast treatment. In addition, no end point for discontinuing treatment is required (348). Surgical containment may be approached from the femoral side, the acetabular side, or both sides of the hip joint. Procedures used for obtaining or maintaining containment in Legg-Calvé-Perthes syndrome are those that were originally used in the treatment of problems associated with developmental hip dysplasia and dislocation. The discussion that follows relates only to hips that are "containable" (relatively full range of motion, congruency between the femoral head and the acetabulum) and in the initial or fragmentation phase of the disease.

Varus Osteotomy. Varus osteotomy, with or without associated derotation, offers the theoretical advantage of deep seating of the femoral head and positioning of the vulnerable anterolateral portion of the head away from the deforming influences of the acetabular edge (127, 145, 247, 359–361). The varus position reduces the forces exerted by the joint on the femoral head (341, 359). This procedure is thought to relieve the intraosseous venous hypertension and improve the disturbed intraosseous venous drainage reported in Legg-Calvé-Perthes syndrome, thereby speeding the healing process (127, 128, 153, 358, 359, 362–364). A number of investigators disagree with these perceived benefits (365–367). (For technique see Chapter 23.)

Prerequisites for varus derotation osteotomy include a full range of motion, congruency between the femoral head and the acetabulum, and the ability to contain the femoral head in the acetabulum in abduction and internal rotation (348, 368) (Fig. 24-27). This assessment usually requires arthrography if the femoral head is well into the fragmentation phase. The procedure must be performed early, in the initial or fragmentation stage of the disease, in order to have any effect on later femoral head deformity (186, 231, 359).

The negative aspects of this treatment modality must be considered. Varus osteotomy, with or without derotation, usually requires the use of internal fixation and external mobilization in plaster for 6 weeks. The patient must incur the inherent risks and costs associated with at least one surgical procedure and most likely a second surgical procedure for hardware removal. The limb is temporarily shortened by the procedure. The varus angle must not exceed a neck-shaft angle of <110 degrees. The varus angle generally decreases with growth (197, 369, 370); however, if there has been physeal plate damage secondary to the disease, this remodeling potential may be lost, and the patient may have permanent shortening and temporary or permanent weakness of the hip abductors (153, 370–374). The proponents of varus osteotomy, with or without derotation, report 70% to 90% satisfactory anatomic results using this method (127, 153, 231, 358, 359, 362, 371, 373, 375–385).

Innominate Osteotomy. Innominate osteotomy provides for containment by redirection of the acetabulum, providing better coverage for the anterolateral portion of the femoral head. The femoral head is placed in relative flexion, abduction, and internal rotation with respect to the acetabulum in the weight-bearing position. Any shortening caused by the disease can be corrected (124, 348, 368, 373, 386–391). Prerequisites for innominate osteotomy include restoration of a full range of motion, a round or almost round femoral head, and congruency of the joint, demonstrated arthrographically. Treatment must be performed early in the course of the disease, and the head must be well seated in flexion, abduction, and internal rotation. (For technique see Chapter 23.)

Innominate osteotomy is performed in a fashion similar to that for residual hip subluxation. The tendinous portion of the iliopsoas muscle is always released at the musculotendinous junction, and any residual contractures of the adductor muscles are released by subcutaneous adductor tenotomy (124, 348). The osteotomy is fixed by two or three threaded pins for internal fixation. Partial weight bearing may be resumed in a cooperative child several days after surgery; however, in an uncooperative patient, immobilization in a spica cast for 6 weeks is required.

The disadvantages of innominate osteotomy are the associated risks and cost factors of the surgical procedure and the procedure for pin removal. Additionally, the operation is performed on the normal side of the joint. This procedure may increase the forces on the femoral head by lateralizing the acetabulum and increasing the lever arm of the abductors (359), although this supposition has so far not been substantiated. Innominate osteotomy may also cause a persistent acetabular configuration change where there was a previously normal acetabulum, leading to loss of motion, particularly flexion (392). Satisfactory anatomic results from this procedure range from 69% to 94% (348, 373, 387–389, 393–397). There is significant biomechanical evidence to show that neither method of surgical containment, innominate or femoral osteotomy, may effectively shield an extensively necrotic segment of the femoral head from stress (339, 340, 398, 399). Wenger (22) reported a high incidence of complications in surgically treated patients, even when the accepted methods were used and prerequisites were met.

Varus Osteotomy Plus Innominate Osteotomy. Several short-term results of combined varus osteotomy plus innominate osteotomy have been reported in patients with severely involved Catterall group 3 or 4 disease. This combined procedure has the theoretical advantage of maximizing femoral head containment while avoiding the complications of either procedure alone. The femoral osteotomy directs the femoral head into the acetabulum, while theoretically reducing any increasing pressure or stiffness of the joint that would result from the pelvic osteotomy. The coverage provided by the innominate osteotomy reduces the degree of correction needed from the femoral osteotomy, thereby minimizing the complications of excessive neck-shaft varus, associated abductor weakness, and limb shortening. Advocates of this procedure also believe that permanent correction of the deformity, early weight bearing, and shortened treatment time are obtained. The disadvantages of the procedure include those mentioned for varus osteotomy and innominate osteotomy alone. Surgical time is increased, potential blood loss is magnified, and the combined procedures are technically more difficult. Satisfactory anatomic results from this combined procedure are reported in up to 78% of patients. As would be expected in short-term follow-up, the clinical results are excellent (400–404). The prerequisites for this operation include those for both varus and innominate osteotomies, in a patient who probably would not achieve satisfactory coverage from either procedure alone.

Shelf Arthroplasty. Recently, shelf arthroplasty has been proposed as a primary method of management in children older than 8 years with Catterall group 2, 3, or 4 disease with or without at-risk signs, lateral pillar type B or C disease, and Salter-Thompson type B disease; if subluxation is present, it must be reducible on a dynamic arthrogram (316, 405) (see Fig. 24-42). Contraindications include hips that

do not meet the aforementioned criteria and the presence of hinge abduction. Only one intermediate-term follow-up study exists, but proponents of this method of treatment believe that containment of the femoral head by shelf arthroplasty, before significant deformity can develop, improves remodeling of the femoral head (316, 406, 407). The shelf procedure may cover the anterolateral portion of the head, preventing subluxation and lateral overgrowth of the epiphysis. Risk factors for poor results with this technique are age older than 11 years, female gender, and Catterall group 4 disease. (For technique see Chapter 23.)

Triple Innominate Osteotomy. Reports of the use of triple innominate osteotomy to treat Perthes disease have begun to surface in the literature (408, 409). This procedure, originally introduced for the treatment of developmental hip dysplasia, is theoretically better able to cover the deforming femoral head. Only longer follow-ups will let physicians know if this will offer better long-term results compared with more commonly applied osteotomies. (For technique see Chapter 23.)

Arthrodiastasis. Recently, reports have been published advocating the use of hip distraction (arthrodiastasis) for periods of 4 to 5 months, with or without soft-tissue release, in older children with Perthes disease (410, 411). The author has concerns about the effect of pin tract contamination on the future outcome of total hip replacement in patients treated by this technique. A judgment about the usefulness of these procedures will have to await further follow-up.

Regardless of the method of containment chosen, any episode indicative of loss of containment, such as recurrent pain or loss of range of motion, must be treated aggressively with rest, traction, and reassessment of containment clinically and possibly radiographically.

Treatment Options in the Noncontainable Hip and the Late-Presenting Patient with Deformity.

Patients presenting with deformity in the later stages (reossification) of the disease, those with noncontainable deformities, and those who have lost containment after undergoing either surgical or nonsurgical containment procedures present a management challenge. These patients usually demonstrate hinge abduction on arthrography and have an extremely poor prognosis without additional treatment (193, 208, 209, 246, 348, 412). They generally present with persistent pain, shortening of the involved extremity, and a fixed deformity, generally 10 to 15 degrees of fixed flexion and 15 to 20 degrees of fixed adduction (246, 412). The salvage procedures to be considered at this point include abduction extension osteotomy (246, 348, 377, 379, 380, 412–415), lateral shelf arthroplasty, Chiari osteotomy, and cheilectomy. These procedures must be viewed as salvage procedures, with each having specific limited aims, which may include pain relief, correction of limb-length inequality, increasing femoral head coverage, improvement in movement of the joint, and strengthening of a weak abductor (412).

Abduction Osteotomy (Figs. 24-28 to 24-35). In patients in the active stage of the disease regardless of their age with a noncontainable hip or patients with a painful hip after healing who demonstrate hinge abduction, abduction osteotomy should be considered. Abduction osteotomy of the femur is indicated when arthrography demonstrates that the congruency of the joint is improved by the extended adducted position (Figs. 24-25, 24-26, and 24-36). In addition to altering the relation of the femoral head to the acetabulum, valgus osteotomy of the hip lengthens the leg and lowers and lateralizes the greater trochanter. To maintain the proper axis through the knee joint, it is desirable to lateralize the femoral shaft (416). Many hips suitable for valgus osteotomy also have a short femoral neck, and the lateralization of the shaft tends to lengthen the neck.

One common problem with this osteotomy in older children and the young adolescent is that often there are no fixation devices of suitable size for these intermediate-sized bones. This situation often requires the modification of existing devices by bending, to avoid medialization of the femoral shaft or by shortening of the blade, of the blade plate devices used for adults. The surgeon may use drains as desired. The wound is usually fairly dry after the osteotomy is secured, and in our experience little drainage is collected in the suction canister. The most important question is whether to use a spica cast. This depends on a variety of factors that the surgeon must judge. How strong is the fixation? How reliable are the parents and children in the following directions about activity? Children tolerate a cast well, but adolescents do not. Adolescents are usually large enough to allow excellent fixation and seldom need a cast. On the other hand, younger children are often best immobilized for 6 weeks in a single-leg spica cast. Depending on circumstances, the cast may end above the knee and crutch walking can be permitted.

The preliminary results with this modality of treatment indicate improvement in limb length, decrease in limp, and improvement in function and range of motion (412). This procedure may be applied in either the active or the late stage of the disease, when arthrography demonstrates that the congruency of the joint is improved by the extended adducted position. This modality of treatment allows for realignment of the congruent position of the hip in the neutral weight-bearing position. Short-term results are promising (348, 377, 380, 412, 417).

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Valgus Osteotomy for Hinged Abduction in Perthes Disease (Figs. 24-29 to 24-35)

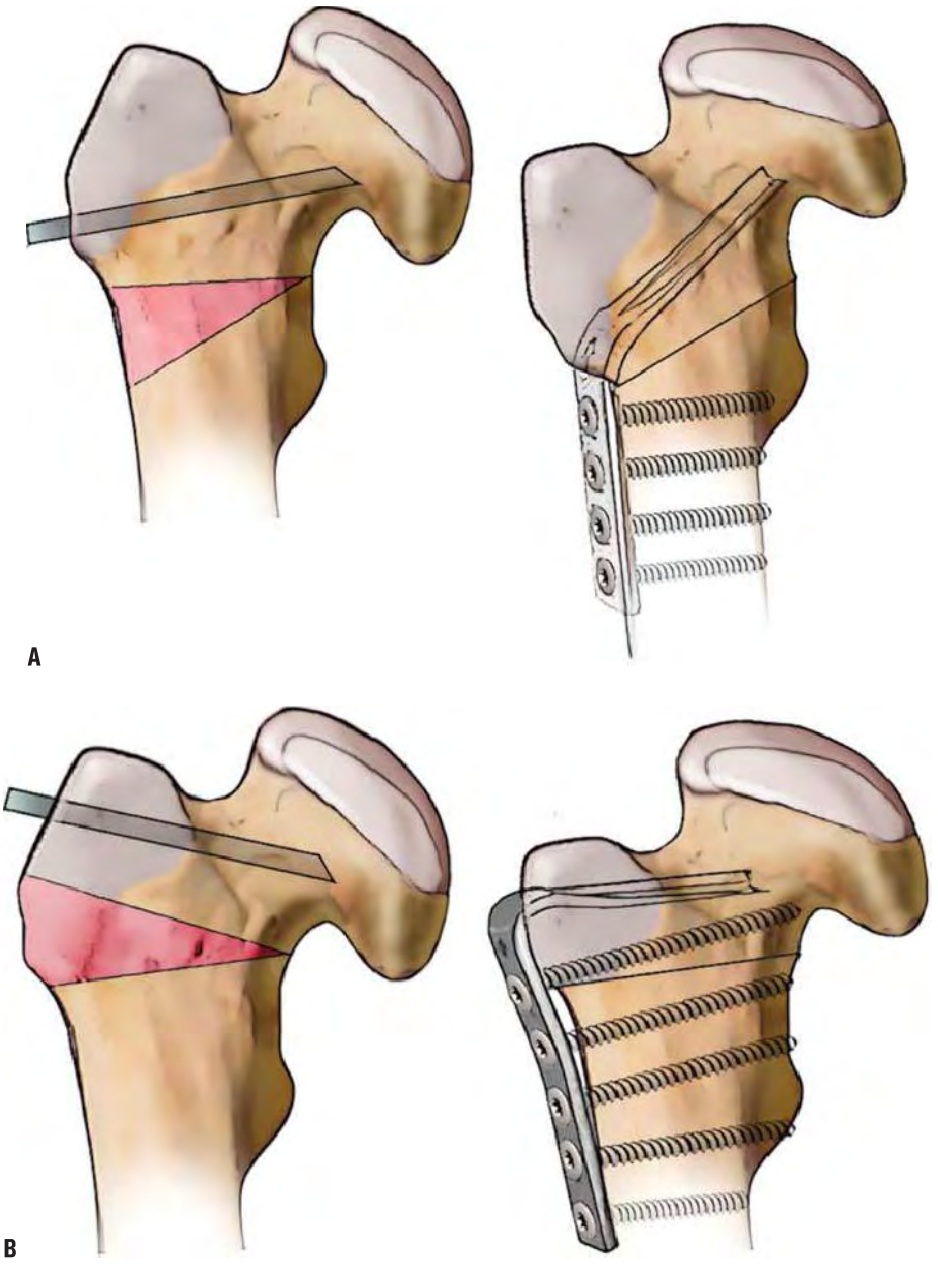
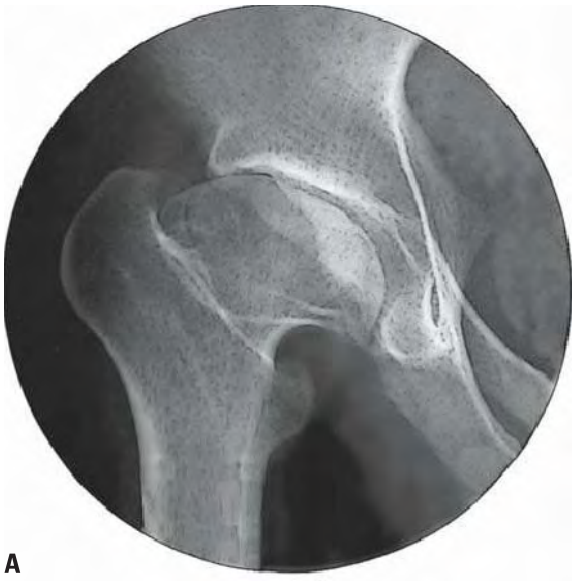
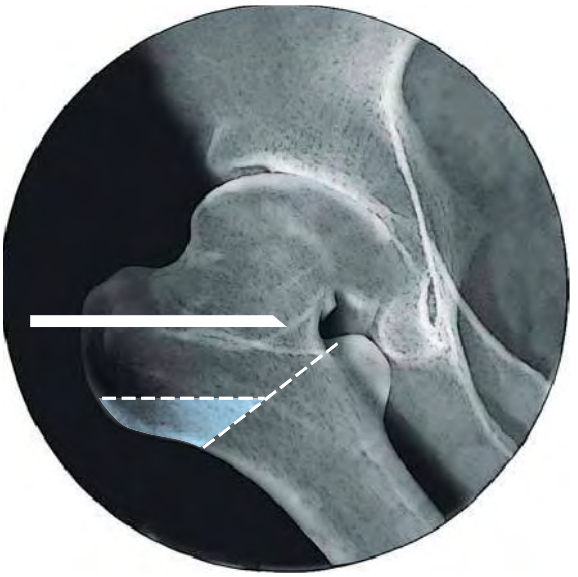


FIGURE 24-29. The simplest technique is resection of a laterally based wedge, in which a triangle of bone is removed from the intertrochanteric area. The angle of the wedge is equal to the desired correction. How the wedge is made depends on the type of fixation used, and the wedge is designed to produce interfragmentary compression (416). If the 130-degree angled blade plate is used, the base of the osteotomy (the distal cut) is inclined and the proximal cut is horizontal **(A)**. Compression across the osteotomy site is provided by the varus stress on the proximal segment. If a 90-degree blade plate is used, the base of the osteotomy is horizontal and the interfragmentary compression is obtained by prestressing the plate **(B)**.



A



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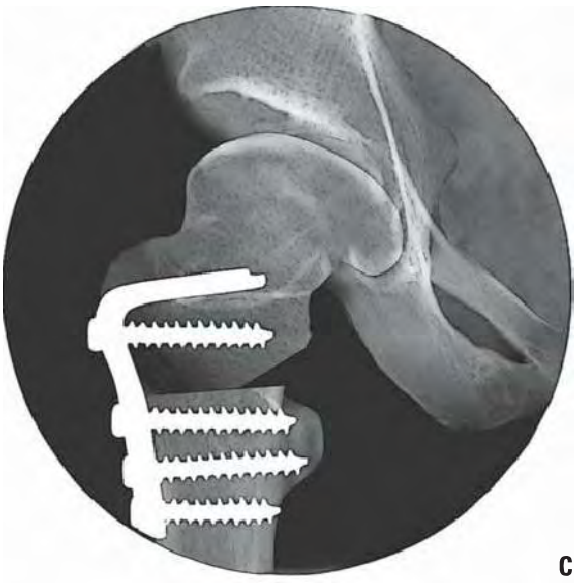


C

FIGURE 24-30. The most difficult of the valgus osteotomies to perform is the osteotomy that lateralizes the distal fragment and that lengthens the femoral neck. Although preoperative planning with templates can be used, a simpler method, which is actually useful for most valgus or varus osteotomies, is one that uses proper intraoperative positioning of the femoral head in relation to the acetabulum, while the osteotomy and fixation are achieved relative to the median and coronal planes of the patient.

Conceptually, the operation is performed by using the following steps. The patient may be placed on a radiolucent table or a fracture table so that a good view of the hip joint is obtained **(A).** The leg is adducted until the femoral head is in the desired relationship to the acetabulum **(B).** A small amount of radiopaque dye in the hip joint may prove useful if there is a significant amount of unossified femoral head. Next, the chisel for the 90-degree fixation device is inserted perpendicular to the median plane of the body **(B).** Finally, an osteotomy is created that will allow the femoral shaft to be brought back into the median plane of the body and secured with the plate **(C).** The following illustrations show in more detail how this is accomplished.

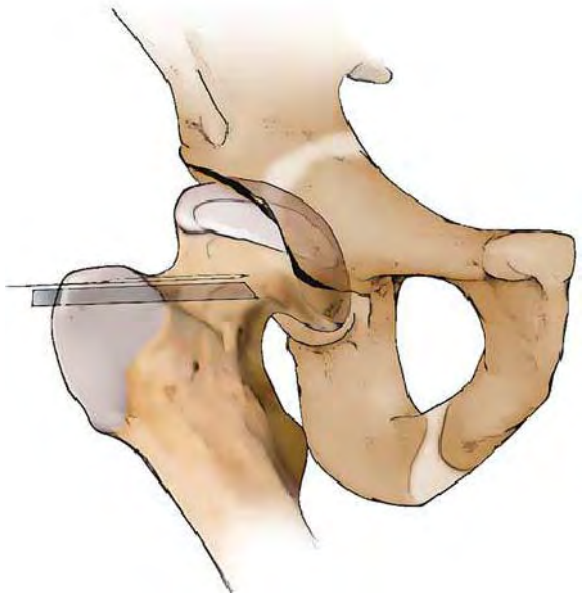


FIGURE 24-31. With the leg held in the desired position, a Steinmann pin is introduced into the most superior portion of the greater trochanter to serve as a guide for the chisel. This pin should be perpendicular to the median plane of the body and parallel to the floor of the operating room, which should be the same as the coronal plane of the patient. The position of this is verified on the image intensifier, and the chisel is driven in just below the guide pin. At this point, it is a good idea to loosen the chisel by driving it part way out so that it will not be difficult to remove it after the osteotomy is completed.

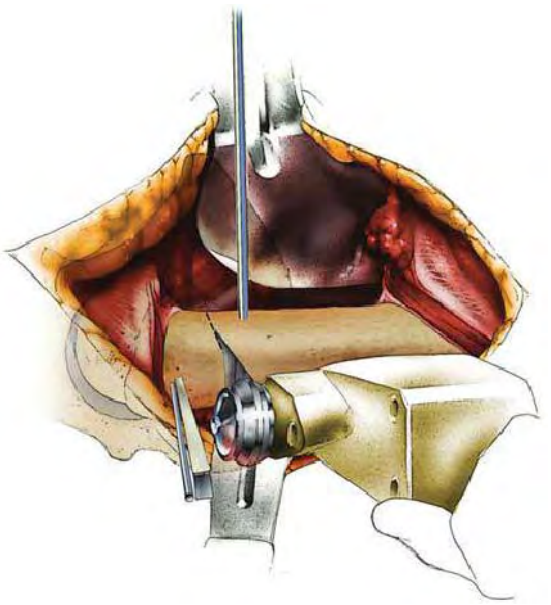
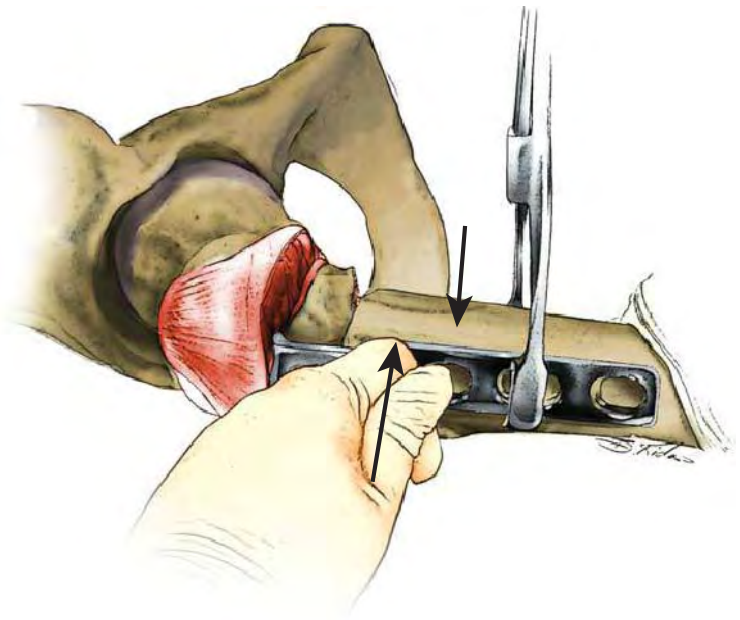
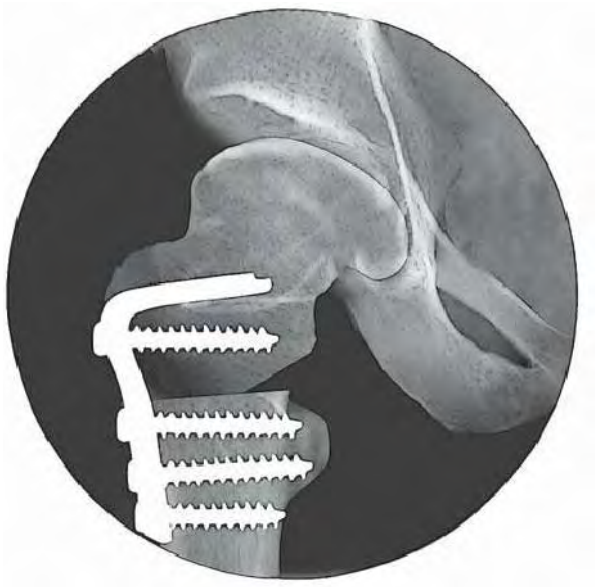


FIGURE 24-32. The next step is to locate the site for the osteotomy. This site should be perpendicular to the shaft of the femur and at the level of the proximal margin of the lesser trochanter. A mark in the cortex crossing the osteotomy site or a Steinmann pin in the anterior cortex distal and at right angles to the osteotomy should be placed as a reference for rotation. A single osteotomy cut is made.



A



B

FIGURE 24-33. The chisel is removed and the blade of the fixation device is inserted. In an adult patient, the condylar blade plate is an ideal device. With the blade in place, the plate is rotated toward the shaft, while the shaft is pulled laterally with a large forceps. The idea of this is to drive the lateral edge of the proximal surface into the medullary surface of the distal fragment **(A)**. However, this often proves difficult and seems to make the femur too long. It is at this point that removing a portion of the proximal fragment parallel to the blade aids in the reduction and increases the contact of the two osteotomy surfaces **(B)**. If still more shortening is needed, additional bone is removed from the distal fragment. The plate is now subjected to tension and secured to the distal fragment.

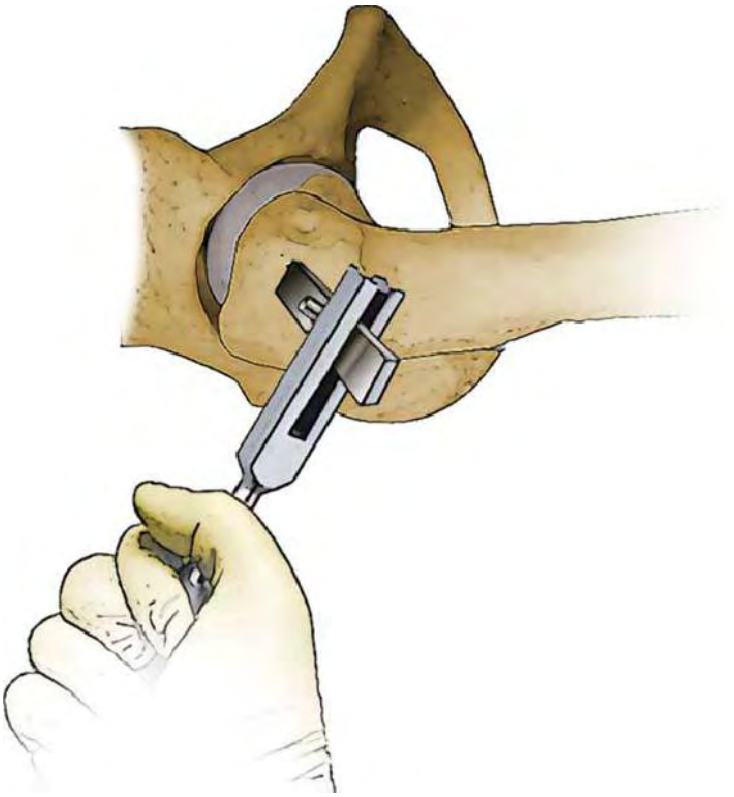


FIGURE 24-34. It is often desirable to add an extension to the osteotomy, depending on the clinical and arthrographic findings. To achieve this extension, the blade is not inserted at an angle perpendicular to the shaft of the femur as is usually done. Rather, it is rotated so that it lies perpendicular to the shaft after the desired correction is obtained. The chisel is guided with the slotted hammer to maintain the correct angle.

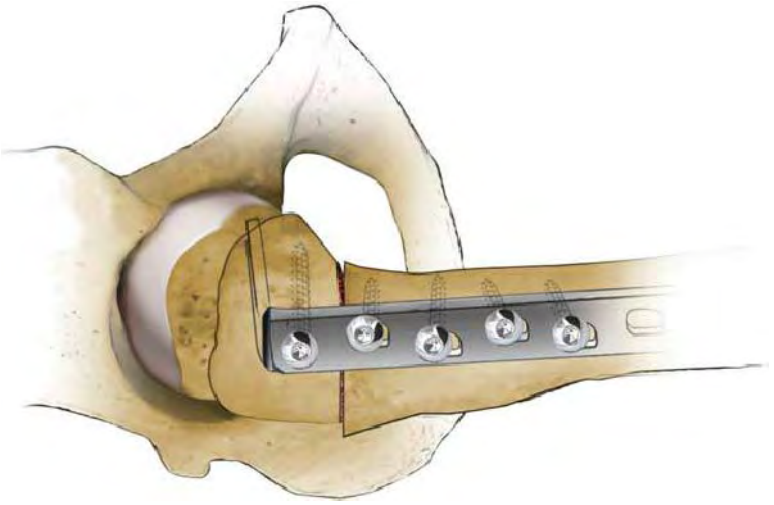


FIGURE 24-35. After the osteotomy is completed, the proximal fragment is allowed to go into flexion. The distal fragment is brought into extension and translated posteriorly. Any other corrections are made at the same time, and the shaft is then secured to the plate.

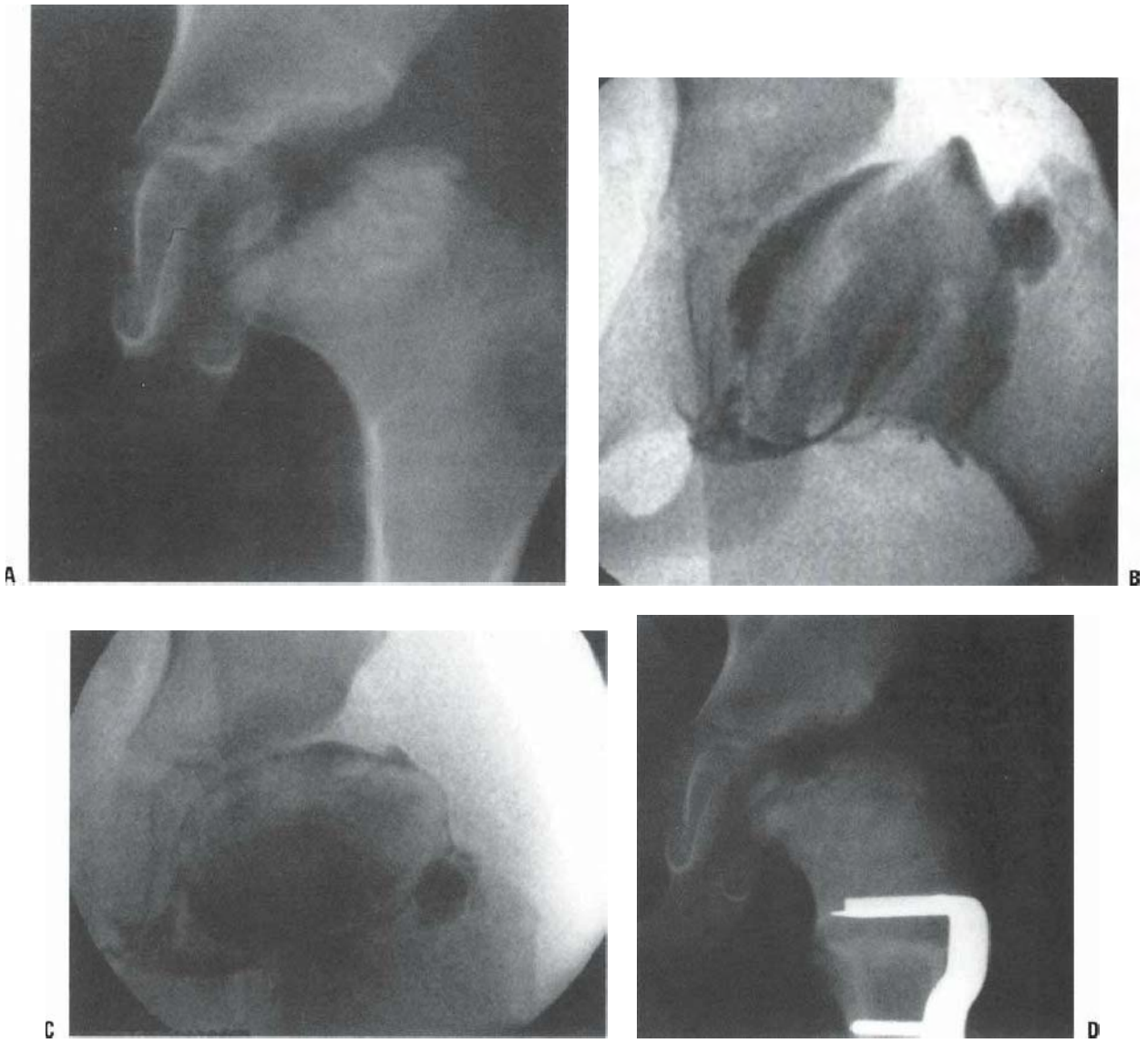


FIGURE 24-36. An 11-year-old boy with bilateral Perthes disease had a painful left hip with marked limitation of abduction and synovitis **(A)**. His arthrogram demonstrates maximal abduction **(B)** and 30 degrees of adduction **(C)**. Results of the valgus osteotomy 4 months after the procedure using a 95-degree angled blade plate **(D)**.

Lateral Shelf Acetabuloplasty (Figs. 24-37 to 24-41). Lateral shelf acetabuloplasty may also be used in "salvage" situations, including lateral subluxation of the femoral head, inadequate coverage of the femoral head, and hinge abduction associated with severe Legg-Calvé-Perthes disease (362, 406, 418–423). The author has been impressed with early results of this technique in older patients in the early stages of Legg-Calvé-Perthes disease. In this scenario, the shelf would cover the enlarged femoral head in hopes of improving the outcome, much as shelves are used as salvage procedures in residual hip dysplasia cases (Fig. 24-41). One recent report does demonstrate resolution of hinge abduction (424). Using this method in the presence of hinge abduction would not be the author's preference as it does not reduce the lateral impingement of the head in abduction.

Text continued on page 1154

Staheli Shelf Arthroplasty (Figs. 24-37 to 24-40)

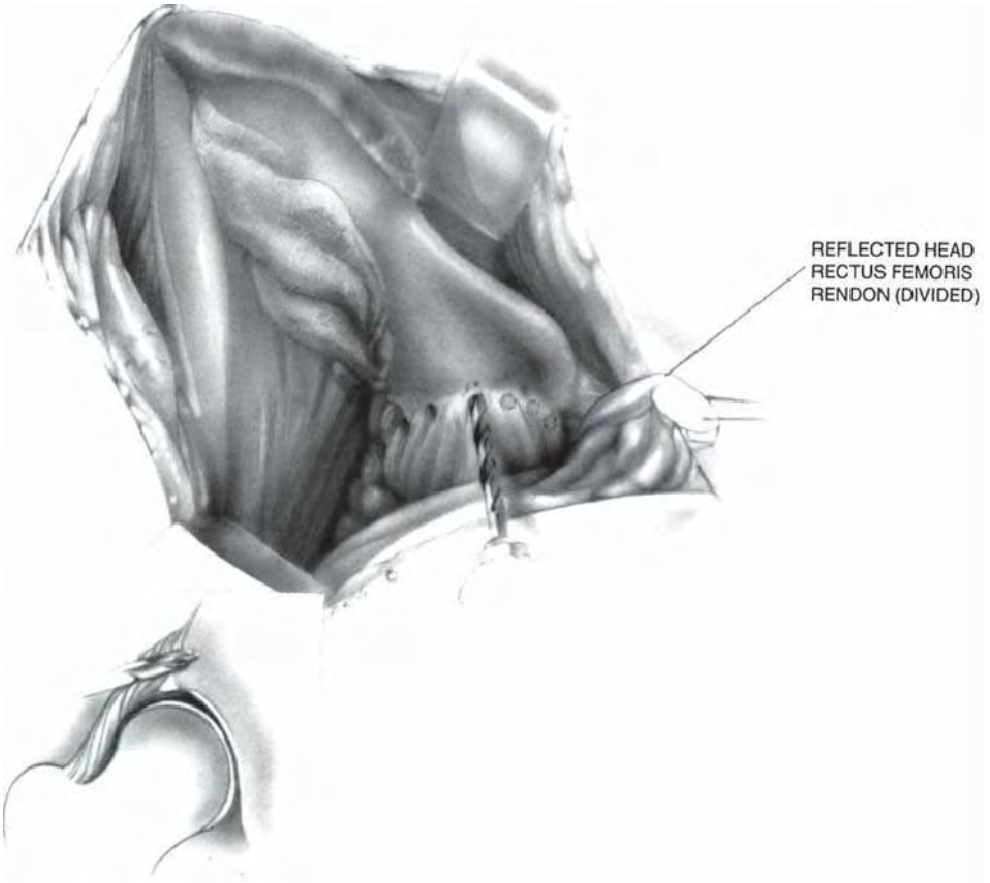


FIGURE 24-37. During the exposure the reflected head of the rectus tendon should be identified, dissected free from the capsule, and divided somewhere between its midportion and its junction to the conjoined tendon. This is used to secure the grafts in place. If it is not present, flaps can be created from the thickened capsule, which serves the same purpose.

The most important part of the surgery is to identify the correct location for the slot. It should be placed at the exact acetabular edge. The surgeon must determine whether this is the true or false acetabulum, based on which of the two affords the greater stability and congruity. The acetabulum is identified by creating a small incision in the capsule or by inserting a probe. In the subluxated and dysplastic hip, the capsule is usually thickened and adherent to the ilium, causing the surgeon to place the slot and therefore the graft too high. The correct location should be verified radiographically by placing a guide pin into the ilium at the presumed acetabular edge. In some cases it may be necessary to thin the capsule to permit the graft to be placed in the proper location.

After the correct location is verified, a 5/32-inch drill is used to make a series of holes at the edge of the acetabulum. These holes should be drilled to a depth of about 1 cm and should incline about 20 degrees, as illustrated. They should extend far enough anteriorly and posteriorly to provide the necessary coverage.

FIGURE 24-38. A narrow rongeur is used to connect these holes and produce the slot. This slot may also be more easily created with the use of a power burr. The floor of this slot should be the subchondral bone of the acetabulum, and it should be level with the capsule.

The bone graft is obtained from the outer table of the ilium. Starting at the iliac crest, corticocancellous and then cancellous strips of bone are removed. In the region above the slot, the decortication should be shallow to aid the incorporation of the graft without disrupting the integrity of the slot.

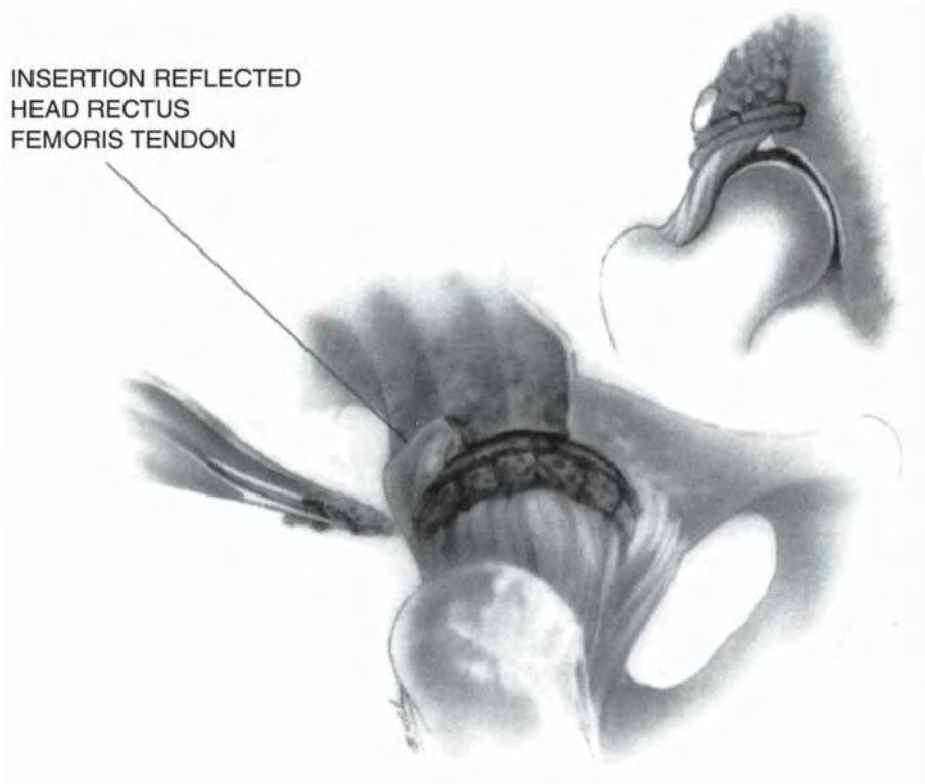


FIGURE 24-39. The cancellous grafts are cut in strips 1-cm wide and of appropriate length to provide the desired amount of lateral coverage. These are placed in the slot extending out over the capsule. A second layer of cancellous strips are placed at 90 degrees to the first layer of strips of graft. The grafts must not extend too far laterally or anteriorly in the quest for spectacular radiographic coverage of the hip because this could result in a loss of motion secondary to impingement.

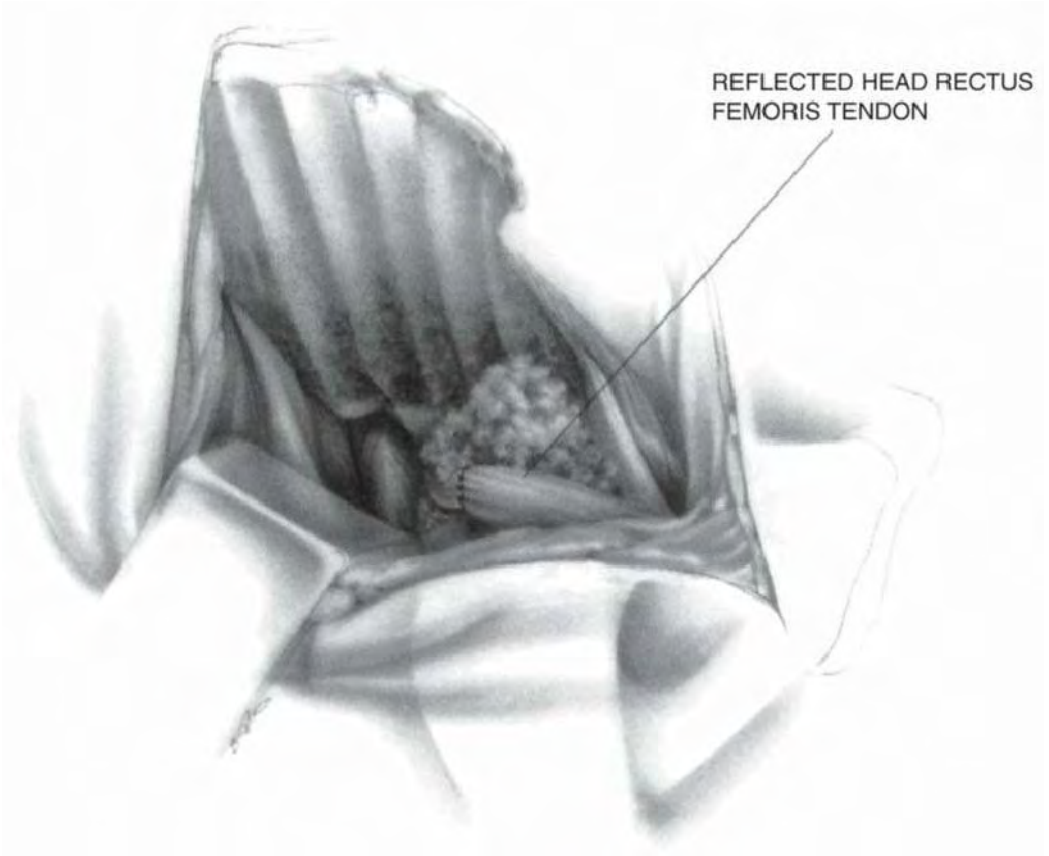


FIGURE 24-40. The reflected head of the rectus tendon is sutured, holding the grafts in place. The remaining bone is cut into small pieces and placed over the previously placed graft. This is held in place by the abductor muscles when the wound is closed.

Chiari Osteotomy. Chiari osteotomy improves the lateral coverage of the deformed femoral head, but does not reduce the lateral impingement in abduction and may exacerbate any existing abductor weakness (246, 412). Chiari osteotomy may be useful in the enlarged, poorly covered femoral head that is beginning to develop symptoms of early degenerative joint disease. Although good preliminary results have been reported (414, 415, 419, 420, 422, 423, 425), the role of Chiari osteotomy in the treatment of Legg-Calvé-Perthes syndrome has yet to be defined.

Femoral Acetabular Impingement. Cheilectomy removes the anterolateral portion of the femoral head that is impinging on the acetabulum in abduction (426) (Fig. 24-43). It is indicated only in patients with functionally limiting and restricted range of motion. The procedure must be performed only after the physis is closed; otherwise, a slipped capital femoral epiphysis may ensue (413, 427). Although cheilectomy may produce gratifying results with regard to improved range of motion, in some cases increasing stiffness may occur secondary to capsular adhesions at the osteotomy site (348). In addition, shortening associated with the femoral head deformity is not corrected. The entity of femoral acetabular impingement is discussed more fully in Chapter 23. Little long-term information, other than for cheilectomy, exists for impingement syndromes in Perthes disease (Fig. 24-43).

Osteochondritis Dissecans. Osteochondritis dissecans after Perthes syndrome may or may not be symptomatic (Fig. 24-15). If it is symptomatic, the pain may be intermittent. In patients with pain, several treatment options are available. Symptomatic treatment with anti-inflammatory agents and protective weight bearing may be used to promote healing. Persistent pain may warrant attempts at revascularization. This may include drilling of the fragment through the femoral neck and internal fixation, either percutaneously with pins or open with devices such as the Herbert screw. If the fragment becomes detached and cannot be reattached and causes mechanical catching symptoms, it may require removal (198, 428). There is a paucity of information on the natural history of the condition and the results of treatment.

Patients with Legg-Calvé-Perthes syndrome and premature physeal arrest may develop a Trendelenburg gait and pain secondary to muscle fatigue (187, 196). This has rarely been a significant problem in long-term reviews (193). However, distal and lateral advancement of the greater trochanter may be necessary (429–431).

FUTURE DEVELOPMENTS

Long-term series of patients with uniform treatment who are matched for age, gender, degree of epiphyseal involvement,

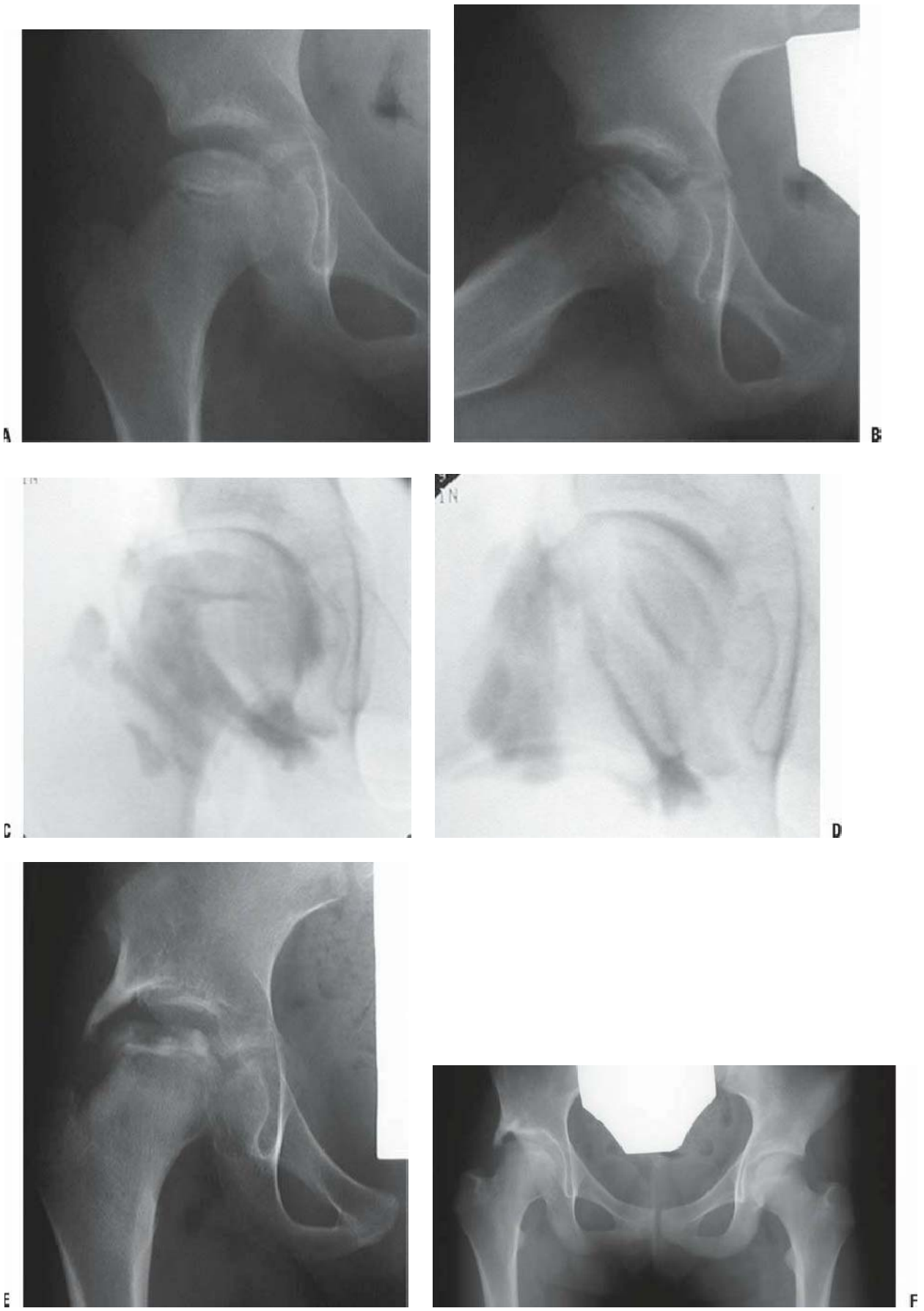


FIGURE 24-41. An 8-year-old girl with total femoral head involvement in the initial stage of disease. **A:** AP view. **B:** Lateral view. **C:** Intraoperative arthrogram in neutral position showing very mild flattening of the femoral head. **D:** Arthrogram in abduction showing no evidence of impingement. **E:** One year after shelf arthroplasty. **F:** Five years after shelf arthroplasty.

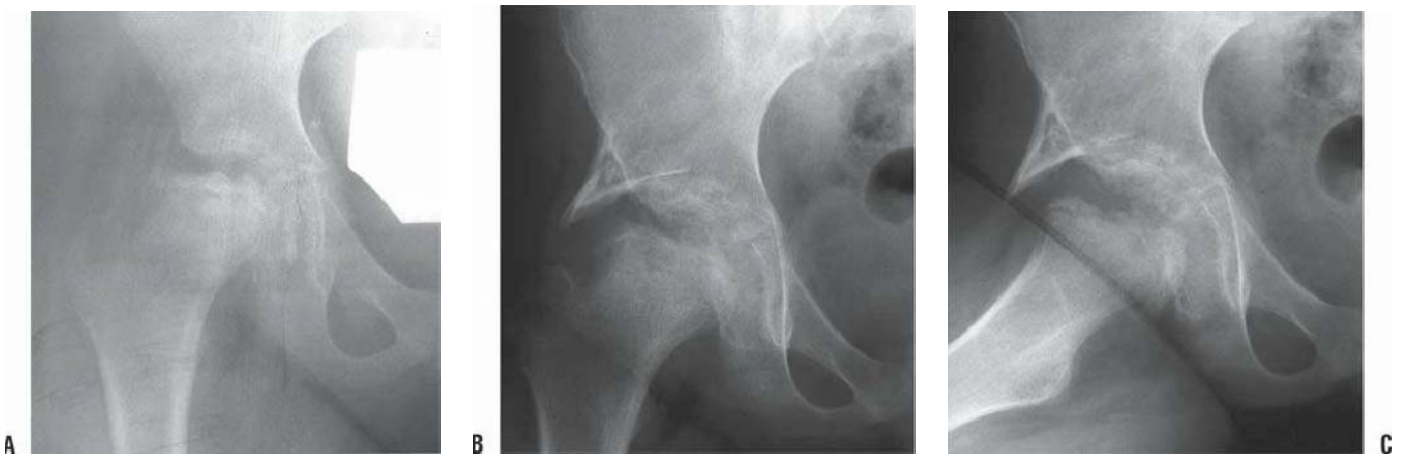


FIGURE 24-42. A 9-year-old girl with Catterall group 4 and lateral pillar type C disease treated with lateral shelf arthroplasty. **A:** Note the marked loss of epiphyseal height. AP **(B)** and Lauenstein **(C)** radiographs 1 year after operation. Note that the femoral head is in the reossification phase. The involved side is 1 cm shorter than the other. Abduction and internal rotation are to 15 degrees, external rotation is to 25 degrees, and flexion is to 100 degrees. (Courtesy of Fred Dietz, MD, University of Iowa, Iowa City, Iowa.)

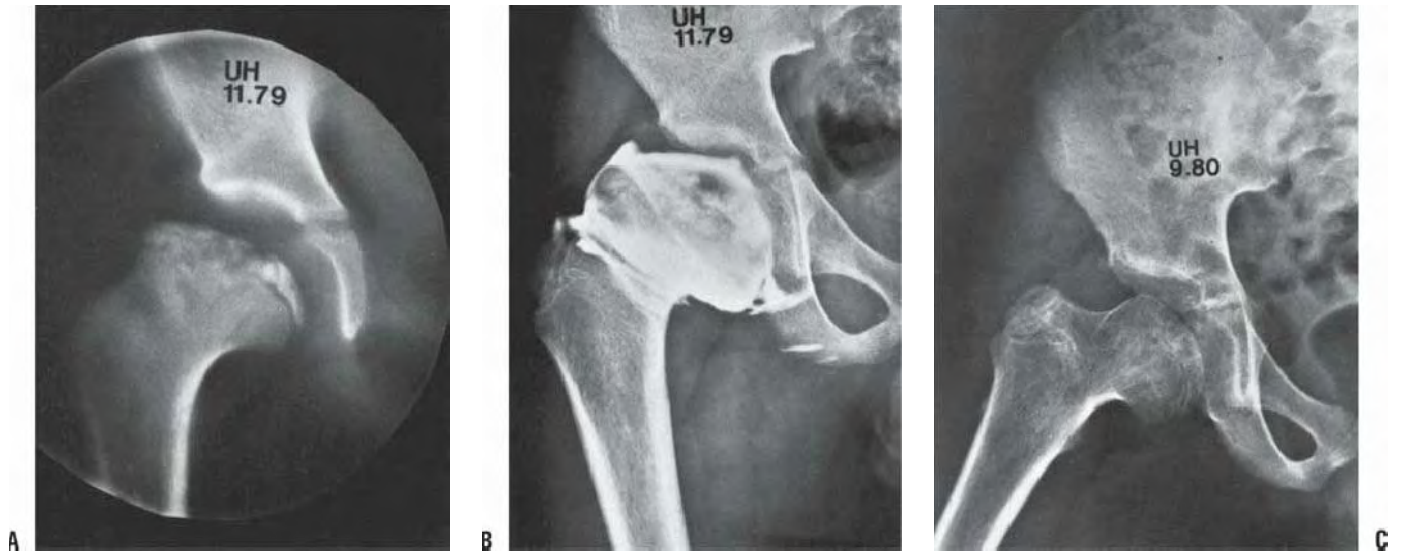


FIGURE 24-43. A boy, 8 years and 6 months of age, with Catterall group 4 disease. The range of motion of the hip included flexion of 140 degrees, extension of 0 degree, abduction of 20 degrees, adduction of 30 degrees, internal rotation of 10 degrees, and external rotation of 30 degrees. **A:** Polytome indicating superolateral growth arrest. **B:** Arthrogram demonstrating femoral head flattening and enlargement, and deformation of the peripheral acetabulum. **C:** Abduction radiograph 7 months after cheilectomy. Range of motion at this time was 130 degrees of flexion, 20 degrees of extension, 50 degrees of abduction, 50 degrees of adduction, 45 degrees of internal rotation, and 40 degrees of external rotation. (Courtesy of J.G. Pous, MD, Montpellier, France.)

and other diagnostic factors, compared with an untreated control group, will no doubt be required in order to determine the most effective treatment for Legg-Calvé-Perthes syndrome. As fundamental understanding of Legg-Calvé-Perthes syndrome increases, so does understanding of how various treatment modalities influence this complex growth disturbance.

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