From the University Hospital, Department of Orthopaedics, Groningen, the Netherlands

Functional treatment of congenital dislocation of the hip

Jan D. Visser

ACTA ORTHOPAEDICA SCANDINAVICA SUPPLEMENTUM NO. 206, VOL. 55, 1984

MUNKSGAARD . COPENHAGEN

ISBN: 87-16-06256-6
ISSN: 0300-8827

"The needs of children should not be made to wait"

John F. Kennedy, 1963

ACKNOWLEDGEMENTS

This thesis was prepared in the Orthopaedic Department (head: Prof. Dr. H. K. L. Nielsen) of the Groningen University Hospital, The Netherlands.

My special thanks go to Prof. Dr. H. K. L. Nielsen, Prof. Dr. C. J. P. Thijn and Drs. B. Hillen for their help and constructive critical remarks during the preparation of this manuscript, and to Prof. Dr. M. J. Kingma under whose guidance the functional treatment of congenital dislocation of the hip was started in our department.

The quality of this thesis is largely attributable to the efforts of the following persons, to whom I am deeply indebted.

Akkie Woudstra, who efficiently and accurately handled the huge task of typing the original manuscript.

Mr. A. J. H. Deddens and the Medical Photographic Service, who supplied photographs of high technical quality; Mr. T. A. J. Deddens, who made the excellent drawings; Drs. S. G. Bulstra and Drs. M. Sluzewski, who did some of the prepatory work.

Mr. Th. van Winsen translated the manuscript and Miss I. F. Brown, FRCS, made the final correction of the translation.

Mr. J. Bosker, Mrs. H. Haanstra-Jansen, Mrs. M. J. Keijer and Mrs. A. Onnes-Bos took care of other administrative matters.

This study was financial supported by grants from BASKO-CAMP, Amsterdam and ORTOMED B.V., Schiedam.

CONTENTS

CHAPTER I

INTRODUCTION

The treatment of congenital dislocation of the hip should aim at:
— achieving reduction;
— preventing redislocation;
— avoiding irreversible damage of the femoral head;
— optimalizing the relation between the acetabulum and proximal end of the femur.

The making of a treatment plan for congenital dislocation of the hip requires a good understanding of the pathology, the pathogenetic mechanism and the origin of ischaemic necrosis of the femoral head. It is also important to understand the development of the relation between the acetabulum and proximal end of the femur during growth and the natural course after reduction of the dislocation.

Between 1969 and 1979 all patients presenting with congenital dislocation of the hip in the Orthopaedic Department of the Groningen University Hospital were treated according to the same guidelines. Their age at the first examination ranged from 3 months to 3 years.

Treatment consisted of two phases:

1. **Reduction phase:** the time required to restore the femoral head to the original acetabulum. Primarily an attempt was made to achieve reduction by skin traction in balanced suspension. Open reduction was resorted to whenever roentgenography after an average traction period of six weeks revealed that no centralization of the femoral head in the original acetabulum had been achieved.
2. **Retention phase:** the time required for fixation of the femoral head in the original acetabulum in order to prevent redislocation and also to promote restoration of the normal anatomy. The femoral head was retained in the acetabulum by means of a bilateral hip spica plaster cast or a splint. Corrective operations on the pelvis and/or proximal end of the femur were performed when insufficient restoration of the anatomy took place and natural restoration in the course of growth was considered to be unlikely.

I.1 AIM

The aim of the study presented in this thesis was to gain insight into the value of functional treatment of congenital hip dislocation by studying the following aspects on the basis of a follow-up on 53 patients with a total of 68 congenital hip dislocations:

a. How often was reduction achieved by functional treatment using skin traction in balanced suspension?
b. How often did redislocation occur?

c. To what extent did irreversible damage of the femoral head occur?
d. Which supplementary operations were required to ensure a better relation between the acetabulum and proximal end of the femur?

I.2 DEFINITIONS

Congenital dislocation of the hip:

Congenital dislocation of the hip is the most pronounced form of a condition in which the femoral heads tends progressively to leave the acetabulum. Dislocation as a result of infection or a neurological condition is left undiscussed, as are hip anomalies which must be regarded as a component of a more complex congenital anomaly of the supportive and locomotor apparatus.

Functional treatment of congenital dislocation of the hip:

Functional treatment of congenital dislocation of the hip consists of closed reduction which, slowly and in a controlled way, reverses the pathogenetic mechanism of the dislocation. After reduction an attempt is made to achieve restoration of the anatomical development of the joint by means of the inductive action of the well-centred femoral head in the acetabulum.

Inclination of the acetabulum (fig. 1):

The inclination of the acetabulum is the angle between the transverse axis and the line of intersection of the plane through the acetabular rim and the frontal plane.

Acetabular torsion (fig. 2):

Acetabular torsion is indicated by the angle between the sagittal axis and the line of intersection of the plane through the acetabular rim and the transverse plane. The term anteversion is used when the plane through the acetabular rim is oriented anteriorly, while the term retroversion applies when this plane is oriented posteriorly.

Anatomical position:

The position of the pelvis is described as anatomical when the apex of the symphysis and the superior anterior iliac spines are located in a single frontal plane.

Neck-shaft angle (fig. 1):

The neck-shaft angle is the angle between the axis of the femoral neck and that of the femoral shaft.

Femoral torsion (fig. 3):

a. Femoral torsion is indicated by the angle between the plane through the transcondylar axis parallel to the femoral shaft axis and the plane through the axes of femoral neck and femoral shaft. The term anteversion is used when the femoral

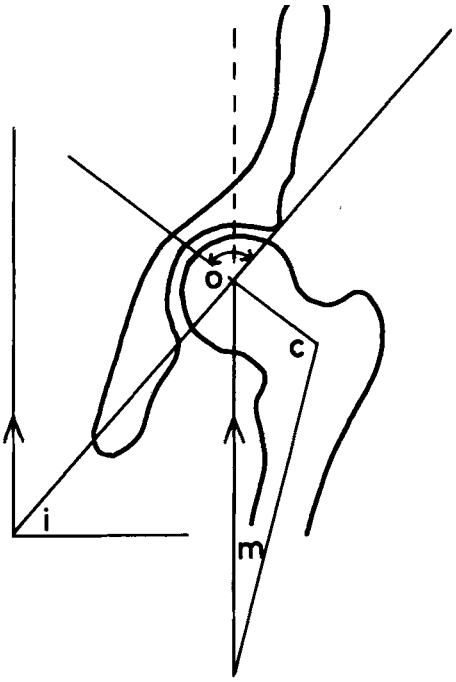


Fig. 1 Frontal section through the left hip-joint. i = inclination of the acetabulum; c = neck-shaft angle; o = supportive sector; m = angle between the axis of the femoral shaft and the mechanical axis of the femur; O = (90-i) + (180-m-c-).

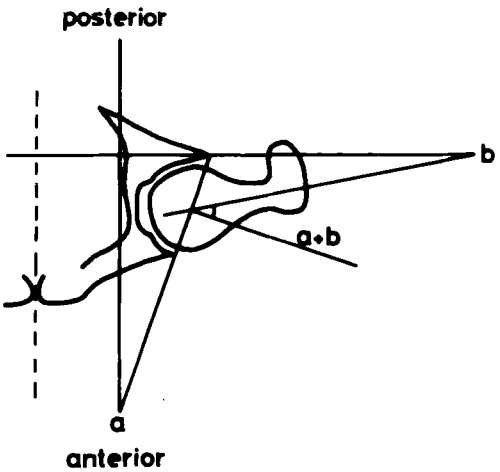


Fig. 2 Transverse section through the left hip-joint. Pelvis in anatomical and femur in neutral position. a = acetabular anteversion; b = femoral anteversion; a + b = instability index (angle between the axis of the femoral neck and a line perpendicular through the anterior and posterior boundaries of the acetabulum).

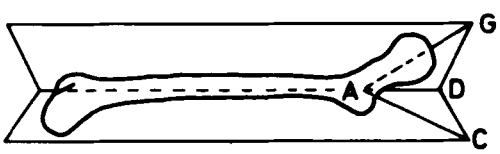


Fig. 3 Femoral torsion. Definition a. is angle GDC. Definition b. is angle GAC.

neck axis lies anteriorly to the transcondylar plane, while the term retroversion applies when it lies posteriorly to this plane.

The above definition is used in the anatomical and radiological calculations. A definition which is more precise but less often used for practical reasons is the following.

b. Femoral torsion is indicated by the angle between the femoral neck axis and the plane through the transcondylar axis parallel to the femoral shaft axis.

Instability index (fig. 2):

The instability index of the hip-joint is the sum of acetabular and femoral torsion.

Supportive sector (fig. 1):

The supportive sector is indicated by the angle between the line of intersection of the plane through the acetabular rim and the frontal plane and the projection of the femoral neck on the frontal plane with the femur in the neutral position.

Mechanical axis of the femur (fig. 1):

The mechanical axis of the femur is a line which connects the centre of the femoral head with that of the knee.

Acetabular angle (fig. 20):

The acetabular angle is formed by two lines on an antero-posterior roentgenogram of the pelvis. The Y-line or Hilgenreiner's line connects the most inferior points of the ilium. From these points a line is drawn to the supero - lateral boundary of the acetabulum. Together with Hilgenreiner's line, this line forms the acetabular angle.

Wiberg's CE-angle (fig. 22):

Wiberg's CE-angle is formed by two lines on an antero-posterior roentgenogram of the pelvis. The first line extends through the centre of the femoral head, perpendicular to the line connecting the centres of the two femoral heads. The second line extends from the centre of the femoral head to the most lateral boundary of the acetabulum.

PATHOLOGY

II.1 PATHOLOGICAL ANATOMY OF CONGENITAL DISLOCATION OF THE HIP

The deformity of congenital dislocation of the hip can assume varying degrees of severity. Morphologically there is a smooth transition from entirely normal anatomical relations of the hip-joint on the one hand, to on the other hand a pronounced pathological situation in which femoral head and acetabulum are totally separated. It is possible to make an arbitrary division into three types on the basis of the shape of the acetabular rim, eversion or inversion of acetabular labrum and the contours of the femoral head (Dunn, 1976; Ogden & Moss 1978; Ogden 1982) (fig. 4).

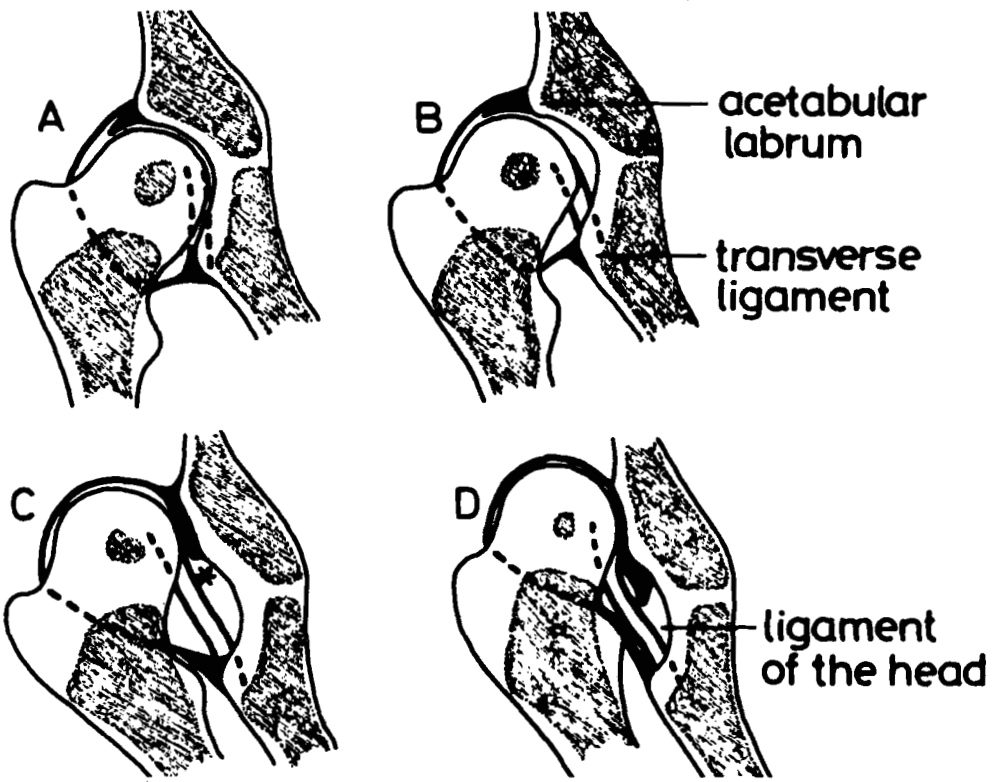


Fig. 4 A = normal; B = tendency to subluxation: lateralization of the femoral head and slight eversion of the acetabular labrum; C = subluxation: distinct eversion of the acetabular labrum and marginal inversion; (*) = incipient inversion of the acetabular labrum; D = dislocation: "false" acetabulum, inversion of the acetabular labrum, inversion of the transverse ligament and the superior part of the capsule.

Tendency to subluxation:

There is unmistakably increased femoral anteversion. Pressure exerted by the femoral head on the superior and posterior parts of the acetabular rim causes this part of the fibro-cartilaginous acetabular labrum to evert. Small areas at the transition of the labrum to the hyaline cartilage of the articular surface hypertrophy and tend to invert. This raises the strong suspicion that inversion of the labrum is not an abrupt event but rather a more gradual architectonic change. Pressure exerted by the posterior aspects of the femoral head on the posterior part of the acetabular rim and by the iliopsoas tendon on the anterior part of the rim causes the acetabular rim to assume an ellipsoid shape.

Subluxation:

In addition to its increased anteversion the femoral head loses its roundness. The deformation of the acetabulum increases and the eversion of in particular the supero-posterior part of the acetabular labrum increases so that, finally, this is pressed against the ilium. The pressure of the femoral head on the postero-superior part of the acetabulum contributes to a delay in the ossification of this part of the acetabulum. The fibro-fatty tissue in the acetabular notch and fossa (the acetabular pulvinar) hypertrophies.

Dislocation:

The situation differs from the above described types in that the acetabular labrum now shows complete inversion. Because the inductive action of the femoral head is lacking, the acetabulum is extremely deformed. The joint capsule is stretched. The ligament of the femoral head is stretched and hypertrophic, and pulls the transverse ligament upwards. Within three months there are contractures of, in particular, the hip adductors, hamstrings and iliopsoas muscle.

When contact between the femoral head and acetabulum is lost, the tendon of the iliopsoas muscle can invade the space between femoral head and acetabulum. As a result of compression on the anterior side the capsule assumes an hour-glass configuration, which impedes a return of the femoral head into the acetabulum (fig. 5).

II.2 PATHOGENETIC MECHANISM IN VERTEX PRESENTATION

The presence of an easily stretchable joint capsule is a prerequisite for the development of dislocation of the hip (Wilkinson 1963). If a joint capsule is of normal structure, then trauma is more likely to cause of slipped upper femoral epiphysis than a dislocation (Somerville 1982).

One of the factors on which the development of dislocation depends, is the position of the foetus in the uterus.

Normally the foetus lies in the uterus with flexed hips and flexed knees. As the foetus leaves the birth canal the hips do not remain flexed but extend because the overall strength of the extensors far exceeds the overall strength of the hip

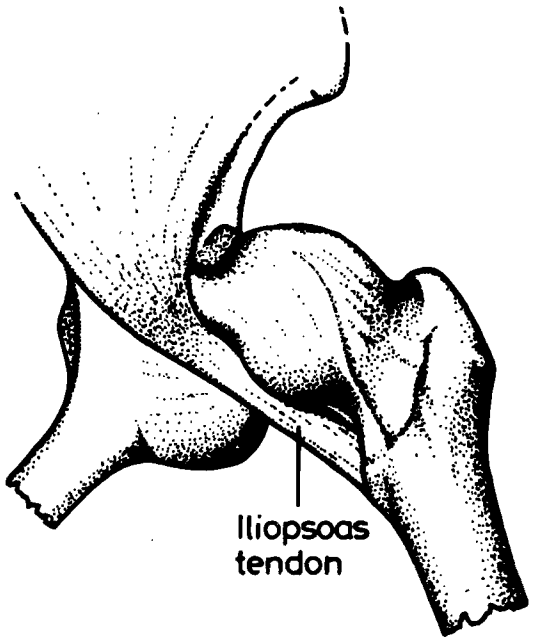


Fig. 5 Due to the relative shortening of the iliopsoasmuscle the tendon of this muscle pushes the femoral head posteriorly and laterally as extension increases, intrudes between femoral head and acetabulum, with hour-glass configuration as a result.

flexors (Lang & Wachsmuth 1972). Sybrandy (1965) demonstrated in newborn rats that the hips are dislocated when they are fixed in extension. Due to the relative shortening of the iliopsoas muscle the tendon of this muscle pushes the femoral head posteriorly as extension increases (McKibbin 1970) (fig. 5).

Extension causes torsion of the joint capsule and ligaments. Once the femoral head loses contact with the acetabulum, this torsion is an additional obstacle to the return of the femoral head into the acetabulum. The human joint capsule and ligaments show maximal relaxation when the hip is in 70° flexion, 5° abduction and 10° lateral rotation (Walmsley 1928).

It is difficult to determine the exact moment of dislocation; it is a smoothly progressive process. If deflection of the hip-joint plays an important role in the pathogenesis of a dislocation, then this process takes place during the perinatal period.

In the postnatal phase dislocation is as a rule in the posterior direction (Ogden & Moss 1978), the anterior dislocation being rare (Stanisavljevic 1982). Assuming that dislocation occurs as a result of contracture of the iliopsoas muscle with the hip more or less extended, it is evident from the site of insertion and origin of this muscle and from the three-dimensional relations between this muscle and the femoral neck and head that only posterior dislocation can occur. As the hip extends, the tendon of the contracted iliopsoas muscle pushes the femoral head (localized posteriorly to it) in the posterior direction. Dependent on the position of the joint,

the orientation of this muscle pulls the femoral head posteriorly with the hip in flexion and superiorly with the hip in extension. The fact that the infant begins to stand up by approximately nine months also plays a role in the superior migration of the femoral head.

II.3 PATHOGENETIC MECHANISM IN BREECH PRESENTATION

In breech presentation the hips are flexed and the knees extended. Hyperextension of the knees increases the tension in the hamstrings and causes dislocation of the femoral head, as Wilkinson (1963) demonstrated in newborn rabbits.

When breech presentation is the cause of dislocation, this can occur prior to birth (Campos da Paz & Karam Kalil 1976). This dislocation probably occurs during the final prenatal weeks, when the muscles surrounding the hip and their innervation have fully developed and there is less amniotic fluid in relation to the rapidly growing foetus. The foetus has less room within the uterus and can easily hyperextend the knees.

When the dislocation is caused by increased tension in the hamstrings with the hip in flexion, the direction of dislocation within the uterus is bound to be posteroinferior. After birth the deflexion and the contracture of the iliopsoas muscle resume an important role and consequently the direction of the dislocation is the same again as that in the vertex presentation.

CHAPTER III

AETIOLOGY

III.1 LIGAMENTOUS LAXITY

Ligamentous laxity is a prerequisite for the development of congenital dislocation of the hip. A hip-joint with capsule and ligaments of normal strength can be dislocated only after removal of the capsule and the ligament of the femoral head (Salter 1968). Smith et al. (1963) observed a large percentage of hip dislocations in young dogs submitted to removal of the joint capsule and ligament of the femoral head during growth. A shallow acetabulum created surgically in dogs did not give rise to dislocation. Experiments causing increased anteversion or retroversion of the femur revealed no significant acetabular changes. In his experiments on rabbits Wilkinson (1963) demonstrated that ligamentous laxity strongly promotes the development of hip dislocation. He registered the laxity of the ligaments on the basis of abnormal mobility observed in the pubic symphysis, sacro-iliac joints, hips and knees. Measurements of the tensile strength of ligaments and capsules were not performed. Ligamentous laxity was induced by intramuscular injection of oestrone and progesterone, and developed mostly in female rabbits. This might explain the fact that the male:female ratio of human congenital dislocation of the hip is 1:4 (Dunn 1976). Andrén and Borglin (1961) reportedly found a higher urinary concentration of oestrone and oestradiol-17B during the first three postnatal days in infants with congenital dislocation of the hip than in normal neonates. Other authors, however, have contradicted these findings (Thieme et al. 1968; Aarskog et al. 1966).

Wynne-Davies (1970) indicated the possibility of a hereditary collagen disorder. She found more ligamentous laxity in infants with congenital dislocation of the hip than in a control group; and the same applied to first-degree relatives of these infants. Although no consensus about the pathogenesis of ligamentous laxity has so far been attained, virtually all investigators agree that it is an prerequisite for the development of congenital dislocation of the hip.

III.2 MECHANICAL FACTORS

The findings reported by Barlow (1962) show that ligamentous laxity is not the sole cause of congenital dislocation of the hip. He examined 9289 neonates and found that manual dislocation of one or both hips was possible in 1 out of every 60 infants. Of these, 60% recovered within a week and 88% within 2 months; 12% developed congenital dislocation of the hip. Ligamentous laxity has a natural tendency to disappear, and no dislocation develops in the absence of an exogenous factor.

A similar conclusion can be drawn from the findings reported by Idelberger (1951), who examined 138 twins. He found that both infants were affected in 2.8%

of the heterozygotic group, and in 42.7% of the homozygotic group. This difference between the heterozygotic and the homozygotic group suggests a strong endogenous factor. As dislocation did not develop in all instances in both infants in the homozygotic group it is evident that this factor is not the only determinant of congenital dislocation of the hip. If an endogenous factor were the sole determinant, moreover, dislocation could be expected to develop bilaterally in all instances. But this is certainly not the case.

The exogenous factor involved in the case of breech presentation is hyperextension of the knees, giving rise to increased tension in the hamstrings (Wilkinson 1963). The deflexion plays an important role in the pathogenesis of dislocation of the hip during and shortly after birth. A striking fact is the higher incidence of hip dislocations among Canadian Indians whose custom it is to swaddle their infants in a so-called "tikonagan" (Salter 1968), thus more or less fixing the hips in adduction and extension. Langenskiöld and Laurent (1966) decsribed a similar swaddling method among Lapps in Scandinavia (where the incidence of this condition is likewise high). This is in contrast to African regions, where infants are carried on the back of the mother with the hips in abduction and flexion. Congenital hip dislocations are rare in these regions (Edelstein 1966).

Congenital hip dislocation involves the left hip twice as frequently as the right. Dunn (1976) suggested as a possible explanation that the foetus lies with the left leg towards the maternal spine twice as often as with the right leg. Due to the stiffness of the maternal spine this leg has less room to move and lies in adduction. An adducted position of the leg increases the risk of dislocation.

CHAPTER IV

INCIDENCE

The incidence of dislocatable hips in neonates is 1.3-17 per 1000 births (Barlow 1962; Rosen 1962, 1970; Mitchell 1972; Hopkins 1975; Paterson 1976; Tredwell & Bell 1981). According to Barlow (1962) some 90% stabilize spontaneously. An attempt to calculate the percentage of hip dislocations should therefore proceed from the presence of this condition in infants older than 2-3 months, thus excluding dislocatable hips which stabilize within a few weeks. If this procedure is to lead to correct estimates, however, none of these dislocatable hips should have been treated (Barlow 1962; Thieme et al. 1968).

Although considerable geographical variations in the incidence of congenital hip dislocations exist even within Europe, the incidence in The Netherlands is not likely to differ much from that in England, where it is 1-2 per 1000, with a male:female ratio of 1:4 (Barlow 1962). The left:right ratio is 2:1 (Dunn 1976). The findings reported by Wynne-Davies (1970) suggest a pronounced familial heredity. If the parents have normal hips but one of their children has a congenital hip dislocation, then the next child runs a 6% risk of developing a similar condition. If one of the parents has a congenital hip dislocation, then the risk is 12%. If congenital dislocation of the hip is present both in one of the parents and in one of the children, then this risk increases to 36%.

ORIENTATION OF THE HIP-JOINT

V.1 ORIENTATION OF THE ACETABULUM

The inclination of the acetabulum (fig. 1) averages 53° in neonates and 48° in adults (Lanz 1951). Reports on the degree of torsion of the acetabulum (fig. 2) show marked inter-observer differences because acetabular torsion is not always measured with the pelvis in the same position. It should be measured with the pelvis in the anatomical position, which can be readily achieved by having the pelvis assume a prone position in which the superior aspect of the symphysis and the superior anterior iliac spines rest on the supporting layer. McKibbin (1970) did this consistently and concluded that in adults the plane through the acetabular rim is always oriented anteriorly. The acetabular anteversion averages 16.5°. In neonates it is less, averaging 7°.

V.2 ORIENTATION OF THE PROXIMAL END OF THE FEMUR

The neck-shaft angle (fig. 1) averages 134° at birth, increases to 144° during the first year of life, and gradually diminishes to 126° in adult life (Lanz 1951). Femoral anteversion (figs. 2 and 3) in adults averages 8° (definition a) (Kingsley & Olmsted 1948). At birth it averages 31° (Lanz 1951). Both neonates and adults show considerable interindividual variations. After birth a physiological process of detorsion occurs which continues until adulthood (Lanz 1951). Throughout childhood detorsion occurs due to the fact that the anterior part of the growth plate of the femoral head grows more rapidly than the posterior part until the growth plate closes (Le Damany 1905, 1908).

V.3 ACETABULO-FEMORAL RELATION

The relation between the acetabulum and the proximal end of the femur in the transverse plane can be indicated by adding acetabular and femoral torsion. The acetabulo-femoral relation is disturbed when the sum exceeds 60° (Le Damany 1908). McKibbin (1970) described this sum as the instability index (fig. 2); its normal value is between 20° and 58°. Proceeding from average values, this instability index is 24.5° in adults and about twice as much in neonates. A high value of the instability index is likely to facilitate dislocation of the hip.

In the frontal plane the supportive sector (fig. 1) of a neonate can be compared with that of an adult (Lanz 1951), assuming that the angle between the mechanical axis of the femur and the femoral axis is 5°. In actual fact this angle is 1-2° less in neonates and small infants. Proceeding from average values, the supportive sector in neonates is about 75°. It diminishes to 60° during the first year of life and then increases to 90° in adults.

During the early foetal period the acetabulum encompasses nearly the entire femoral head. Subsequently the relative depth of the acetabulum diminishes to only 4/10 of a hemisphere at birth. After birth the relative depth of the acetabulum increases again, and in adulthood it is about 6/10 of a hemisphere (Le Damany 1908; Ralis & McKibbin 1973). The covering of the cartilage of the femoral head is optimal when the axis of the femoral neck coincides with the central axis perpendicularly on the plane through the acetabular rim.

It will be evident from the above that the acetabulo-femoral relation is least favourable at birth and during the first year of life, and improves with increasing age. During the first year of life the instability index has its highest value and the supportive sector its lowest.

V.4 ACETABULO-FEMORAL RELATION IN CONGENITAL DISLOCATION OF THE HIP

In most cases of congenital dislocation of the hip there is increased femoral anteversion and an enlarged neck-shaft angle. The inclination of the acetabulum increases. The increased femoral anteversion as a rule amounts to 50-60° (Shands & Steel 1958). This phenomenon has not so far been adequately explained, but it has been demonstrated in rabbits that the position of the leg is of influence (Wilkinson 1962). Protracted medial rotation of the hip-joint causes increased anteversion, while lateral rotation of the hip-joint reduces anteversion. Perhaps this suggests a mechanical cause. The anteversion in cases of congenital hip dislocation could occur at the time when the hip dislocates but also during the retention phase of treatment when the hip is kept fixed in extreme positions (Wilkinson 1963). In the case of initially pathologically increased anteversion, also, there is a natural tendency to correction during growth (Bedouelle 1977; Schwarzenbach 1971; Scholder 1968; Huguenin & Bensahel 1980; Brouwer 1981). In principle, correction can occur as long as the growth plates remain open. Correction is most pronounced during the first few years after reduction, but very limited after the eighth year of life. Correction during growth is observed in about 80% of the patients with pathologically increased anteversion.

In a normal hip-joint the proximal end of the femur is exposed to strong varus forces: part of the body weight, the hip abductors, the hip flexors and in particular the iliopsoas muscle, the hip extensors and the adductors which insert distally on the femur. In the case of dislocation the counterpressure exerted by the acetabulum on the femoral head is absent. Some of the muscles exerting varus forces on the proximal femur (e.g. the hip abductors) are eliminated, and the iliopsoas muscle exerts a valgus rather than a varus force (Bernbeck 1949) (fig. 6). The valgus force exerted by the short rotators and the adductors which insert proximally on the femur, is enhanced. A dislocated hip is predominantly exposed to valgus forces, which cause growth stimulation on the medial side and compression on the lateral side of the growth plate. This results in an enlarged neck-shaft angle.

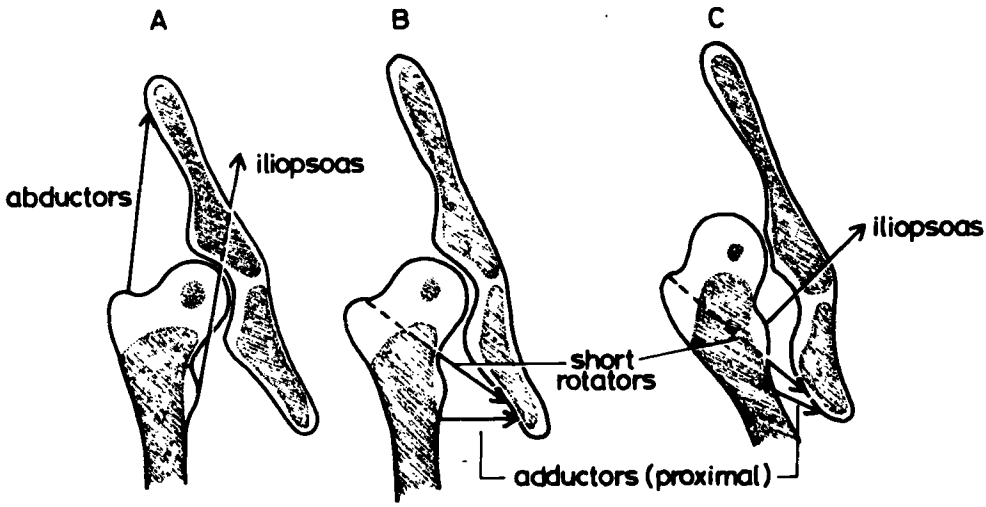


Fig. 6 Diagram of frontal section through the right hip-joint. A = varus forces; B = valgus forces; C = forces with the hip-joint dislocated: the valgus force exerted by the short rotators and adductors, which insert proximally on the femur is enhanced. The iliopsoasmuscle exerts a valgus rather than a varus force.

Delayed ossification and plastic deformation of the supero-posterior part of the acetabulum are a result of the dislocation or tendency to dislocation. This has been experimentally demonstrated in dogs by Smith et al. (1963), in rats by Harrison (1961) and in rabbits by Langenskiöld et al. (1962). They result from increased pressure exerted by the femoral head on that part of the acetabular rim. Recovery is possible when the dislocation is abolished and the femoral head properly centralized in the acetabulum. Goodfellow and Mitsou (1977) demonstrated in animal experiments that constant pressure of the femoral head in the cup can lead to adequate development of the acetabulum. Acetabular concavity develops in response to the presence of a spherical femoral head (Ponseti 1978). Delayed ossification and plastic deformation of the superior part of the acetabulum, manifested by increased inclination of the acetabulum, shows a marked tendency to recovery after reduction of the hip. Improvement may be expected up to eight years after reduction, but the tendency is most marked during the first three years (Harris 1976; Lindstrom et al. 1979; Weintroub et al. 1979). When reduction is achieved in the first year of life, normalization can be expected within two years (Lindstrom et al. 1979). After reduction between the third and the fourth year of life the result of the inductive action of the femoral head on the acetabulum is unmistakably less than that in younger children. Normalization of the acetabulum can no longer be expected when reduction is achieved after the fourth year of life.

In the case of dislocation or tendency to dislocation delayed ossification and plastic deformation occur not only in the superior but also in the posterior part of the acetabular rim. The extent to which this influences acetabular torsion has not so far been adequately studied.

CHAPTER VI

NATURAL HISTORY OF UNTREATED CONGENITAL DISLOCATION OF THE HIP

VI.1 DISLOCATION

In a totally dislocated hip the femoral head receives no counterpressure from the acetabulum and consequently enlarges (Siffert 1981). The depth of the acetabulum diminishes (fig. 7). The femoral head is situated outside the original acetabulum and usually articulates with the lateral surface of the ilium. Pressure exerted by the femoral head on the ilium can cause the formation of a shallow local depression: the "false" acetabulum. But the joint capsule still separates the femoral head from the ilium (Wedge & Wasylenko 1978).

Pain is most likely to be present when the roentgenogram reveals degenerative changes in the "false" acetabulum. Osteo-arthritis never develops when there is no "false" acetabulum. Some patients complain of pain on the non-dislocated side, which is due to overload. The flexion contracture in the hips leads to increased lordosis. In the unilateral cases this is combined with scolliosis as a result of the difference in leg length, which in high dislocations may be as much as 6 cm. However, the incidence of complaints about the back is not higher than that in a population without congenital dislocation of the hip (Wedge & Wasylenko 1979).

The adduction contracture in the hips causes increasing valgus deformation of the knee, as a result of the fact that the growth plates of the distal end of the femur and the proximal end of the tibia resume a position perpendicular to the load-bearing (Visser & Veldhuizen 1982). Subsequently this valgus deformation of the knees is often associated with overexertion of the medial ligament complex and pain as a result of degenerative changes in the lateral knee compartment. In unilateral cases the valgus deformation of the ipsilateral knee is more marked. In these cases the significant shortening and the valgus deformation in the knee give rise to an equinovarus position of the posterior and an adduction-supination position of the anterior part of the foot. As a result, the patient often has to wear disfiguring orthopaedic shoes.

VI.2 SUBLUXATION

In the case of subluxation the femoral head shows supero-posterior displacement and can articulate only with this part of the acetabulum. Because the articulating surface is thus reduced, the lateral acetabular rim is exposed to increased pressure and flattens when this situation persists. The femoral head, not inhibited in its growth on the lateral side, increases in size asymmetrically and the same applies to the medial side where counterpressure from the acetabulum is absent. The result is a flattened and broader femoral head. The cartillage of the medial part of the

Fig. 7 Natural history of untreated hip dislocation. A = normal; B = subluxation: the femoral head increases in size asymmetrically and the acetabulum becomes shallow; C = dislocation: the femoral head enlarges and the depth of the acetabulum diminishes.

acetabulum, which is likewise free from the femoral head, continues to grow - widening the acetabular floor and making the acetabulum shallow. As a result of a combination of inhibited growth in the lateral part of the acetabulum with increased growth in its medial part, the inclination of the acetabulum increases (fig. 7).

The onset of pain depends on the severity of the subluxation. Even in early adulthood any abnormal effort may give rise to complaints of fatigue or a dull pain in the inguinal region or thigh. A classical feature is the occurrence of complaints during slow, irregular efforts, e.g. sauntering, shopping, visiting a gallery or a museum. The average age of onset of pain is 35 years in women and about 55 years in men (Wedge & Wasylenko 1978). Osteo-arthritis develops about 10 years later but increased sclerosis in the part exposed to the greatest load may develop earlier. Due to the poor covering of the femoral head the area, over which the load is distributed, is smaller. The sclerosis is an expression of an increased load and may persist unchanged for years.

VI.3 NON-OPTIMAL ACETABULO-FEMORAL RELATION IN THE FRONTAL PLANE

What applies to subluxation also applies, if to a lesser extent, to a situation in which the joint is still congruent but the covering of the femoral head is insufficient. As a rule, complaints develop some 10 years later than in the case of subluxation (Wedge & Wasylenko 1978).

VI.4 NON-OPTIMAL ACETABULO-FEMORAL RELATION IN THE TRANSVERSE PLANE

Only increased femoral anteversion is considered as a possible cause of the early development of osteo-arthritis. The orientation of the acetabulum and the relation between the acetabular and femoral anteversion have not so far been considered in this context. Only Reikerås and Høiseth (1982) have so far attempted to study the possible correlation between arthrosis and increased femoral anteversion systematically. Their series of 44 patients is small, however, and their patients were selected for adequate function. The difference from the control group without arthrosis was 10° anteversion with a standard deviation of 9°.

PHYSICAL EXAMINATION

VII.1 INTRODUCTION

The findings at physical examination of an infant with congenital dislocation of the hip are largely dependent on the age at which the condition is diagnosed. The initial clinical manifestations are a result of ligamentous laxity. They are followed by changes due to muscular contractions, particularly adductor contractures. Some additional clinical symptoms develop when the infant starts to walk.

VII.2 PHYSICAL EXAMINATION OF THE NEONATE

The most reliable tests to diagnose congenital dislocation of the hip in a neonate are the Ortolani test (1948) and the Barlow test (1962).

The Ortolani test (fig. 8) involves manual reduction of the dislocated hip. The test can only be performed if the child is relaxed. A resisting, crying child contracts the hip adductors and the hamstrings, in which case the test is likely to fail. During this examination the child is lying supine on the examining table. The hips are flexed 90° and the knees are fully flexed. The hips are examined one by one. Starting with the right hip, for example, the investigator grasps the child's right upper leg with his left hand, the thumb on the inside of the thigh and the index finger and middle finger on the outside. The investigator's right hand stabilizes the left femur and the pelvis. By abducting the leg the dislocated femoral head is returned into the acetabulum past its posterior rim. Doing this the investigator experiences a

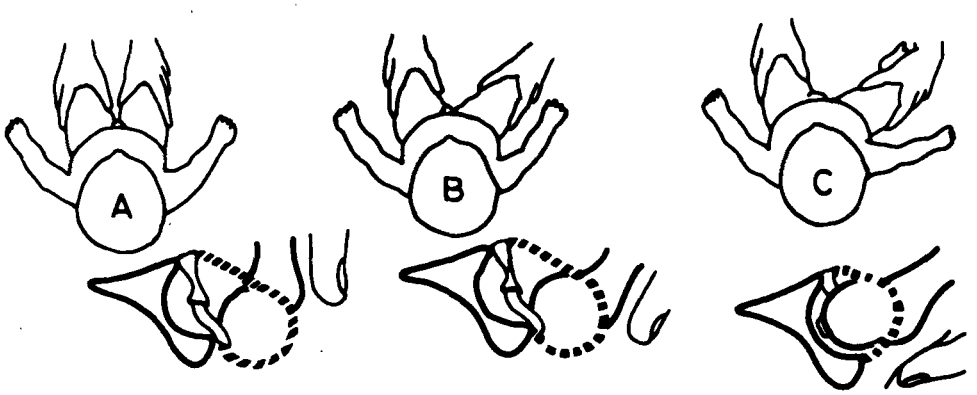


Fig. 8 The Ortolani test involves manual reduction of the dislocated hip. A: the hips are flexed 90° and the knees are fully flexed; B and C: by abducting the leg the dislocated femoral head is returned into the acetabulum past its posterior rim. Doing this the investigator experiences a sensation as if something jumps, described as "click".
(Reproduced from Stanisavljevic (1982) by permission of the editor).

sensation as if something jumps. A similar sensation is experienced when the knuckles of the fist are rubbed together. This is (incorrectly) described as "click" or "clunk". Ortolani himself described this phenomenon as "segno dello scatto" ("ridge sign"); in this way he wanted to indicate that the phenomenon is felt rather than heard. Audible "clicking" originating from soft tissues, bone and cartilage can lead to an erroneous diagnosis.

The Barlow test (fig. 9) involves two manoeuvres: one to dislocate the hip and one to reduce it. This test is used to establish the extent to which a non-dislocated hip is dislocatable. In this test the hips are in 90° and the knees in maximal flexion, the legs being otherwise in the neutral position. The investigator grasps the leg to be tested in the same way as in the Ortolani test, but during the first part of the test the thumb exerts pressure on the inside of the proximal end of the femur. When ligamentous laxity exists, the femoral head can be easily dislocated by pushing it past the posterior acetabular rim. At this moment the "click of exit" is felt: the hip is dislocatable. In the second manoeuvre the middle finger exerts pressure on the greater trochanter and, as the "click of entrance" is felt, the femoral head is returned into the acetabulum past its posterior rim.

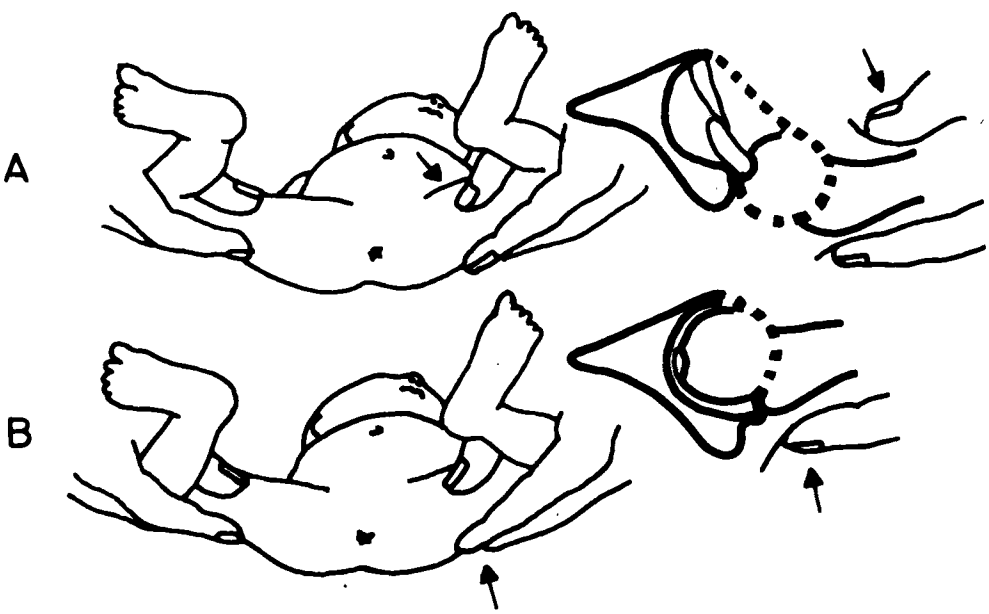


Fig. 9 The Barlow test is used to establish the extent to which a non-dislocated hip is dislocatable. A: the hips are in 90° and the knees in maximal flexion. In the first part of the test the thumb exerts pressure on the inside of the proximal end of the femur; when ligamentous laxity exists, the femoral head can be dislocated. At this moment the "click of exit" is felt. B: in the second manouvre the middle finger exerts pressure on the greater trochanter and as the "click of entrance" is felt, the femoral head is returned into the acetabulum. (Reproduced from Stanisavljevic (1982) by permission of the editor).

The importance of the two tests is that they enable us to establish at birth whether we are dealing with a dislocated or with a dislocatable hip. In the former case there may be more ligamentous laxity, and this could have implications for treatment. However, this hypothesis has been insufficiently verified; the difference in findings probably largely depends on the position of the legs during the test (Cyvin 1977).

At birth there is a flexion contracture of about 28°. There is 80°-90° abduction, 60° medial rotation and 90° lateral rotation measured on the supine infant with the hips and knees in 90° flexion (Haas et al. 1973).

Occasionally the Ortolani test is negative when the hip is dislocated. In that case the hip is fixed in the "false" acetabulum and the findings at physical examination are the same as those obtained after the neonatal age (Ortolani 1976).

VII.3 PHYSICAL EXAMINATION AFTER THE NEONATAL AGE

In the case of a dislocated or dislocatable hip, ligamentous laxity is always present at birth. There are hardly any contractures. In a large number of cases, however, the ligamentous laxity disappears spontaneously. Only a minority of about 10% develops permanent dislocation (Barlow 1962).

By the time the child is two months old secondary changes, particularly contractures, become more pronounced. In the Ortolani test and in the second manoeuvre of the Barlow test the flexion contracture of the iliopsoas muscle is abolished by flexing the hip 90°, but the adduction contracture prevents reduction. At the age of three months the normal abduction of the hip in 90° flexion still is 60°-70° (Cyvin 1977). Less than 60° abduction is to be regarded as pathological until the contrary is proven (fig. 10).

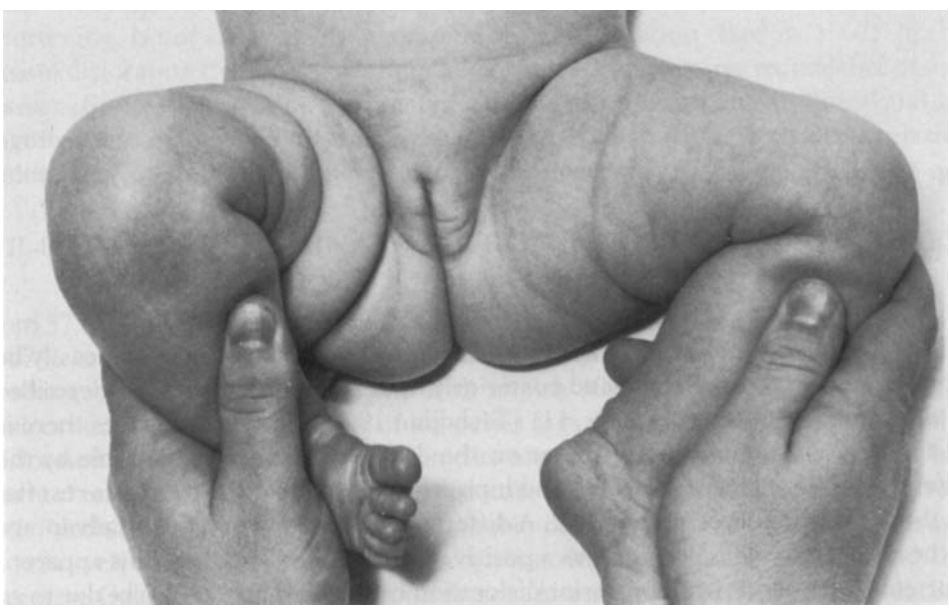


Fig. 10 Restricted abduction in congenital dislocation of the right hip with deepened inguinal and thigh folds.

At the age of six weeks the flexion contracture has diminished to about 19°, and at the age of three months it is only about 7°. At the age of three months the medial rotation measured on the prone infant with the hips extended and the knees in 90° flexion is 25° and the lateral rotation 45° (Coon et al. 1975). The higher value of lateral rotation is explained by the fact that, in childhood, the iliopsoas muscle is still a strong lateral rotator as well as a flexor of the hip (McKibbin 1968). With a dislocated hip the leg is often in 15°-20° lateral rotation due to contracture of this muscle.

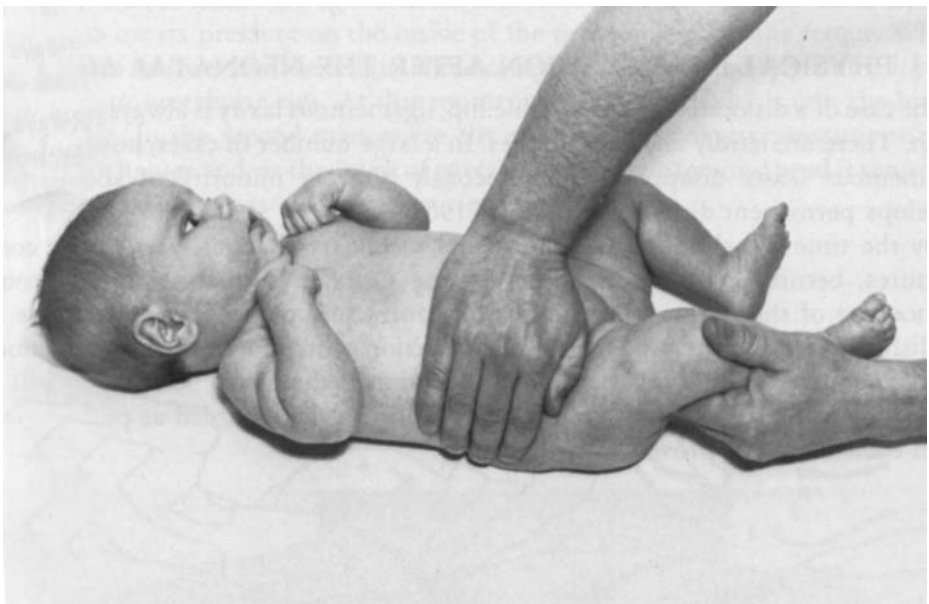


Fig. 11 Telescoping test.

Because the femoral head lacks the covering of the acetabulum, it can easily be moved superiorly in extension and posteriorly in flexion. This situation is described as a positive telescoping test (fig. 11) (Tachdjian 1972). In unilateral cases there is an apparent shortening of the femur on the dislocated side, demonstrable by the difference in knee level. The knees and hips are so flexed that the footsoles rest flat on the supporting layer, side by side. A difference in knee level to the disadvantage of the dislocated side is described as a positive Galeazzi sign (fig. 12). This apparent shortening can result from posterior dislocation of the hip but may also be due to an adduction contracture. It is therefore of importance to perform this test with both legs in a position perpendicular to the line connecting the two anterior iliac spines.

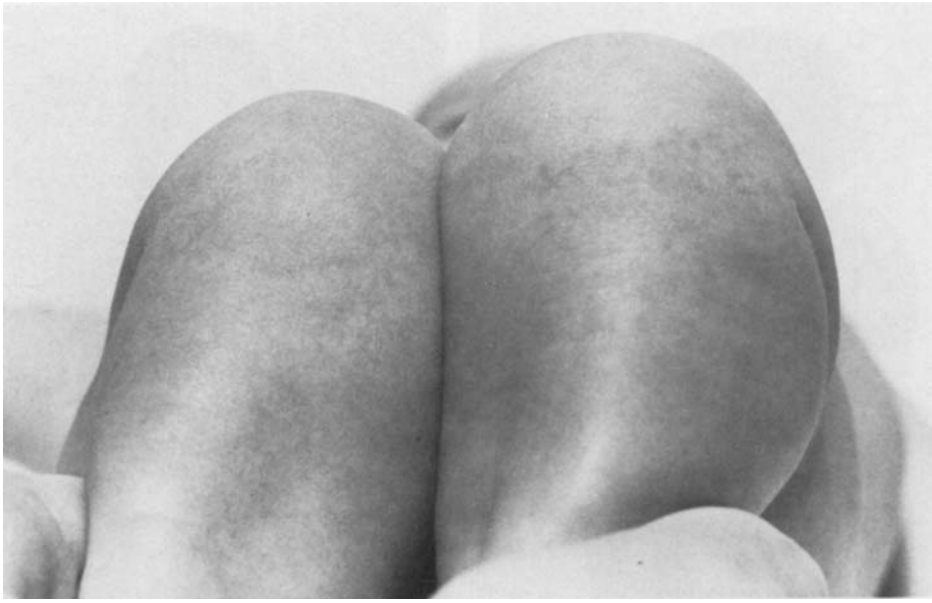


Fig. 12 Positive Galeazzi sign. Difference in knee height to the disadvantage of the dislocated right side.

The additional thigh fold especially near the perineum, which is caused by shortening, is not always pathognomonic of hip dislocation (Barlow 1962). In the case of dislocation the additional thigh folds are caused by relative redundance of soft tissues (fig. 13a). A striking feature in the unilateral cases is that the gluteal and/or inguinal fold is longer than that on the unaffected side (fig. 13b). Due to relative redundance of soft tissues, these folds are also deeper.

VII.4 PHYSICAL EXAMINATION AFTER THE INFANT HAS STARTED TO STAND AND WALK

Som 37.5% of all children start to walk between the 9th and the 12th month of life; 84.7% started between the 13th and the 15th month, and normally 100% are walking between the 16th and the 19th month (Cyvin 1977). In the case of hip dislocation the contralateral side of the pelvis sags during the standing phase of the dislocated side. The vertrebral column tilts towards the affected side and there is a vertical telescoping movement in the dislocated hip. In bilateral cases the characteristic "duck-like waddle" develops. The number of bilateral cases revealed at this age is relatively large because, due to the symmetrical abduction limitation and the negative Galeazzi sign, the condition is not infrequently overlooked in an earlier phase. Especially in the bilateral cases the space between the legs immediately below the perineum is increased; there is hyperlordosis and the pelvis tilts (fig. 14a and b).

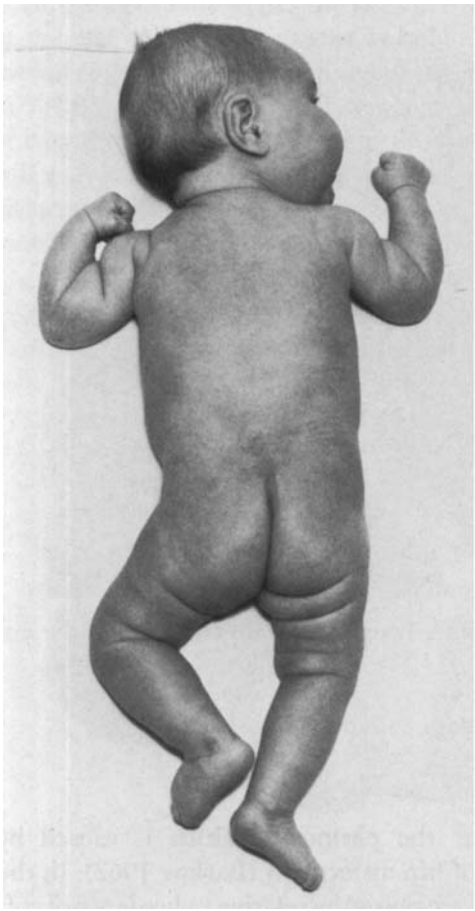


Fig. 13a Additional thigh fold on the dislocated right side.

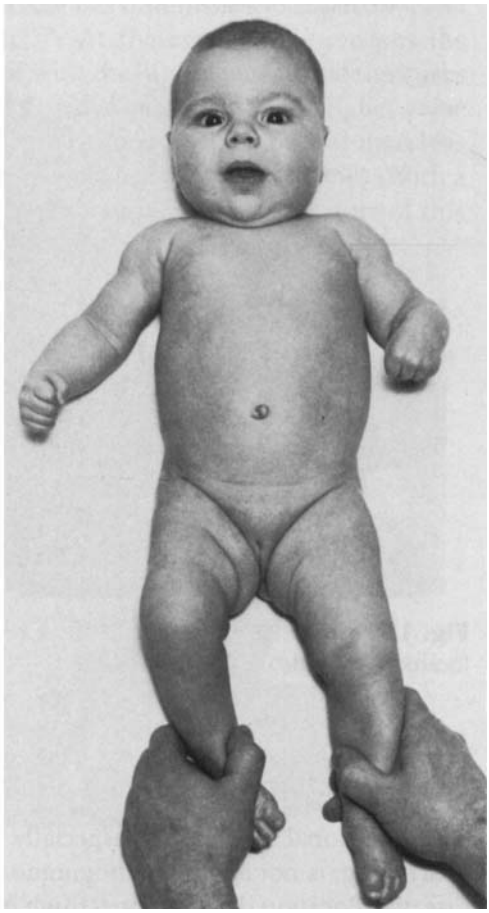


Fig. 13b Apart from the additional thigh fold the inguinal fold is longer and deeper than on the normal side.

The Trendelenburg test is positive when the infant is standing on the dislocated side (fig. 15a and b). On the contralateral side the pelvis sags because the distance between origin and insertion of the hip abductors diminishes, placing these muscles low in the stress-strain diagram. Given a normal hip, the pelvis on the contralateral side is lifted as a result of contraction of the hip abductors.

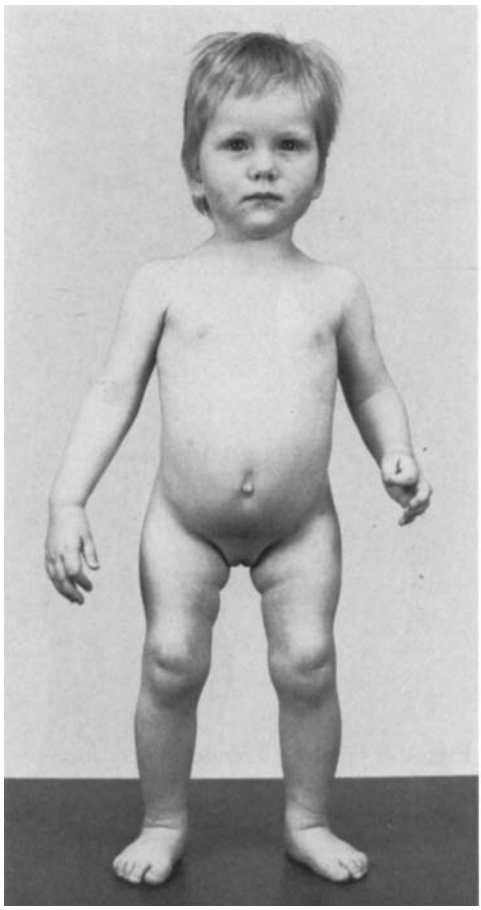


Fig. 14a Bilateral congenital hip dislocation with widening of the space between the thighs at the level of the perineum.

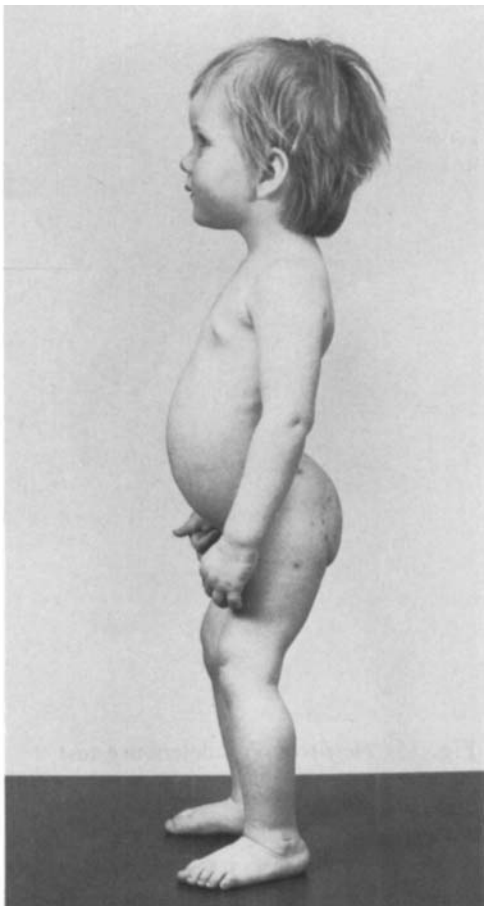


Fig. 14b Deep lordosis and tilted pelvis in bilateral congenital hip dislocation.

Fig. 15a Negative Trendelenburg test.

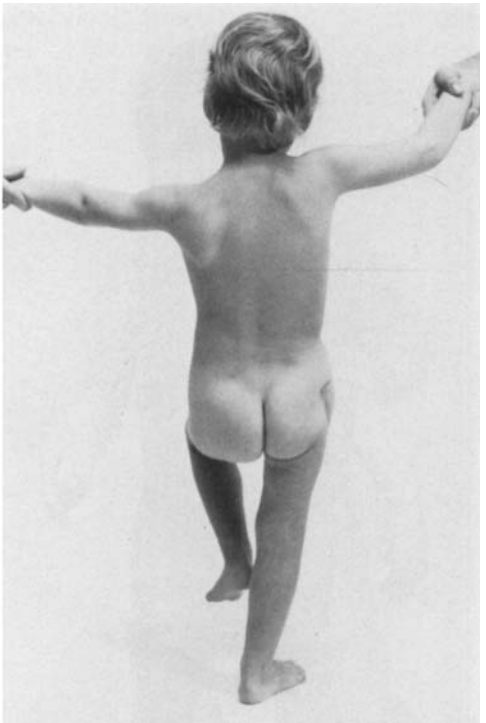


Fig. 15b Positive Trendelenburg test.

VII.5 PHYSICAL EXAMINATION AFTER TREATMENT OF CONGENITAL DISLOCATION OF THE HIP

In order to diagnose a disturbance in the function of the hip-joint one should understand the normal excursions of the hip-joint. These excursions are measured in accordance with the guidelines provided by "The American Academy of Orthopaedic Surgeons" (1965). Flexion, abduction and adduction are measured in a supine position; extension, lateral rotation and medial rotation in a prone position. The excursions are measured with the aid of a goniometer.

The normal values in a child aged four to six years (Cyvin 1977) are:

— flexion 130°± 5°
— extension 20°± 5°
— abduction 45°±10°
— adduction 25°± 5°
— medial rotation 55°±15°
— lateral rotation 55°±15°

At the adult age flexion has diminished to about 120° and extension to about 12°, while lateral and medial rotation are both about 45° (Boone & Azen 1979).

The increased anteversion which develops as a rule, causes increased medial rotation and decreased lateral rotation. A slow correction normally follows. An

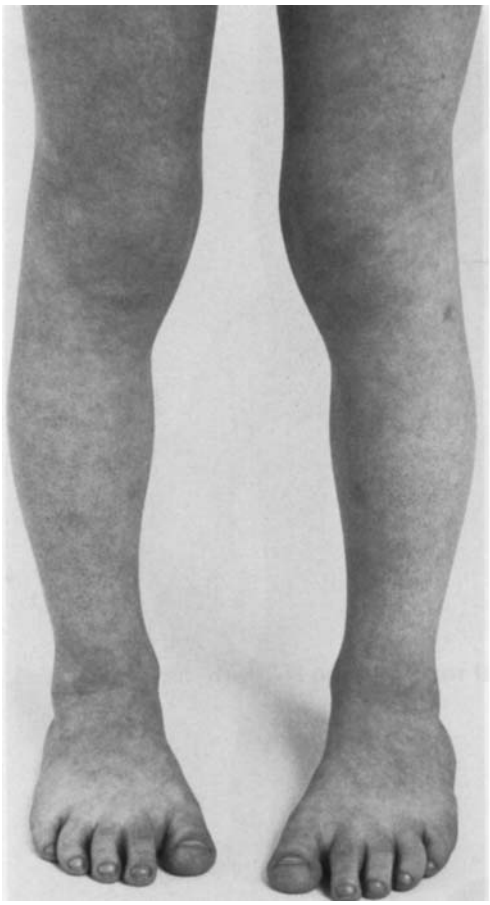


Fig. 16 medially rotated patellae and in-toeing feet, indicating increased possible medial rotation.

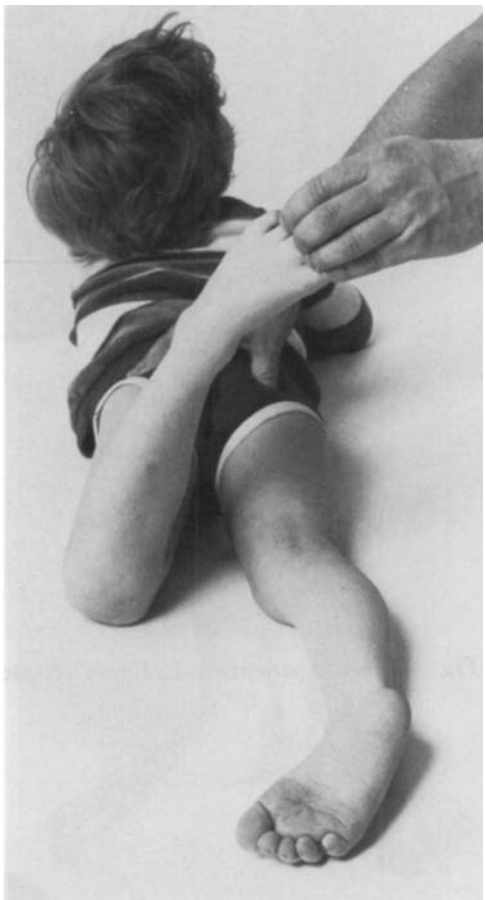


Fig. 17a Same patient is in figure 16. Lateral rotation up to 20° with the hip extended.

in-toeing gait with the patellae rotated medially (fig. 16) indicates an increased possibility of medial rotation from 60° to 80° and a diminished possibility of lateral rotation from 40° to 20° (fig. 17a and b) (Crane 1959). The total rotation possible with the hip extended is about 100°. The lateral rotation possible with the hip flexed increases. The ratio between medial and lateral rotation differs from that with the hip extended (Somerville 1982). The children often sit in the characteristic television or W-position (fig. 18). Sometimes they stumble noticeably more often than other children. At a later age the increased medial rotation in the hip-joint is sometimes corrected by lateral rotation in the lower leg. In that case there is no in-toeing but the patellae are rotated medially (fig. 19a and b), and the lateral torsion in the tibiae (normally 20°) is increased (Staheli 1980). This medial rotation of the patellae can later give rise to patello-femoral complaints.

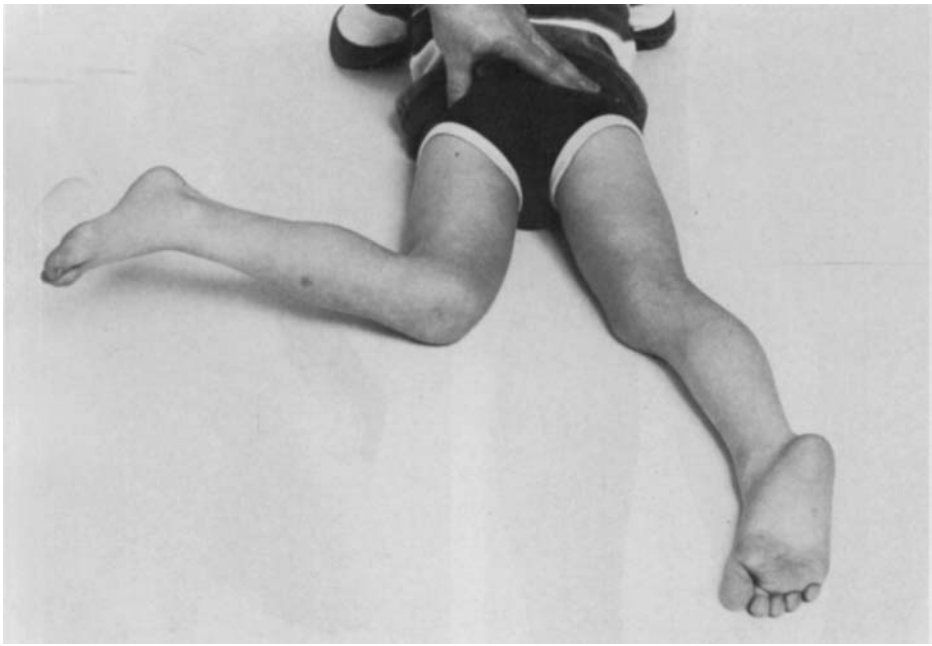


Fig. 17b Same patients as in figure 16. Medial rotation up to 80° with the hip extended.

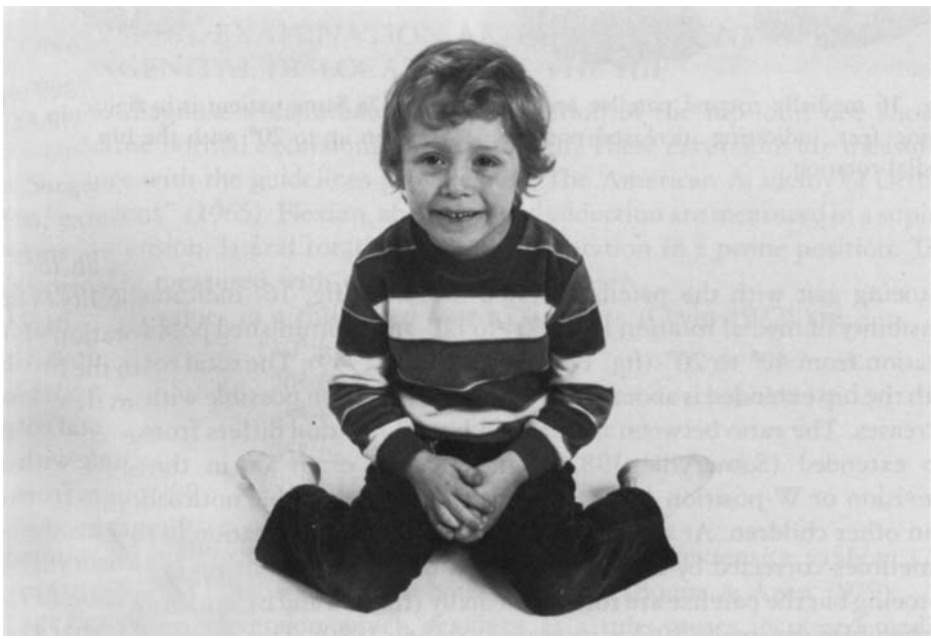


Fig. 18 W-position or television position.

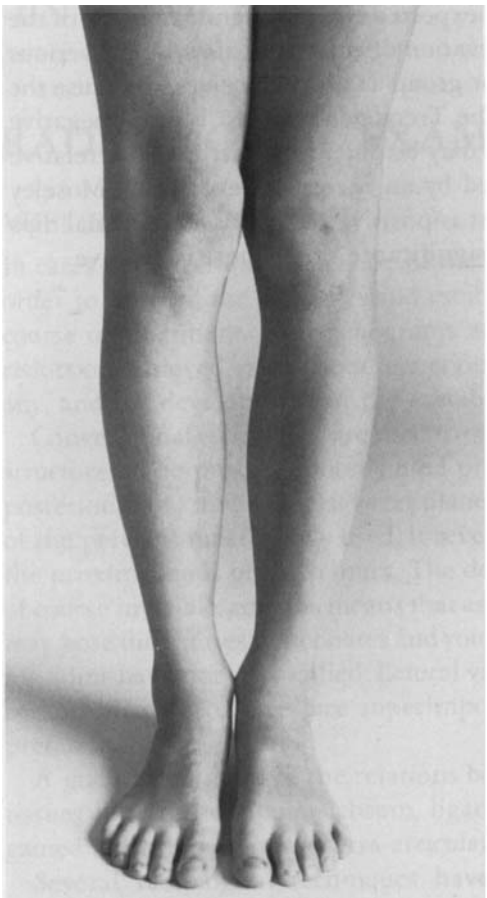


Fig. 19a Increased medial rotation in the hip-joint compensated by lateral torsion in the lower leg. Medial rotation of the patellae but no intoeing.

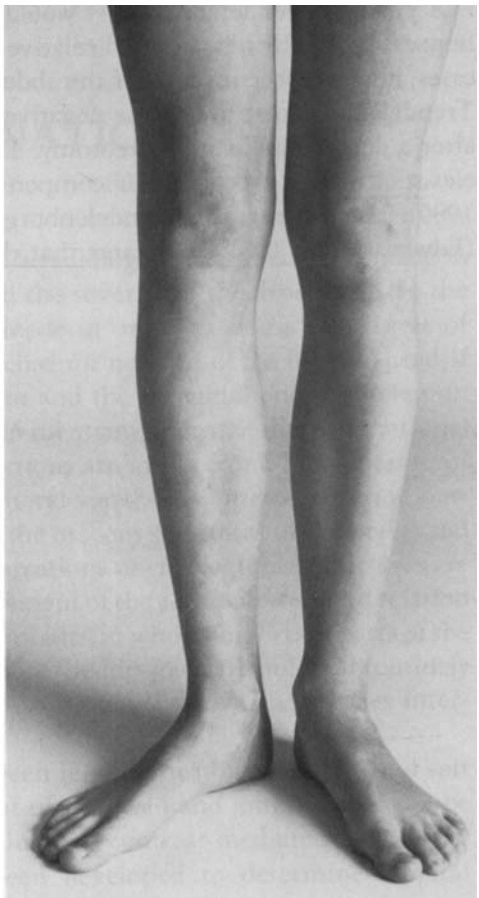


Fig. 19b When the patellae are straightened the feet are in lateral rotation.

In assessing leg length difference, the superior anterior iliac spines are palpated with the patient standing upright with the legs in the neutral position. If the spines are at the same level, then there is no difference in leg length. Otherwise, pieces of wood of varying thickness are placed beneath the foot of the short leg untill the spines are at the same level. The total thickness of the pieces of wood required to achieve this, indicates the leg shortening. A leg length difference of 5 cm can occur in cases of total ischaemic necrosis of the femoral head (Kalamchi and McEwen 1980).

An intertrochanteric derotational varus osteotomy can cause shortening of the leg on the side of the operation, which in a number of cases disappears as a result of recurrence of the valgus position (Jones 1977). After a Salter osteotomy (1961) the treated leg is likely to become about 1 cm longer (Rab 1978).

A positive Trendelenburg test would be expected after ischaemic necrosis of the femoral head which has caused relative elevation of the trochanter. In less serious cases, however, the muscles of the abductor group adapt themselves and cause the Trendelenburg test to become negative. The Trendelenburg test is often negative after a derotational varus osteotomy. This may be due to the fact that the relative elevation of the trochanter is compensated by an increased lever arm (Moseley 1980). The fact that the Trendelenburg test is positive in 9.5% of all normal hips (Edwards et al. 1981) illustrates that the significance of this test is relative.

CHAPTER VIII

RADIOLOGICAL EXAMINATION

VIII.1 INTRODUCTION

In cases of congenital dislocation of the hip a radiological examination is made in order to confirm the diagnosis and establish the severity of the dislocation. In the course of treatment, roentgenograms are made in order to assess the degree of reduction achieved, permanent reduction, ischaemic necrosis of the femoral head, if any, and the development of the acetabulum and the proximal end of the femur.

Conventional techniques are used to obtain roentgenograms of threedimensional structures. The most commonly used projections are in the frontal plane (antero-posterior view) and in the sagittal plane (lateral view). The antero-posterior view of the pelvis is most widely used. It reveals the osseous structures of the pelvis and the proximal ends of the femurs. The demarcations of cartilaginous structures are of course invisible, and this means that assessment of the acetabulo-femoral relation may pose difficulties in neonates and young infants, in whom important parts of the hip-joint have not yet ossified. Lateral views of the hip-joint are not used routinely because many structures are superimposed in these views, which impedes interpretation.

A good impression of the relations between femoral head/acetabulum and soft tissues like the acetabular labrum, ligament of the head and joint capsule can be gained with the aid of an intra-articularly injected contrast medium.

Several radiological techniques have been developed to determine femoral torsion; but the torsion of the acetabulum has received far less attention because the degree of acetabular torsion cannot be determined by conventional roentgenographic techniques. It can be done, however, by means of computer-aided tomography, which depicts transverse sections. In this way the positions of acetabulum and femoral neck, and especially the acetabulo-femoral relation ("instability index") can be determined without undue difficulty. Moreover, this technique provides a good impression of the degree of posterior dislocation.

VIII.2 PROJECTION IN THE FRONTAL PLANE

In a neonate the ossification centre of the femoral head is not yet visible on roentgenograms of the hip. In normal hips it appears during the fourth month in some 50% of cases, and normally it is present at the age of eight months. There is no difference between males and females in the time of appearance of the ossification centre of the femoral head (Kaiser 1958). In the case of congenital dislocation of the hip the ossification centre becomes visible later and is smaller than that on the normal side (Putti 1933).At birth, the lateral part of the normal acetabulum is not yet fully ossified either. In the case of congenital dislocation of the hip the ossification of this part is clearly delayed as compared with that in the normal hip.

Acetabulum

The yardstick used to measure the progressive ossification in the lateral part of the acetabulum is the acetabular angle (Hilgenreiner 1925), otherwise known as the "acetabular index" (Kleinberg & Lieberman 1936) (fig. 20).

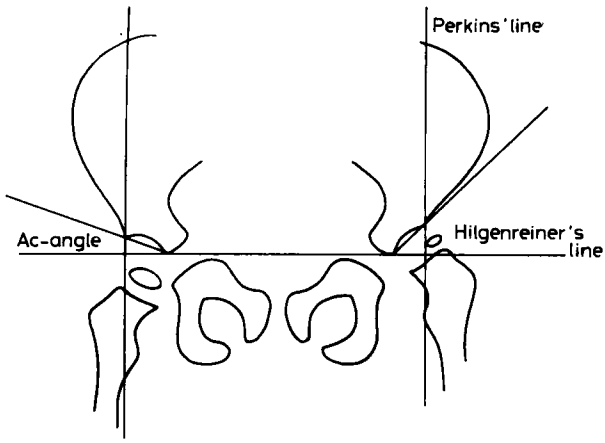


Fig. 20 Diagram of an antero-posterior view of the pelvis. The following auxiliary lines are drawn: a horizontal line: the Y-line or Hilgenreiner's line; perpendicular to this line are drawn from the lateral boundary of the acetabulum: Perkins' lines. In a normal hip-joint the ossification centre of the femoral head is localized inferiorly to the former and medially to the latter. The left hip-joint is dislocated. The acetabular angle is increased; Shenton's line is interrupted and the ossification centre of the femoral head is smaller than that on the contralateral side (Rogge & Driessen 1974).

The orientation of the acetabulum in the frontal plane is indicated by means of the acetabular angle, not by means of the inclination of the acetabulum. Only Sharp (1961) recommends the latter as a measure of the orientation of the acetabulum in the frontal plane. A disadvantage of the inclination is that the medio-inferior demarcation of the acetabulum cannot be determined until the age of about three months, and more specifically when the "U-figure" or "pelvic tear-drop" is visible in the antero-posterior view of the pelvis. The "U-figure" or "pelvic tear-drop" consists of three lines: a semicircular line formed by the acetabular rim, a near-vertical line formed by the rim of the true pelvis and a short, inferiorly curved transverse connecting line formed by the semicylindrical demarcation of the acetabular notch (fig. 22).

The width of the projected acetabular angle depends on the anteversion of the acetabulum. Increased anteversion causes widening of the acetabular angle (Visser & Konings 1982). A similar effect is obtained by rotating the pelvis on a vertical axis. In order to gain an impression of the degree of pelvic rotation the projections of the obturator foramina can be compared. For this purpose a line is drawn parallel

to Hilgenreiner's line through the most medial points of the obturator foramina at the site of their maximal diameter (fig. 21). When the diameter of the left obturator foramen equals that of the right, there is no pelvic rotation. When the ratio between the two diameters is between 0.56 and 1.8, the error in measuring the acetabular angle is less than 2° (Tönnis & Brunken 1968).

The orientation of the acetabulum is also influenced by the pelvic tilt. In a normal standing human subject the plane through the pelvic inlet describes an angle of about 60° with the horizontal plane. If the angle is wider, then the pelvis is described as tilted; if it is narrower, then the pelvis is described as upright. In the case of a tilted pelvis the projection of the pelvic inlet in the antero-posterior view becomes more circular, while that of the obturator foramina assumes a transverse oval shape. In the case of an upright pelvis the projection of the pelvic inlet assumes a transverse oval shape and the obturator foramina seem more circular. The symphysioischial angle provides a measure of the degree of rotation of the pelvis on the horizontal axis. This angle is formed by two lines drawn through the most superior points of the pubic bone in the immediate vicinity of the symphysis and the most superior medial points of the ischium (fig. 21).

In order to prevent the measuring error in calculation of the acetabular angle from exceeding 3°, the symphysio-ischial angle should be between 100° and 125° in infants younger than one year, and between 90° and 115° in children older than one year (Tönnis & Brunken 1968).

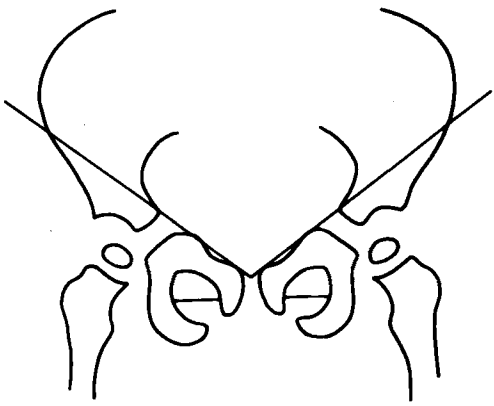


Fig. 21 Assessment of rotation and tilt on an antero-posterior view of the pelvis. A line is drawn parallel to Hilgenreiner's line through the obturator foramina. The proportion between the diameter of the right and that of the left obturator foramen provides a measure of the pelvic rotation. Two lines are drawn through the most superior points of the pubic bone at the symphysis and the most superior medial points of the ischium; these lines indicate the symphysio-ischial angle which gives an impression of the degree of pelvic tilt.

Femur

The orientation of the proximal end of the femur in the frontal plane is indicated by the neck-shaft angle. The width of the projected angle is dependent on the degree of torsion. It increases as anteversion or retroversion increases.

Acetabulo-femoral relation in the frontal plane

The relation between acetabulum and femoral head in the frontal plane is indicated by the CE-angle (C for "centre" and E for "lateral Edge of the acetabular roof" according to Wiberg (1939) (fig. 22)). Wiberg's CE-angle is more useful in measuring the covering of the femoral head than the supportive sector, because the latter largely depends on the femoral anteversion and the position of the femur. Wiberg's CE-angle is independent of the anteversion unless this gives rise to lateralization of the femoral head. Given a spherical femoral head, the CE-angle is independent of abduction and adduction of the hip. In the case of subluxation the CE-angle increases in abduction and diminishes in adduction.

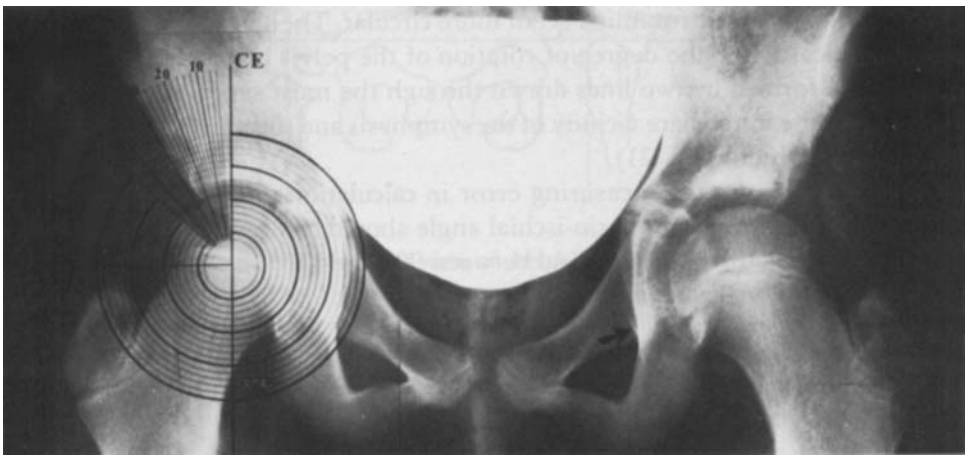


Fig. 22 Antero-posterior view of the pelvis. The black arrow indicates the "U-figure" or "pelvic teardrop". The centre of the femoral head is located by placing a transparent ruler with concentric circles over the femoral head. With the aid of the concentric circles an impression of the femoral head can also be gained. CE = CE-angle.

In an immature skeleton the connecting line through the femoral heads can be replaced by Hilgenreiner's line (Massie & Howorth 1950). The latter is more accurate than the former when dislocation is present. The centre of the femoral head is located by placing a transparent ruler with concentric circles over the contours of the femoral head on the roentgenogram (fig. 22). In older children and adults one of these circles coincides with the demarcation of the femoral head, and its centre can thus be determined without difficulty (Mose 1964). In younger infants the ossified part of the femoral head is usually not spherical. In these cases the centre of the acetabular concavity is taken as centre of the femoral head. The curvature of the acetabulum is the segment of a circle which is congruent with a circle round the femoral head, and consequently the centres of these circles coincide. This applies only to a non-dislocated or concentrically reduced hip-joint. In younger infants the centre of the femoral head as a rule falls just within the metaphyseal part of the

femoral head. In a deformed femoral head the centre of the mass does not coincide with the centre of rotation (Moseley 1980) (fig. 23). The centre of rotation is taken for calculation of the CE-angle. The general rule is: the wider the CE-angle, the larger the covering of the femoral head. An exception to this rule is any situation in which one femoral head is enlarged. In that case the CE-angle on the side of the enlarged femoral head is less wide than that on the contralateral side. Given identical acetabula, the surface area over which the load is distributed, is the same. It can be stated that, given the same CE-angle, the femoral head surface area over which the load is distributed, increases as the size of the femoral head increases (Moseley 1980).

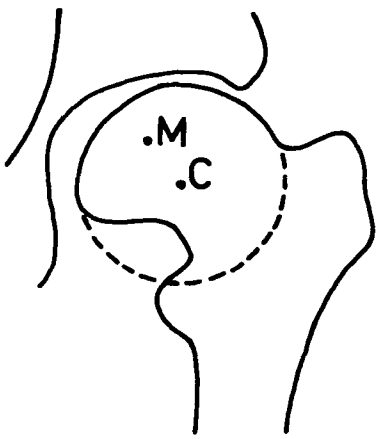


Fig. 23 In a deformed femoral head the centre of the mass (M) does not coincide with the centre of rotation (C). The latter is the centre of the acetabular concavity. For calculation of the CE-angle the centre of rotation is used.

Lateralization of the femur can be detected by drawing a vertical line from the most lateral demarcation of the acetabulum on the roentgenogram (Perkins 1928) (fig. 20). The roentgenogram should have been made with both femurs in neutral position between adduction and abduction. In a normal hip-joint the medial part of the femoral metaphysis is seen medially to Perkins' line. If it is seen laterally to this line, then dislocation always exists (Coleman 1978).

Upward migration of the femoral head can be determined by comparing the dislocation side with the normal contralateral side. In the case of bilateral dislocation an auxiliary line can be drawn through the superior demarcations of the public symphysis parallel to the Hilgenreiner's line (Rosen 1956) (fig. 24). In infants the medial part of the femoral metaphysis normally lies below this line. A neutral position of the legs is an absolute prerequisite because the position of the medial part of the femoral metaphysis largely depends on the abduction, adduction and rotation of the proximal femur. In adduction and lateral rotation the medial part of the femoral metaphysis is elevated. When the supero-medial demarcation of the femoral metaphysis is projected level with or higher than Hilgenreiner's line, the condition is described as a high dislocation (fig. 24). If it is projected level with that

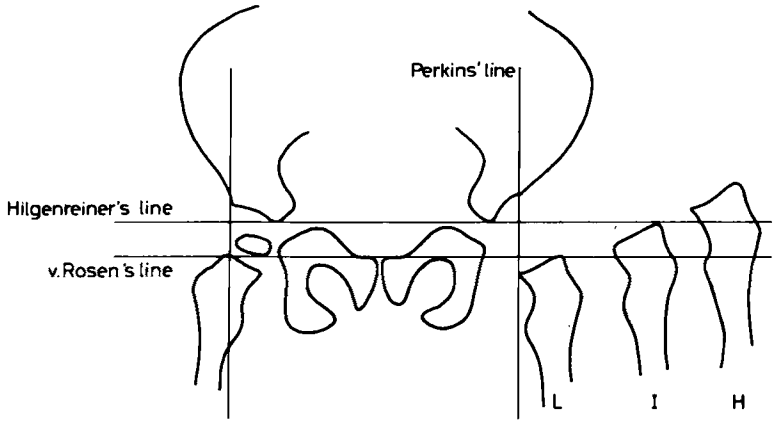


Fig. 24 To determine the level of dislocation a Y-line or Hilgenreiner's line and a parallel line through the superior boundaries of the pubic bones are drawn (V.Rosen's line). L = low dislocation; I = intermediate dislocation: H = high dislocation.

on the normal contralateral side or, in the case of bilateral dislocation, level with or lower than the line through the symphysis parallel to Hilgenreiner's line, then the condition is described as a low dislocation (fig. 24). Intermediate dislocation is present when the medial part of the metaphysis is seen between these lines (fig. 24).

In some neonates there may be doubt about the presence or absence of dislocation. In these cases an antero-posterior view of the pelvis with the legs in 45° abduction and in full medial rotation can be helpful. In the case of dislocation the femoral shaft axis points in the direction of the anterior superior iliac spine. In a normal hip-joint the femoral shaft axis points in the direction of the lateral part of the acetabulum (Andrén & Rosen 1958). A source of error in this context lies in the fact that reduction can be achieved by abducting the legs, leading to the erroneous conclusion that the hip examined is not abnormal.

On an antero-posterior roentgenogram of the pelvis an arc can be drawn which extends from the lesser trochanter along the medial edge of the femoral neck to the medial demarcation of the obturator foramen (fig. 20). This line - known as Shenton's line - is a regular, uninterrupted, bilaterally congruent arc. In the case of dislocation this line is interrupted, but the same is observed in the case of increased valgus position or increased anteversion of the femur (Ball & Kommenda 1968).

VIII.3 TORSION OF THE FEMUR

There are three conventional methods which can be used to determine femoral torsion:

a. **Fluoroscopy** (Rogers 1931)

The patient lies prone with the roentgen tube focused on the extended hip, while the investigator flexes the patient's knees 90°. Under fluoroscopic control the hip is rotated laterally until the projections of the axes of femoral neck and femoral shaft are in line. The femoral neck then has its minimal projected length.

The angle formed by the lower leg and the plane of the examining table provides a measure of the degree of anteversion of the femoral neck. In the case of retroversion the hip should be rotated medially in order to line up the axis of the femoral neck and that of the femoral shaft. Anteversion can also be measured by rotating the leg medially until the neck-shaft angle is minimal and the projection of the femoral neck has its maximal length. The angle between the lower leg and the axis perpendicular to the examining table in that case indicates the degree of anteversion. In the case of retroversion the leg should be rotated laterally in order to obtain the minimal neck-shaft angle.

b. **Axial roentgenography** (Budin & Chandler 1957)
The patient lies supine the knee and the hip are flexed 90° while the leg is in the neutral position between abduction, adduction, lateral- and medial rotation. The roentgen rays are focused on the hip with the beam parallel and medial to the axis of the femoral shaft. This method is applicable only until the age of approximately seven years; after this the projection of the soft tissues blurs the image of the proximal femur. This problem can be solved by combining this technique with tomography (Manlot et al. 1966).

c. **Biplanar roentgenography** (Dunlap et al. 1953)
This is the technique most widely used. Torsion and neck-shaft angle are calculated from their projected images on two roentgenograms. First, an anteroposterior roentgenogram of the pelvis is made with the patient supine and the lower legs dangling in the neutral position. The second roentgenogram is made with the hips and knees in 90° flexion and in addition the hips in 20° (Rippstein 1955; Dunlap et al. 1953) or in 30° abduction (Ryder & Crane 1953) and neutral rotation (case 5). For this purpose the legs are fixed in this position in a special device (Rippstein 1955). The real neck-shaft angle and torsion can be calculated with the aid of two goniometric equations. As a rule, projected values are converted to real values with the aid of tables prepared for this purpose.

Proper positioning of the patient is of paramount importance in these techniques. When applied by the same investigator each of the three methods entails a measuring error of about 5° (Ruby et al. 1979). When used by different investigators the biplanar technique entails a measuring error of about 15° (Sullivan et al. 1982).

VIII.4 TRANSVERSE SECTIONS

Transverse sections through the hip-joints can be visualized by means of computer-aided tomography. This technique makes it possible to measure the torsion of the acetabulum and the femoral neck as well as the instability index with an accuracy of 2° (fig. 25) (Visser & Jonkers 1980; Visser et al. 1982a).

When all sections are made through the hips the legs should be exactly in neutral rotation and 0° extension. When additional sections through the femoral condyles are made and projected over the sections through the hip-joints, the values prove to be virtually independent of the patient's position. In this way the three-dimensional image of the hip-joint is completed by assessing computer-aided tomograms as well as conventional roentgenograms.

Computer-aided tomography of neonates in whom congenital hip dislocation is suspected, is useless with most types of tomograph unless a contrast medium is injected into the hip-joint. Otherwise the cartillage is indistinguishable from the adjacent structures and dislocation, if any, can therefore not be demonstrated, nor can femoral torsion be measured. This is not possible until the ossification centre in the femoral head appears (Visser et al. 1982b). Since it involves a high radiation load this examination may be considered only if an indication for it arises in the course of treatment of congenital dislocation of the hip.

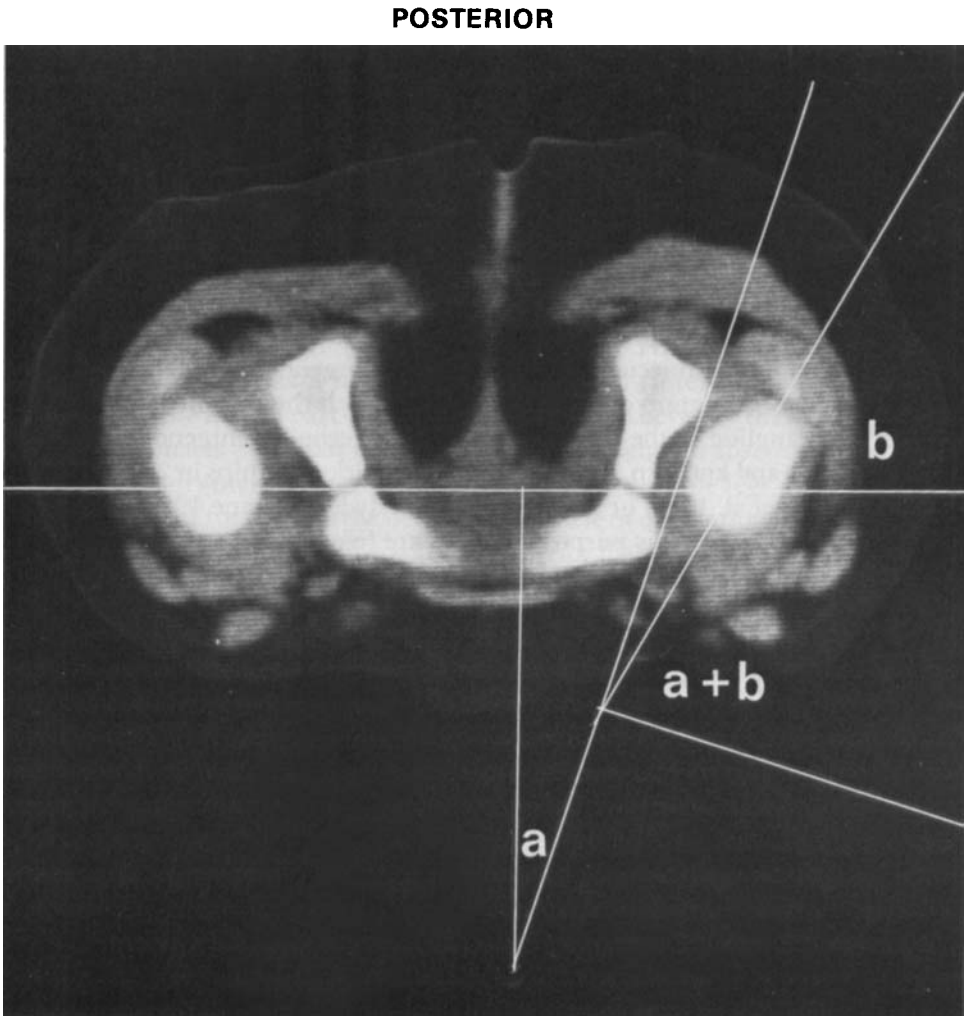


Fig. 25An 18-month-old boy with congenital dislocation of the right hip. The distance between the right femoral head and the triradiate cartilage is greater than on the left side. The posterior edge of the right acetabulum is deficient. Acetabular anteversion on both sides a = 20°. Femoral anteversion on both sides b = 60°. Instability index a + b = 80°. Baseline through the triradiate cartilages.

VIII.5 ARTHROGRAM

By intra-articular injection of a contrast medium the demarcations of the articular surfaces of non-ossified parts of the acetabulum and femoral head as well as the synovial membrane can be visualized roentgenographically (Grech 1977). Capsule constrictions can be observed, and an impression can be obtained of the amount of fibro-fatty tissue in the acetabulum (fig. 26). In some cases a well-defined profile of the ligament of the head becomes visible. An inverted acetabular labrum can be distinguished from an everted one, and thus this technique can differentiate between subluxation and dislocation. Finally an acetabulo-femoral discongruence may be revealed by arthrography.

Arthrography cannot be used as routine procedure in view of the high radiation load it involves. It is indicated only if in the course of treatment doubt arises about the sufficiency of the degree of reduction achieved.

Arthrography is performed under general anaesthesia, the child lying supine with both hips in 90° flexion and maximal abduction and lateral rotation. The hip-joint is punctured under strict aseptic precautions, using a needle with a stylet inside. The needle is inserted immediately posterior to the long adductor muscle and 1 cm lateral to its origin, and moved parallel to the body axis. The capsule of the hip-joint is punctured on the medio-inferior side under fluorscopic control. A degree of resistance is felt, and slight pressure is exerted to drive the needle into the joint. As the needle advances it touches the femoral head, whereupon it is very slightly retracted and the stylet is removed. A normal saline solution is injected into the joint and, if this meets with no resistance, the puncture can be regarded as successful.

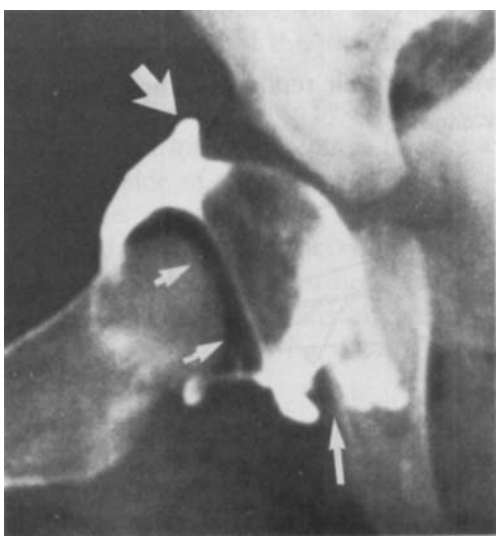


Fig. 26 Arthrogram of the right hip. The broad arrow indicates the transition from acetabular labrum to capsule; contrast medium is visible between the labrum and the capsule, this site resembling a "rose thorn". This "rose thorn" is absent when the acetabular lip is inverted. The long arrow indicates the site of the transverse ligament. The two short arrows indicate the "orbicular zone", where the capsule fits snugly against the femoral head.

A few drops of contrast medium are then injected under fluoroscopic control. When the needle is properly positioned, 1-2 ml contrast medium is injected into the hip-joint.

VIII.6 NORMAL VALUES

Acetabular angle

In a normal hip-joint the acetabular angle does not exceed 30° in the first year of life; it does not exceed 25° between one and three years, and is not wider than 20° between the age of three years and adult life (Harris 1976; Weintroub et al. 1979; Tönnis 1981).

Neck-shaft angle

This angle is 134° at birth, increases to 144° during the first year of life, and then gradually diminishes to 126°. There are considerable interindividual variations, and 145° can still be regarded as within normal limits up to the age of 16 years (Lanz 1951).

CE-angle

Severin (1941) held that CE-angles of 20° and wider should be regarded as normal between six and 13 years of age. CE-angle measurements are unreliable until the age of three years, because the ossification centres of the femoral heads are irregular until that time. Above the age of three years the CE-angle in normal hips is 20° or wider (Massie & Howorth 1950; Weintroub et al. 1979).

Femoral anteversion

Investigators differ widely in their reports on the average value of femoral ante-

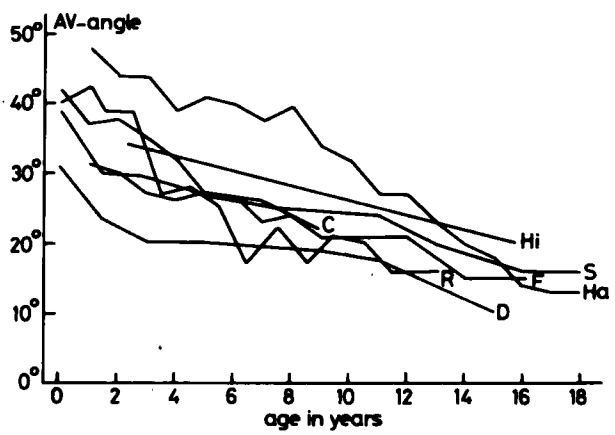


Fig. 27 Some of the major studies describing the progress of physiological detorsion during the postnatal stages of development. AV = anteversion; C = Crane (1959): 172 children; D = Dunlap et al. (1953): 215 children; F = Fabry et al. (1973): 432 children; Ha = Hamacher (1974): 994 children; Hi = Henriksson (1980): 122 children; R = Rogers (1934): 99 children; S = Shands & Steel (1958): 238 children.

version (Rogers 1934; Dunlap et al. 1953; Shands & Steele 1958; Crane 1959; Fabry et al. 1973; Hamacher 1974; Henriksson 1980) (fig. 27).

The mean values are between 20° and 40° at the age of four to eight years, between 20° and 30° between eight and 12 years, and between 15° and 25° at the age of 12 to 16 years. Considerable interindividual variations occur, even in normal hips.

Acetabular anteversion

Acetabular anteversion averages 7° in the neonate and 16.5° in the adult (McKibbin 1970). Only very recently has acetabular anteversion been measured by means of computer-aided tomography (Visser & Jonkers 1980; Visser et al. 1982a; Reikerås et al. 1982).

Instability index

Few data are available. McKibbin (1970) reported the instability index to range from 20° to 58°, and in 1908 Le Damanay described values in excess of 60° as pathological.

VIII.7 SUMMARY

Arthrography and computer-aided tomography are not acceptable as routine procedures in view of the relatively high radiation load involved. On an antero-posterior roentgenogram congenital dislocation of the hip is characterized by a steep acetabular angle and lateralization of the proximal femur (fig. 28a). In the case of slipped upper femoral epiphysis in neonates (fig. 28b) and acute septic arthritis of the hip (fig. 28c) there is lateralization of the proximal end of the femur but no steep acetabular angle.

The value of measuring femoral anteversion by conventional methods should be questioned. The risk of inaccurate measurements is fairly grave, and information can be obtained only on one side of the joint; moreover, femoral anteversion diminishes with increasing age.

The values most widely used to indicate the development of the hip-joint are the acetabular angle and Wiberg's CE-angle; the former can be determined from birth on, and the latter from an age of about three years. Above the age of three years the acetabular angle should not exceed 20° and the CE-angle should not be less than 20° (Table I).

TABLE I NORMAL VALUES AT THE AGE OF THREE YEARS AND OLDER

Acetabular angle		$\leqslant$ 20°
CE-angle		$\geqslant$ 20°
Neck-shaft angle		$\leqslant$ 145°
Femoral anteversion	4- 8 years	$\leqslant$ 40°
	8-12 years	$\leqslant$ 30°
	12-16 years	$\leqslant$ 25°
Acetabular anteversion		$\leqslant$ 20°
Instability index		$\leqslant$ 60°

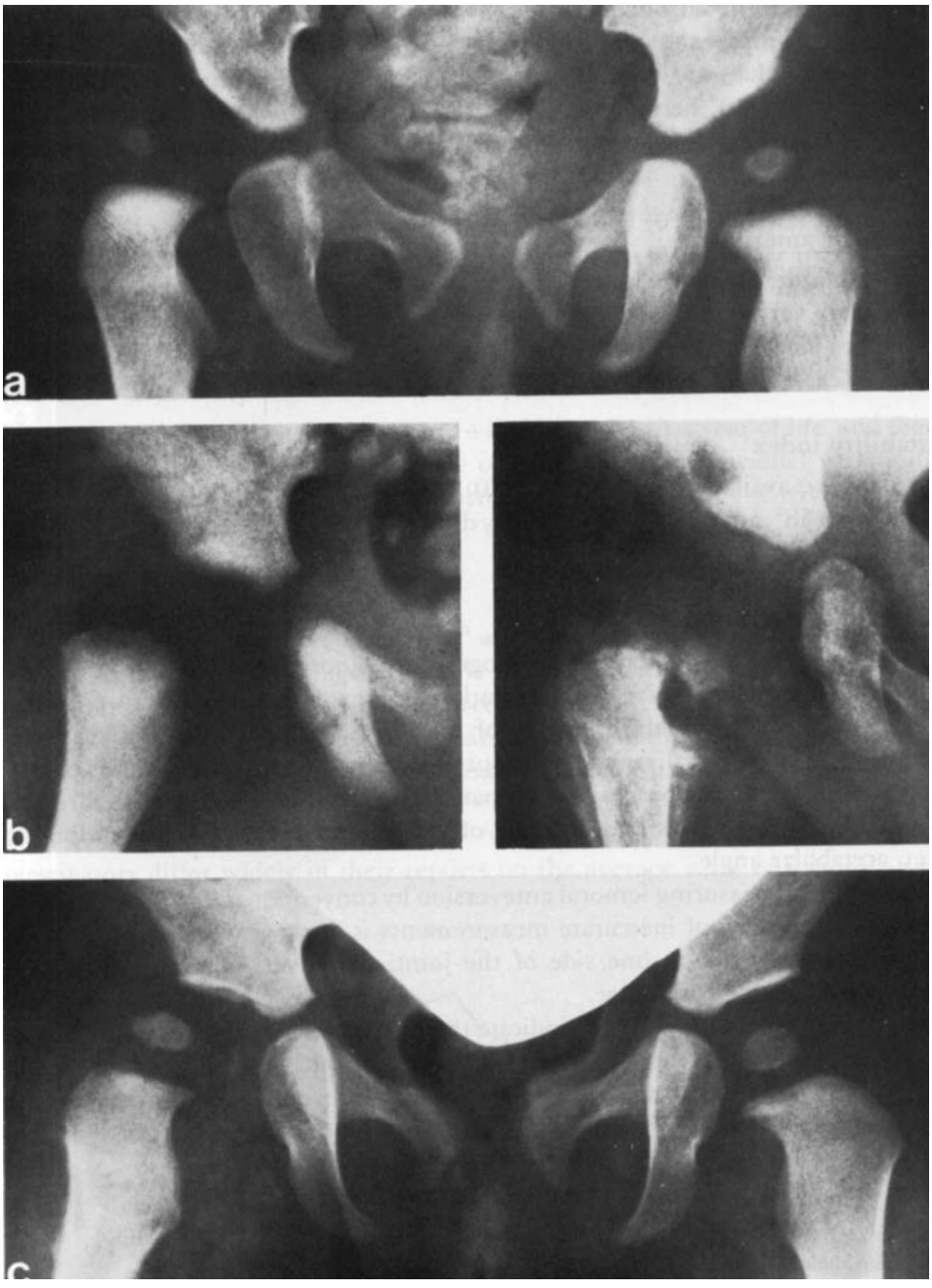


Fig. 28 a. Congenital dislocation of the hip. Lateralization of the proximal end of the femur and a steep acetabular angle; b. Slipped upper femoral epiphysis. Situation immediately after birth (on the left) and two months after birth (on the right) (photograph: D. F. de Zwart, Department of Orthopaedics, Sneek); c. Acute septic arthritis of the hip. In b. and c. there is lateralization of the proximal end of the femur but no steep acetabular angle.

CHAPTER IX

FUNCTIONAL TREATMENT

IX.1 PRINCIPLES OF FUNCTIONAL TREATMENT

IX.1.1 Reduction phase

The functional treatment of congenital dislocation of the hip encompasses closed reduction, in which the pathogenetic mechanism of dislocation is reversed slowly and in a controlled way.

It has been shown in Chapter II that dislocation is facilitated by a relative shortening of the iliopsoas muscle which, when the hip is extended, pushes the femoral head in the posterior direction. In breech presentation the increased tension in the hamstrings with the knees in hyperextension plays an additional role in the pathogenetic mechanism of dislocation.

In order to eliminate these dislocating forces the hips and knees have to be flexed. After birth dislocation as a rule occurs in the posterior direction and in a number of cases it also occurs in the superior direction. When the femoral head is round and the joint is congruent, the centre of rotation coincides with the centre of the femoral head. In the dislocated hip the centre of rotation is the point of application of the forces which keep the femur fixed against the ilium. The muscles which keep the femur fixed against the ilium are the iliopsoas muscle and the adductors. In a dislocated hip, therefore, the centre of rotation lies immediately beneath the lesser trochanter. When the hip is flexed, the femoral head moves inferiorly past the posterior rim of the acetabulum.

The passive muscular effect of the adductor muscles is utilized for reduction (Mittelmeyer 1961). In a flexed hip, decomposition of the resulting force leaves a vector directed posteriorly (fig. 29A). In slight abduction there is still a vector directed posteriorly (fig. 29B). Upon further abduction this force diminishes. Since the origins of the adductors are localized more anteriorly than the posterior rim of the acetabulum, this force is eliminated even before the hip attains 90° abduction. In 90° abduction the decomposed force along a sagittal axis is in fact directed anteriorly (fig. 29C). As a result of the decomposed forces of the adductors, which in 90° abduction are directed medially and anteriorly, the femoral head is returned into the acetabulum past the posterior acetabular rim.

Abduction of the hip increases the tension in the iliopsoas muscle, and consequently medial rotation of the hip is no longer possible (fig. 30) (McKibbin 1968).

In functional treatment, the effect of the adductor muscles is very important for reduction. After an adductor tenotomy reduction in this way is virtually impossible. However, abduction of the hip must not be effected too rapidly because an increased tension in the adductor muscles increases the risk of ischeamic necrosis of the femoral head (see Chapter X.3.3).

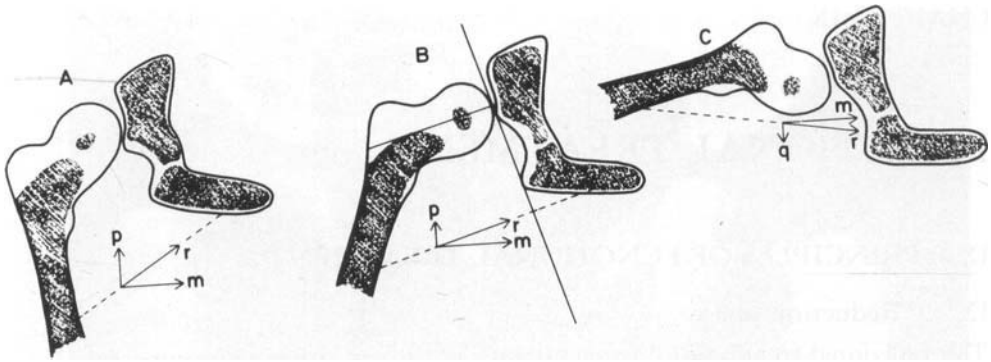


Fig. 29 A. Transverse section through the right hip-joint, with the femur in 90° flexion, 0° abduction and neutral rotation. At 90° flexion of the femur the neck-shaft angle is visible in the transverse section. Resolution of the resultant force (r) of the adductor muscles gives a posteriorly directed vector (p) and a medially directed vector (m).
B. Transverse section through the right hip-joint, with the femur in 90° flexion, 30° abduction and neutral rotation (human position). Assuming a neck-shaft angle of 140° and 20° acetabular anteversion, the axis of the femoral neck is perpendicular to the line connecting the anterior with the posterior boundary of the acetabulum. C. Transverse section through the right hip-joint, with the femur in 90° flexion and 90° abduction. Resolution of the resultant force (r) of the adductor muscles gives an anteriorly directed vector (q).

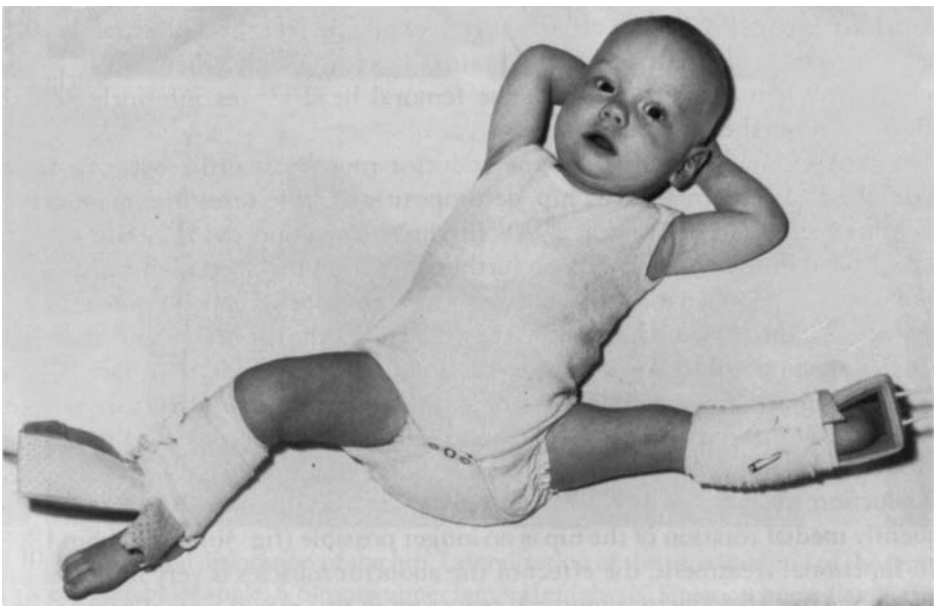


Fig. 30 Patient with congenital dislocation of the left hip. Skin traction in balanced suspension has led to virtually complete abduction. Abduction of the hip causes increased tension in the iliopsoas muscle, precluding medial rotation in the left hip.

IX.1.2 Retention phase

After reduction an attempt is made to restore the anatomical architecture of the joint by means of the inductive effect of the accurately centred femoral head in the acetabulum. The constant pressure exerted by the femoral head causes hypertrophied structures like the ligament of the head and pulvinar to atrophy; capsule constrictions (if present) can disappear; and the inverted acetabular labrum can resume its proper shape (Severin 1950; Staheli et al. 1978).

In the retention phase measures should be taken to ensure that redislocation of the hip does not occur. The hip should be kept in flexion in order to eliminate the dislocating force of the iliopsoas muscle. This muscle is maximally relaxed in full flexion, abduction and lateral rotation (McKibbin 1968). Some degree of abduction is likewise necessary to minimize the posteriorly acting vector of the adductors. On the basis of myogenic relations the Lorenz position (90° flexion and 90° abduction) is the most stable position. Extension and medial rotation would increase the tension in the iliopsoas muscle, as a result of which the femoral head could again be pushed in the posterior direction. In less than 90° abduction redislocation occurs because the posteriorly directed vector of the adductor muscles is increased. The most stable position should be maintained for about three months in order to prevent redislocation (Krämer 1975). After these three months the option is between a different position in a plaster cast or the use of a splint.

In the Lorenz position the femoral head is not properly centred in the acetabulum. An optimal inductive effect of the femoral head is not to be expected in this position. the ideal centralization of the femoral head in the acetabulum is that in which the axis of the femoral neck and the central axis perpendicular to the acetabular orifice coincide. For the frontal plane this implies that, given a supportive sector of 75° in a neonate and of 60° during the first year of life, accurate centralization of the femoral head in the acetabulum can be achieved between the neonatal age and two years by abducting the leg 15° to 30°.

The instability index in a neonate is about 50°. If in the transverse plane the axis of the femoral neck is to be placed perpendicular to the line through the anterior and posterior demarcations of the acetabulum, the leg has to be medially rotated or flexed. Due to the effect of the iliopsoas muscle, only limited medial rotation is possible in young infants. It averages 21° at the age of six months (Coon et al. 1975). In young infants it is therefore impossible to cause 50° medial rotation with the hip extended. In order to ensure proper centralization of the femoral head in the acetabulum, the hip should also be flexed.

The ideal position for proper centralization of the femoral head in the acetabulum is 30° abduction, 20° medial rotation and 45° flexion. This was established by Krämer (1975), who studied pelvic bone specimens in various positions.

In 90° flexion, 0° abduction and neutral rotation the axis of the femoral neck is directed posteriorly in the transverse plane (fig. 29A). When the hip is abducted the femur rotates on a longitudinal axis describing as many degrees of anterior rotation as there are degrees of abduction. Given a neck-shaft angle of 140° and 20° acetabular anteversion, the human position (90° flexion, 30° abduction and neutral

rotation) also ensures proper centralization of the femoral head in the transverse plane (fig. 29B).

Given 50° acetabular inclination and 40° femoral anteversion, with the leg in 90° flexion, 30° abduction and neutral rotation, the axis of the femoral neck is properly centred in the acetabulum in the frontal plane.

Immobilization of the hip-joints in medial rotation may give rise to increased anteversion. This can be corrected in a subsequent phase by fixing the legs in lateral rotation by means of a bilateral hip spica plaster cast or a splint.

An immobilized joint, of which the cartilage surfaces are exposed to greater than normal pressure, after some time develops adhesions and degenerative changes of the cartillage (Evans et al. 1960; Salter & Field 1960). Evans et al. (1960) demonstrated in rats that the changes in the knee-joint were reversible when the joint was immobilized no longer than 30 days. More than 30 days' immobilization was followed by irreversible changes. Whether this also applies to man is uncertain, but it seems likely that protracted immobilization of the hip-joint in a forced position is harmful.

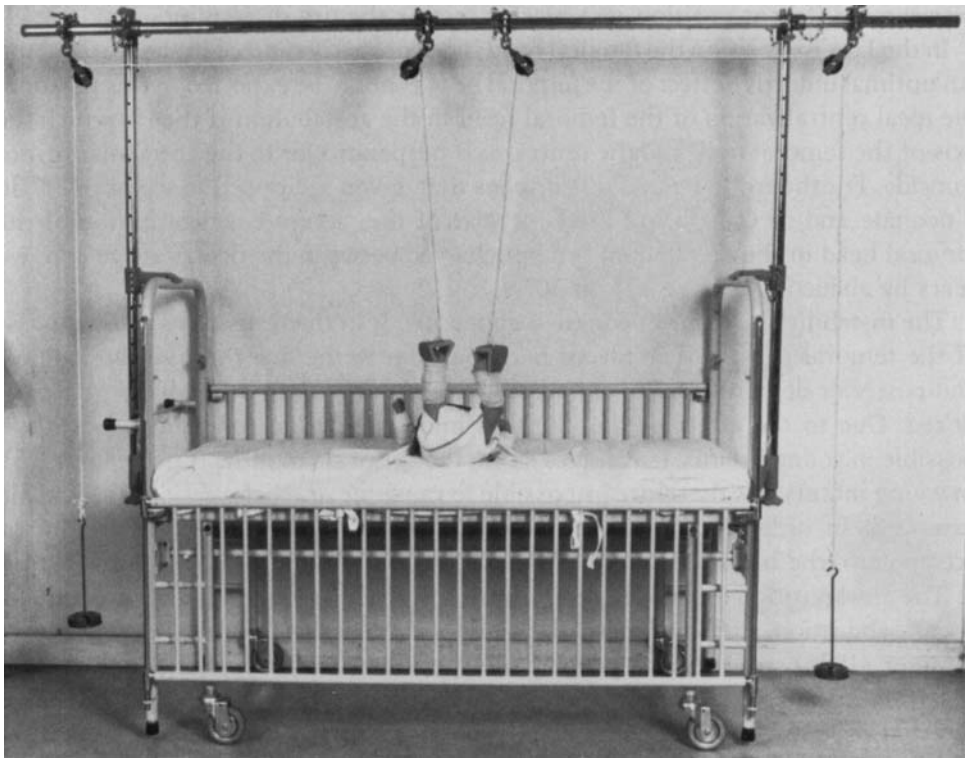


Fig. 31 A child's bedstead with a simple system for skin traction in balanced suspension. The traction is intended only to neutralize the weight of the legs.

IX.2 TECHNICAL PROCEDURES

IX.2.1 Reduction phase

An infant with congenital dislocation of the hip is admitted to the orthopaedic department for treatment. A simple extension frame is mounted on a normal child-size bedstead (fig. 31). The frame consist of two vertical tubes; one is fixed at the head and the other at the foot of the bed. A perforated horizontal tube bridges the distance between the two verticals. Two fixed cross-links ensure stability. Pulleys are suspended both from the ends of the horizontal tube and from the middle. The infant's lower legs are both swathed in non-adhesive traction bandages. Each of the cords of these bandages is guided through two suspended pulleys on either side of the middle of the horizontal tube. A weight-holder (a hook with base-plate) is attached to the end of each cord. The distance between the horizontal tube and the floor is such as to permit free movement of the weight-holder when the infant moves its legs. The sole intention of the traction is to neutralize the weight of the legs. For small infants the weight of the hook with base-plate (approximately 0.5 kg) is often sufficient to ensure this. For larger infants a weight of 0.5-1 kg (dependent on the weight of the legs) is placed on each base-plate.

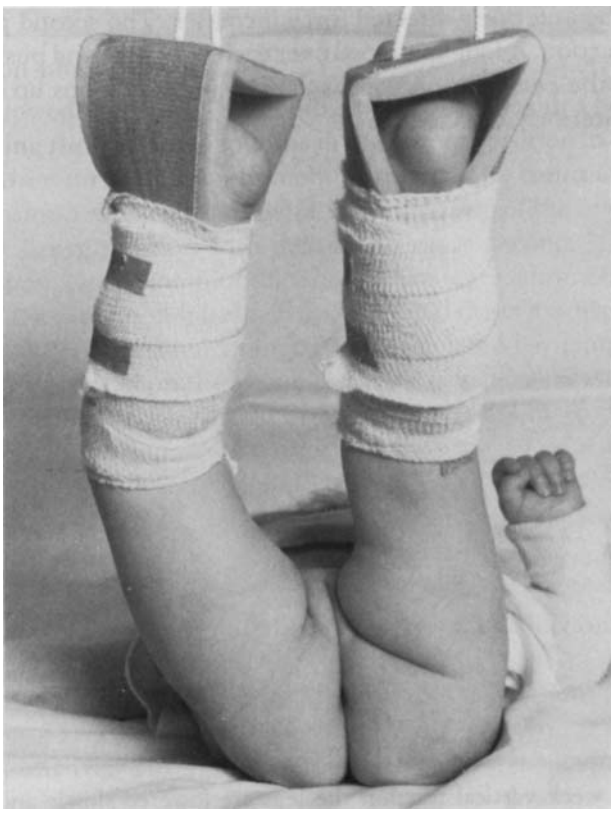


Fig. 32 During the first week of traction the legs are pulled up vertically so that the hips are in 90° flexion. The system allows active movement of all joints of the legs.

During the first week the legs are kept upright in the vertical position, ensuring 90° flexion of the hips (fig. 32). During the first few days the infant cries a little more than usual but it soon becomes accustomed to the situation. Gradual abduction of the legs commences after one week. This is done on the basis of the tension in the adductor muscles, which are palpated daily both before and after adjustment of the traction. As a rule the suspended pulleys can be moved slightly further during the first few days than later. When the pulleys approach the ends of the horizontal tube, a side-pulley is attached to each vertical tube. The cords of the traction bandages are then guided over these pulleys, whereupon these are slowly and symmetrically lowered, on the basis of the tension in the adductor muscles (fig. 33), until the legs are in full abduction.

Bottle feeding and breast feeding remain possible throughout the reduction phase. Hygiene and nappy changes pose no difficulty either.

When the legs are in full abduction an antero-posterior roentgenogram of the pelvis is made to establish whether reduction has been achieved. On this roentgenogram the axis of the femoral neck should point towards the triradiate cartilage (fig. 34). If there is doubt, arthrography is resorted to. If there is no reduction of the hip, two supplemental measures can be taken to ensure subsequent reduction. The first measure is to place a pillow beneath the buttocks; this enables more than 90° abduction so that the anteriorly directed force increases. The second possibility is to establish cross-traction. A loop is slipped over each upper leg and pushed up as far as possible towards the perineum. A cord is used to pull the loops up crosswise, thus enhancing the anteriorly directed force.

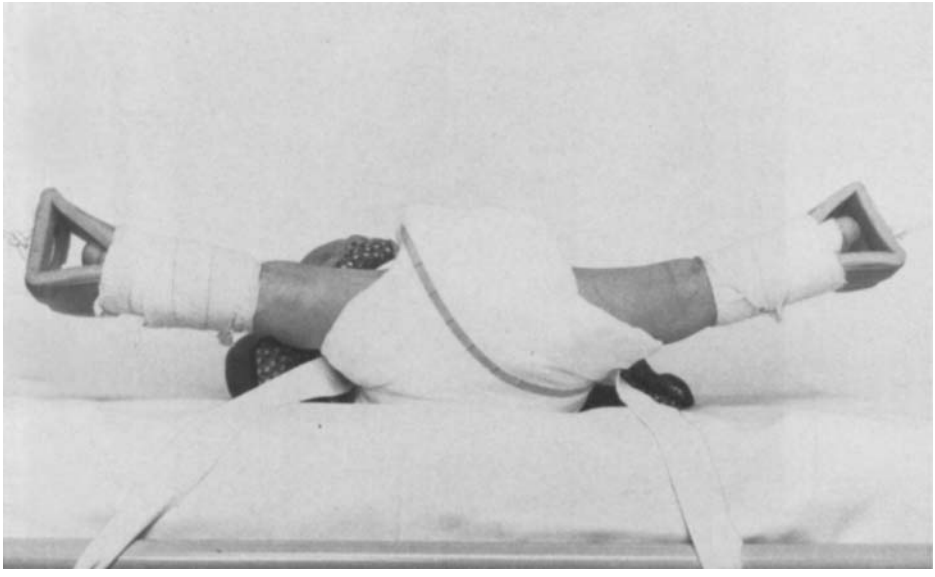


Fig. 33 After one week vertical traction the legs are lowered slowly and symmetrically, guided by the tension in the adductor muscles, until complete abduction of the legs is achieved.

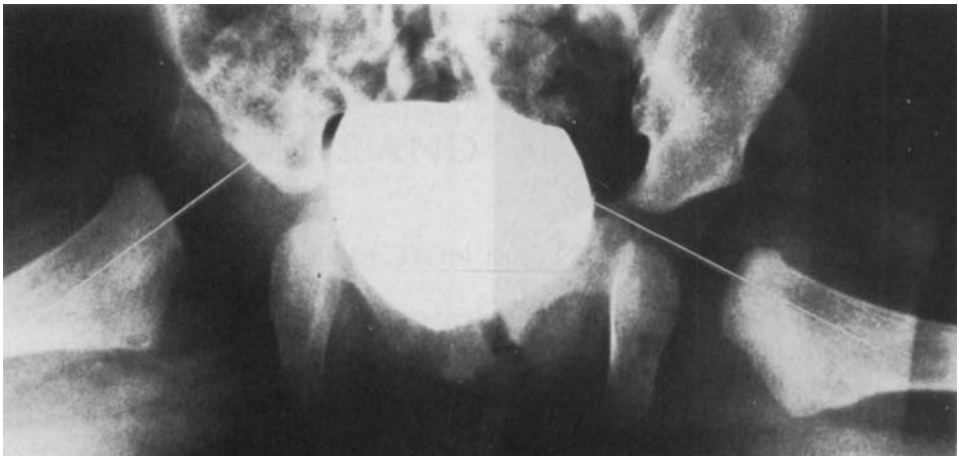


Fig. 34 When the legs are completely abducted an antero-posterior roentgenogram of the pelvis is made. With a reduced hip-joint the axis of the femoral neck should point at the triradiate cartillage. The photograph shows that the left hip-joint has been reduced while the right hip-joint is still dislocated.

IX.2.2 Retention phase

Reduction is followed as a rule by immobilization of the hips in a bilateral hip spica plaster cast, during the first three months in the Lorenz position in order to prevent redislocation. After three months immobilization can be continued in a bilateral hip spica in a position which ensures better centralization of the femoral head in the acetabulum: the Lange position with the hips in slight flexion, 30° abduction and 20° medial rotation. If the nine-month period of plaster cast immobilization is completed, then the legs are immobilized during the final three months in a position in which medial rotation has been changed to slight lateral rotation: the modified Lange position. Dependent on the acetabular angle, the plaster cast immobilization is followed by treatment with the aid of an abduction splint (figs. 35 and 36).

IMMOBILIZATION IN	POSITION OF THE HIPS
Lorenz position	90° flexion; 90° abduction; lateral rotation
Lange position	slight flexion; 30° abduction; 20° medial rotation
modified Lange position	slight flexion; 30° abduction; 20° lateral rotation
Human position	90° flexion; 30° abduction; neutral rotation
Craig splint (fig. 35)	90° flexion; 60° abduction; permits rotation
Hilgenreiner splint (fig. 36)	permits flexion; 30° abduction; permits rotation
dynamic abduction splint (fig. 35)	permits flexion; abduction within certain predetermined limits and rotation

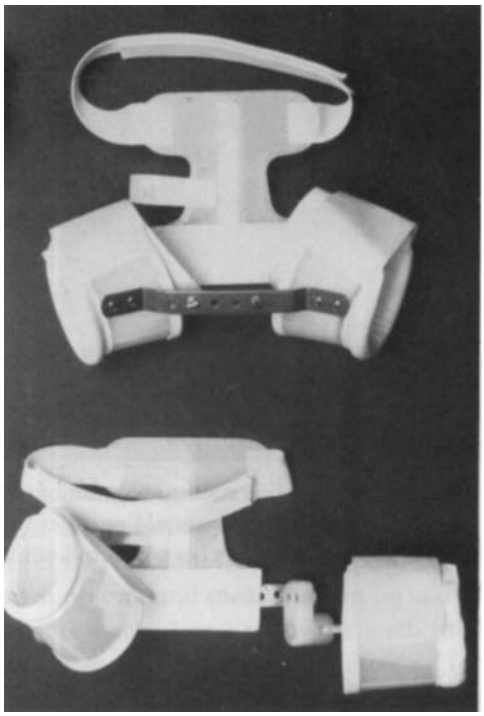


Fig. 35 Top: Craig's hip abduction splint. Bottom: Dynamic hip abduction splint, with hinges which permit abduction, flexion within certain predetermined limits and rotation (distributor: BASKO-CAMP, Amsterdam).

Fig. 36 Patient with a Hilgenreiner splint. When the patient is a walking child it is advisable after the period in a bilateral hip spica plaster cast to ambulate with the aid of a walking toy, because supracondylar femoral fractures in particular can readily occur due to the skeletal atrophy resulting from the enforced inactivity.

CHAPTER X

COMPLICATIONS AND THEIR TREATMENT

X.1 UNSUCCESSFUL REDUCTION AND REDISLOCATION

Reduction can be achieved by traction in some 80-90% of cases (Bartolomaeus et al. 1971; Mittelmeier et al. 1981; Morel & Briard 1982) until the age of about three years (Krämer 1975). Treatment of congenital hip dislocation with the aid of a Pavlik harness, is possible only until the age of approximately eight months (Krämer 1975; Brückl & Refior 1981).

Redislocation is most likely to occur, if at all, during the first three months after reduction; it usually results from immobilization in an insufficiently stable position.

If reduction cannot be achieved by traction, an attempt can be made to obtain the desired result by manual reduction under general anaesthesia or by open reduction. If redislocation occurs during the retention phase after reduction, traction can be repeated to ensure retention in a more stable position.

For open reduction there are two possible approaches to the hip: the medial and the antero-lateral approach. In the medial approach the joint can be reached either anteriorly (Ludloff 1912) or posteriorly (Ludloff 1908) to the adductor brevis muscle. The antero-medial approach (Machacek & Salzer 1977; Mau et al. 1971; Weinstein & Ponseti 1979; Staheli 1982) entails a graver risk of ischaemic necrosis of the femoral head than the postero-medial approach (Ferguson 1973, 1982; Roose et al. 1979), but the former is technically simpler. A disadvantage of this approach is that the acetabular labrum cannot be removed and the stretched capsule cannot be plicated; consequently the risk of redislocation is considerable, especially in patients who are older than 12 months at operation (Roose et al. 1979). It is advisible to confine this approach to infants who are less than one year old, or between one and two years if the acetabular angle is less than 40°.

In view of the abovementioned disadvantages and limitations of the medial approach we prefer the antero-lateral approach, which makes it possible to remove the acetabular labrum and expose the anterior, superior and posterior aspects of the joint capsule. The capsular volume can be reduced by plication of the capsule or excision of a wedge to impede redislocation. A disadvantage is that the extensive dissection may entail a degree of functional impairment (Scaglietti & Calandriello 1962).

To begin with, an adductor tenotomy is performed via a medial incision. The antero-lateral incision extends from the anterior onethird of the iliac crest to the superior anterior iliac spine and then follows a gap between the tensor fasciae latae muscle and the sartorius muscle. Salter (1961) modified this incision in that he made its distal part parallel to the inguinal fold. The apophysis of the iliac crest is split lengthwise. The origins of the gluteus minimus and medius muscles and of the

tensor fasicae latae are stripped away subperiosteally and drawn aside together with the lateral part of the apophysis. The fascia lata is divided between the tensor fasciae latae and the sartorius muscle, leaving the lateral cutaneous nerve of the thigh intact. The two origins of the rectus femoris muscle are divided and turned over inferiorly. The tendon of the iliopsoas muscle is divided at the level of its insertion or lengthened by a Z-shaped incision. The capsule is then opened with a T-shaped incision; the first incision is placed parallel to the anterior aspect of the acetabular rim and the second is made perpendicularly to the first. The labrum can be removed if it prevents reduction. This has no untoward effect on the development of the acetabulum (Somerville & Scott 1957). The ligament of the head clearly marks the direction to the original acetabulum. This ligament, which is usually thickened and stretched, is removed along with the hypertrophic acetabular pulvinar. The hip is then reduced. The capsule is plicated and the origin of the rectus femoris muscle sutured to its original site. The two halves of the apophysis are apposed and fixed together. Suction drains are left in situ and the wound is closed in layers using absorbable synthetic suture material.

The procedure can be limited if preceded by longitudinal traction to reduce the contracture of the iliopsoas muscle (Somerville 1953). In that case the tendon of the iliopsoas muscle need not be divided or lengthened. The incision is smaller and can follow the skin fold ("bikini" incision), giving cosmetically more acceptable scars. Since the method of traction with the hip in flexion yields to the contracture of the iliopsoas muscle and does not stretch this muscle, we must opt in favour of the more extensive approach.

Postoperative management calls for the use of a bilateral hip spica plaster cast with the hips in Lange or human position during the first three months.

X.2 NON-OPTIMAL ACETABULO-FEMORAL RELATION

X.2.1 Persistently increased femoral anteversion

Increased femoral anteversion persists in some 20% of cases of congenital hip dislocation. Very often this has no consequences for the gait. The infant initially walks with the knees in medial rotation and intoeing feet, but after a while proves to walk normally, without complaints and showing no secondary deformities. In some cases, however, the rotational disorder of the lower extremities persists and secondary deformities can eventually occur. The intoeing can be compensated by talonavicular subluxation ginving rise to pes planovalgus with verticalization of the talus.

Secondarily increased lateral torsion of the tibia can also occur by way of spontaneous correction. In that case the result is medial rotation of the patellae, increased lateral rotation (more than 20°) of the lower legs and a normal or slightly valgus position of the feet (fig. 19a). When the patellae are straightened, the feet are in lateral rotation (fig. 19b).

Treatment of torsional disorders may be motivated by: loss of function, cosmetic considerations, risk of developing symptoms and, possibly, prevention of secondary degenerative changes at a later age. Rotational disorders cause no loss of function.

The infant's day-to-day activities are not impaired, although the parents sometimes notice that these children stumble over their own intoeing feet when they are tired. When running, children with intoeing feet often make swinging movements from the hip. A complaint often expressed by the parents and later also by the child (particularly by girls) concerns the position of the legs. There is no adequate evidence that increased anteversion increases the risk of osteo-arthritis of the hip. But medial rotation of the patellae can be the cause of subsequent patello-femoral symptoms.

Treatment, if any, should first aim at correction of the increased anteversion in such a way that approximately 45° lateral rotation is achieved with the hip extended. A secondary lateral rotation of the lower leg corrected by a lateral rotational osteotomy distal to the tibial tuberosity. Even in patients whose growth plates are already fused, this osteotomy should be performed distal to the tibial tuberosity, because an osteotomy proximal to the tuberosity has an unfavourable effect on the angle between the patellar tendon and the thigh (the Q-angle). This is a very extensive therapy which entails two to four major operations, often followed later by operations to remove the osteosynthesis material. When less satisfactory cosmetic features are the only complaint, this should be discussed in detail with the patient and the parents.

X.2.2 Insufficient covering by the acetabulum

The acetabular angle (Ac-angle) is the accepted yardstick for the development of the acetabulum. Given proper centralization of the femoral head in the acetabulum, reduction prior to the fourth year of life is followed by spontaneous restoration of the Ac-angle: the angle diminishes. Adequate centralization of the femoral head can be ensured by abduction treatment with the aid of a plaster cast or a splint; but an intertrochanteric derotational varus osteotomy before the third year of life also has a marked inductive effect on the acetabulum (Somerville & Scott 1957; Chapchall 1976; Lloyd-Roberts 1982).

The degree of improvement of the Ac-angle largely depends on the age at which reduction is achieved. After reduction within the first year of life a normal Ac-angle develops in two years (Lindstrom et al. 1979), but even after reduction at a later age marked improvement of this angle can be expected. If reduction is performed between the ages one and two years, acetabular normalization occurs in 55% of the patients. After the second year of life it occurs in only 20% of the cases (Morscher 1978). A favourable development of the Ac-angle can be expected up to eight years after reduction prior to the fourth year of life (Lindstrom et al. 1979; Harris 1976). The improvement will be rapid during the first three years after reduction, but subsequently no more than 5° further improvement is to be expected. After concentric reduction prior to the fourth year of life it is advisable to follow the development of the Ac-angle over a period of three years. When the Ac-angle has been reduced to less than 25° three years after reduction, there is no indication for a pelvic osteotomy to improve the covering of the femoral head, because 5° further improvement can be expected up to eight years after reduction. This means that the Ac-angle will ultimately be 20°, which is a normal value.

There are two fundamentally different methods of improving the covering of the femoral head: a. construction of a bone formation above the femoral head, with the fibrous capsule changing to fibrous cartilage in the long term, and b. rotation of the acetabulum over the femoral head (McKay 1982).

a. The self operation can be mentioned as the first procedure of this group. In this procedure a fragment of bone, usually taken from the iliac crest, is placed immediately above the fibrous capsule of the femoral head. When exposed to a load, the capsule changes to fibrous cartilage. Numerous techniques have been described (Wilson 1974). Colonna (1936) developed a procedure in which the acetabulum is reamed out and deepened; the capsule is sutured over the femoral head and the latter is returned into the acetabulum. The next step was the Chiari procedure (1956), in which the ilium is sawn through immediately above the capsule, the cut surface extending from the lateral to the medial aspect and 15° superiorly. The entire distal fragment with the femoral head is then displaced medially (fig. 37).

b. The more recent techniques involve rotation of the acetabulum in such a way that the femoral head remains in constant contact with the hyaline cartilage of the acetabulum. In principle there are two different techniques: peri-acetabular osteotomy with rotation of the acetabulum alone, and osteotomy through the coxal bone with rotation of the entire distal fragment of the coxal bone, including the acetabulum. Peri-articular osteotomies can be divided into complete and incomplete osteotomies. The Pemberton osteotomy (1965) was the first to be described. This is an incomplete osteotomy in which the osteotomy plane begins between the inferior and the superior anterior iliac spine and extends around the hip-joint to the triradiate cartilage, using the latter as fulcrum. The part inferior to the osteotomy plane is rotated anteriorly, inferiorly and laterally. The resulting aperture is filled with bone from the iliac crest (fig. 38). Eppright (1975) and Wagner (1973) perfected the technique by converting it into a complete osteotomy. Salter (1961) was the first to describe the osteotomy through the coxal bone with rotation of the entire distal fragment. Using a Gigli saw, the ilium is sawn through laterally from the deepest point of the greater sciatic notch to a point immediately inferior to the inferior anterior iliac spine. The distal fragment is turned anteriorly and rotated inferiorly with the symphysis as fulcrum. The new position is maintained with the aid of a triangular bone fragment from the iliac crest, which is fixed by means of two Kirschner wires passed through the proximal fragment, the triangular bone fragment and the distal fragment successively (fig. 39). The osteotomy should be combined with a simultaneous tenotomy of the iliopsoas muscle and a myotomy of the hip adductors. Steel (1973) modified this technique by adding osteotomies through the rami of the pubic bone and ischium. Another modification is the double osteotomy of Sutherland & Greenfield (1977) with a second osteotomy close to the pubic symphysis.

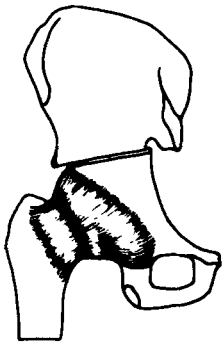


Fig. 37 Chiari osteotomy, in which the ilium is sawn through immediately above the capsule, the cut surface extending latero-medially and 15° superiorly. The entire distal fragment with the femoral head is displaced medially.

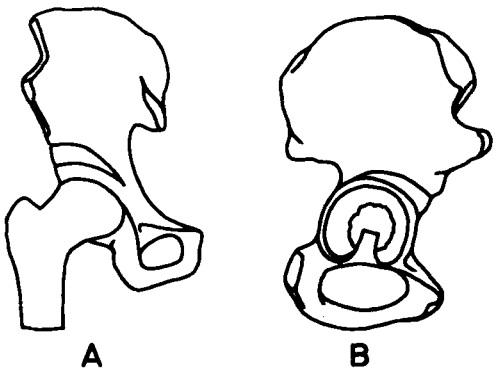


Fig. 38 Pemberton's incomplete peri-acetabular pelvic osteotomy. A = anterior view. B = lateral view.

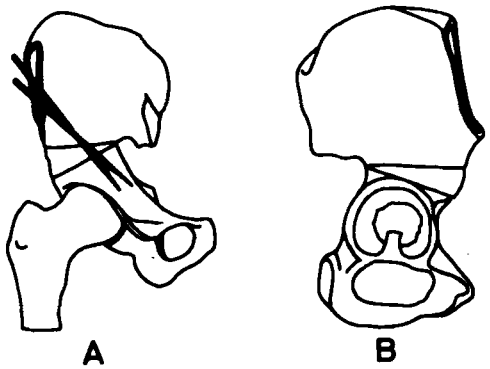


Fig. 39 Salter's osteotomy. The triangular bone fragment taken from the iliac crest is fixed by means of two Kirschner wires. The entire distal fragment is rotated anteriorly and inferiorly, with the symphysis as fulcrum. A = anterior view. B = lateral view.

Important data have become available as a result of the development and application of these techniques:

Hyaline cartilage is more durable than fibrous cartilage, and consequently the shelf operation and the Colonna and Chiari procedures have become second choice techniques. The shelf operation and the Chiari procedure are especially suitable for older children and adults who show subluxation and/or deformation of the femoral head. The advantage of the peri-acetabular osteotomies is that the osteotomy plane is close to the joint, enabling more ample correction. In the incomplete osteotomy the triradiate cartilage is used as fulcrum, and consequently the configuration of the acetabulum is changed. This is why the procedure should be restricted to children under six years of age in whom acetabulum and femoral head still have a considerable remodelling capacity (Coleman 1974). This osteotomy entails the risk of damaging the triradiate cartilage with the osteotome, with the possibility of subsequent disturbances in the growth of the acetabulum. For this reason a complete peri-acetabular osteotomy should be performed when the triradiate cartilage is closed. Technically this is a very difficult operation because the direction of the osteotomy has to be determined blindly for the most part, or with the guidance of an image intensifier; there is consequently a grave risk of perforation into the joint (McKay 1982). The Salter osteotomy likewise has its limitations. It cannot be performed unless concentric reduction has been achieved. Moreover, the hip-joint should be sufficiently mobile and radiologically there should be adequate congruence of the articular surfaces. If a maximal wedge of 30° is placed in the osteotomy, then the acetabulum is tilted anteriorly about 29° in the sagittal plane; this implies that better covering of the anterior aspect of the femoral head is attained at the expense of the covering of the posterior aspect of the femoral head. In the frontal plane the acetabulum is rotated inferiorly about 13° (Rab 1978). An acceptable rule of thumb is that in the sagittal plane the acetabulum is tilted anteriorly as many degrees as the angle formed by the wedge in the osteotomy. The amount of inferior rotation in the frontal plane is about half the number of degrees of the angle formed by the wedge. For an osteotomy using a 30° wedge the postoperative situation can be imitated by flexing the hip 30° and abducting it 15°. If the hip is still dislocatable in this position, then the Salter osteotomy cannot be expected to prevent this. The acetabular angle on the antero-posterior pelvic roentgenogram is corrected by an average of about 10° (Utterback & McEwen 1974). This osteotomy is not suitable when the Ac-angle requires more than 10° correction or when the CE-angle is less than 10° (Tachdjian 1982). More ample corrections can be carried out by means of triple and double osteotomies. Special roentgenographic exposures can give an impression of the maximal correction to be achieved after a Salter osteotomy (Rab 1981). For this purpose the patient lies supine with the hip to be treated in 30° flexion, 15° abduction and neutral rotation. The antero-posterior view of the hip is obtained with the roentgen tube pointing inferiorly, at an angle of 30° with the vertical axis (fig. 40). This exposure indicates how the acetabulo-femoral relation will be performed on the postoperative antero-posterior pelvic roentgenogram.

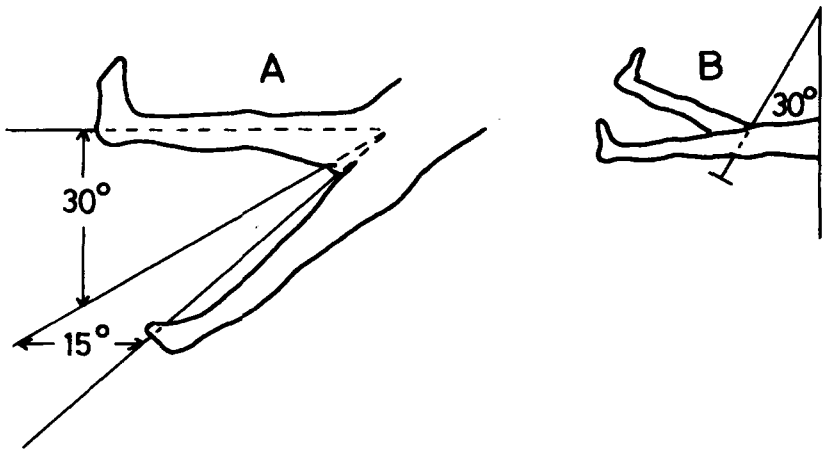


Fig. 40 Technique for a special roentgenogram with the tube aimed 30° inferiorly (B) and the hip-joint examined in 30° flexion and 15° abduction (A). The roentgenogram thus obtained gives an impression of the correction to be expected after a Salter osteotomy.

To summarize: the decision to perform a pelvic osteotomy cannot be made until three years after concentric reduction of the femoral head. The indication for the operation is an Ac-angle in excess of 25°. The Salter osteotomy is the procedure of choice because it is technically the least difficult operation. However, this technique fails to produce an optimal result when the Ac-angle requires more than 10° correction. In that case the choice lies between triple or double osteotomies and peri-acetabular osteotomies. The incomplete peri-acetabular osteotomy can be performed until the age of six years. For the complete peri-acetabular osteotomy the lower limit is approximately 14 years, when the triradiate cartilage is closed.

None of these osteotomies should be performed unless concentric reduction has been achieved with adequate congruence of the articular surfaces and sufficient mobility of the joint. In the presence of subluxation and a deformed femoral head, a procedure which provides better covering for the femoral head such as a Chiari osteotomy or a shelf operation should be considered.

X.3 ISCHAEMIC NECROSIS OF THE FEMORAL HEAD

X.3.1 Vascularization of the femoral head (fig. 41)

The treatment of congenital hip dislocation may give rise to a disturbance in the vascularization of the femoral head which in some cases leads to ischaemic necrosis, both of the dislocated and of the normal contralateral femoral head (Salter et al. 1969). Ischaemic necrosis of the femoral head is never observed in untreated cases of congenital hip dislocation. The adult femoral head is vascularised by the foveal artery and the retinacular arteries.

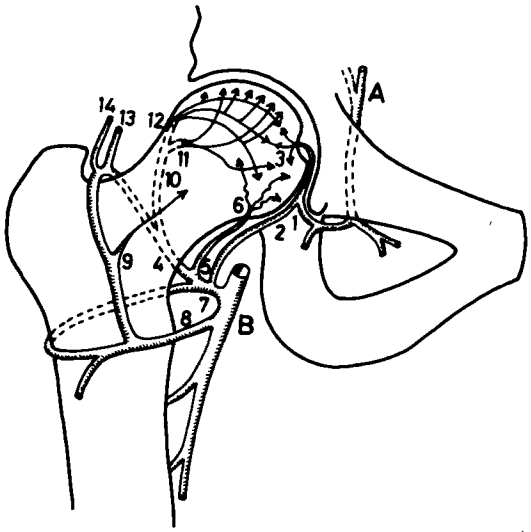


Fig. 41 Arterial vascularization of the adult hip-joint. A. Obturator artery. B. Deep femoral artery. 1. Origin of foveal artery from lateral branch of obturator artery. 2. Origin of foveal artery from medial femoral circumflex artery. 3. Medial epiphyseal arteries. 4. Ascending branch of medial femoral circumflex artery. 5. Postero-medial retinacular artery. 6. Inferior metaphyseal arteries. 7. Medial femoral circumflex artery. 8. Lateral femoral circumflex artery. 9. Anterior retinacular artery. 10. Postero-lateral retinacular artery. 11. Superior metaphyseal arteries. 12. Lateral epiphyseal arteries. 13. Inferior gluteal artery. 14. Superior gluteal artery.

The artery of the ligament of the head or foveal artery, as a rule arises from the lateral branch of the obturator artery but may also arise from the epigastric, the external iliac, the femoral or even the medial femoral circumflex artery. This vessel enters the hip-joint beneath the transverse ligament and reaches the fovea of the femoral head via the ligament of the head.

The retinacular arteries pass the retinacular fibres of the capsule and take a subsynovial course until it reaches the rim of the cartilaginous surface. Here they enter the cortex and reach the interior of the femoral neck. These arteries are usually divided into two groups: the postero-lateral and the postero-medial retinacular arteries - both ramifications of the medial femoral circumflex artery. The latter can arise from the deep femoral as well as from the femoral artery. It takes a meandering course, passing the tendon of the iliopsoas muscle on the medial side and then extending between this tendon and the pectineal muscle. It meanders round the tendon of the iliopsoas muscle and then finds its way to the posterior aspect of the femoral neck along the intertrochanteric crest. In the trochanteric fossa it may anastomose with the lateral femoral circumflex artery; this is called the extracapsular vascular ring (Crock 1965). This extracapsular vascular ring can receive additional blood from the inferior and superior gluteal arteries. In isolated cases there is an anterior retinacular artery which arises from the lateral femoral circum-

flex artery. The latter usually arises from the deep femoral artery. Trueta & Harrison (1953) divided the postero-lateral retinacular arteries into the lateral epiphyseal and the superior metaphyseal arteries, and described the postero-medial retinacular arteries as inferior metaphyseal arteries.

The epiphyseal plate extends horizontally from the lateral aspect of the femoral head, whereas the boundary between the cartilage of the femoral head and that of the femoral neck extends from the supero-lateral to the infero-medial aspect. This implies that the infero-medial part of the femoral head is of metaphyseal, not of epiphyseal origin. Even in adults the growth plate is still discernible as a line.

The lateral epiphyseal arteries, after entering the bone, extend to the centre of the femoral head superior to the plane through the original growth plate, and then anastomose with the branches of the foveal artery. The superior metapyseal vessels, which likewise arise from the postero-lateral retinacular arteries, perforate the cortex at a slightly more inferior level and then ascend perpendicularly to the plane of the original growth plate. The postero-medial or inferior metaphyseal arteries enter the cortex in the most proximal part of the femoral neck on the postero-medial side. They likewise extend in the direction of the plane through the original growth plate and anastomose with the superior metaphyseal branches. There are also anastomoses between the epiphyseal and metaphyseal arteries (except in children, in whom the growth plate constitutes a barrier). Finally, the retinacular arteries can anastomose subsynovially on the cartilaginous boundery: the subsynovial inter-articular vascular ring (Chung 1976).

X.3.2 Changes in the arterial vascular pattern of the femoral head during growth (fig. 42) (Trueta & Harrison 1953; Trueta 1957; Clair Strange 1965; Ogden 1974; Ogden & Moss 1978; Ogden 1982)

The vascular anatomy of the femoral neck is not constant during growth but differs considerably in different periods.

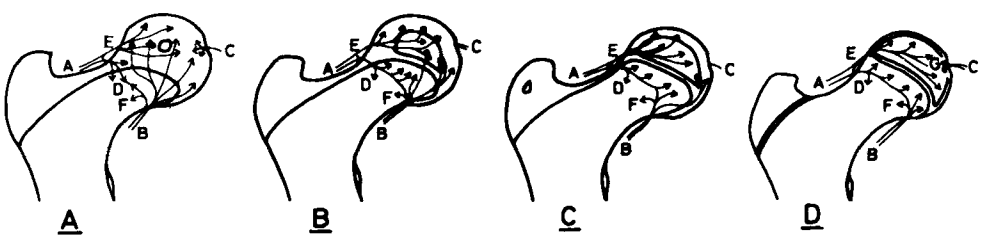


Fig. 42 Changes in the arterial vascular pattern of the femoral head during growth. **A.** Vascularization at birth. **B.** Vascularization between four months and four years. **C.** Vascularization between four years and seven years. **D.** Vascularization from the seventh year until the end of puberty. A. Postero-lateral retinacular artery. B. Postero-medial retinacular artery. C. Foveal artery. D. Superior metaphyseal arteries. E. Lateral epiphyseal arteries. F. Inferior metaphyseal arteries. G. Medial epiphyseal arteries.

Vascularization at birth (fig. 42A):

At birth, the process of enchondrial ossification has extended from the centre of the femoral shaft to the femoral neck and the trochanteric complex. Three groups of arteries vascularize the femoral head: the lateral epiphyseal arteries, the inferior metaphyseal arteries and the foveal artery.

The lateral epiphyseal arteries extend horizontally from the trochanteric fossa to the femoral head. The inferior metaphyseal arteries extend almost vertically on the medial side and pass the growth plate. These arteries extend perpendicularly to the lateral epiphyseal arteries. The foveal artery vascularizes a small area of the femoral head around the insertion of the ligament of the head. Trueta & Harrison (1953) described the branches of the foveal artery as medial epiphyseal arteries. There are no anastomoses between these vascular systems.

Vascularization between four months and four years (fig. 42B):

The greatest change within four months of birth is the disappearance of the vessels from the ligament of the head, more or less corresponding with the appearance of the ossification centre in the femoral head. In most cases there is a single ossification centre but in some instances there are several, with the largest in the middle. By the age of four years the inferior metaphyseal vessels no longer pass the growth plate. Only on the medial sid they can reach a small part of the epiphysis past the growth plate. The epiphysis is vascularized for the most part by the lateral epiphyseal arteries.

Vascularization between four and seven years (fig. 42C):

The situation in terms of changes in the vascular pattern of the femoral head is stable throughout this period.

Vascularization from seven years until the end of puberty (fig. 42D):

During this period new vessels develop from the ligament of the head (medial epiphyseal arteries). For the first time, anastomoses with the lateral epiphyseal arteries appear.

Postpuberal vascularization (fig. 41):

By the time of puberty the vascularization in the metaphyseal part increases and, when the growth plate degenerates, anastomoses with the lateral epiphyseal arteries and with the arteries from the ligament of the head are established. The previously described arterial vascular pattern develops.

X.3.3 Pathogenesis of ischaemic necrosis of the femoral head

Ischaemic necrosis of the femoral head is a serious complication which may develop in the treatment of congenital hip dislocation. The necrosis probably develops as a result of interruption of the circulation outside the femoral head, both intracapsularly and extracapsularly (Nicholson 1954; Ogden 1974, 1982). The first site at which

occlusion can occur is where the medial femoral circumflex artery meanders around the tendon of the iliopsoas muscle. The occlusion is most likely to occur when the hips are in maximal abduction and flexion, and also in medial rotation; and more in particular when a contracture of the muscles of the adductor-pectineus group exists. In that case the medial femoral circumflex artery is compressed between this muscle group and the tendon of the iliopsoas muscle (fig. 43A). The contracture is more marked if the dislocation is of longer standing. In treatments in which in particular the adduction contracture is insufficiently abolished the rate of necrosis can be expected to rise with increasing age (Tönnis & Kuhlman 1969; Gage & Winter 1972). In the case of extreme abduction the medial femoral circumflex artery can be compressed between the tendon of the iliopsoas muscle and the ramus of the pubic bone (fig. 43B). In flexion and abduction the tendon of the iliopsoas muscle can also compress and occlude the postero-medial retinacular vessels against the femoral neck on the postero-medial side (fig. 43D). The trochanteric fossa is an extremely vulnerable site. In maximal abduction the acetabular rim impinges against the fossa and may thus cause occlusion of the vessels on the postero-lateral side: the postero-lateral retinacular arteries (fig. 43C).

With the hip-joint in various extreme positions the blood flow in the lateral femoral circumflex artery is not interrupted. However, its anastomoses with the medial femoral circumflex artery are apparently not always able to prevent necrosis when the latter artery is occluded (Ogden 1982). An alternative possibility is the absence of these anatomoses (Chung 1976).

Finally, intracapsular arteries can be compressed due to torsion of the joint capsule during extention and medial rotation of the hip (Coleman 1978).

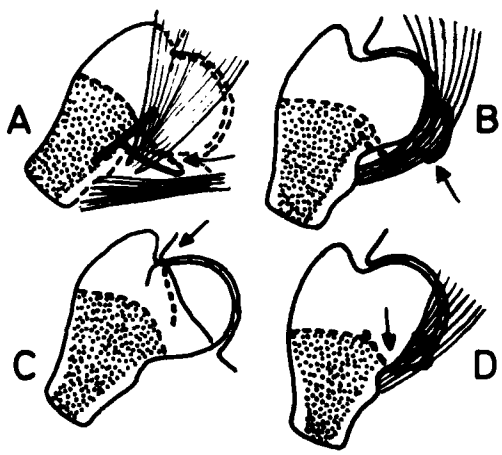


Fig. 43 Schematic representation of the various areas in which vascular compression can occur. A. Compression of the medial femoral circumflex artery between the pectineus muscle and the iliopsoas tendon. B. Compression of the medial femoral circumflex artery between the iliopsoas tendon and the ramus of the pubic bone. C. Compression of the postero-lateral retinacular arteries in the trochanteric fossa in maximal abduction in which the acetabular wall knocks against the fossa. D. Compression of the postero-medial retinacular arteries between the iliopsoas tendon and the femoral neck in flexion and abduction, (Reproduced from Ogden (1982) by permission of the editor).

X.3.4 Classification of ischaemic necrosis of the femoral head (fig. 44)

On the basis of the radiologically demonstrable changes in the epiphysis and metaphysis as a result of ischaemic necrosis, a fairly accurate prognosis can be made of the deformity of the proximal femur to be ultimately expected (Bucholz & Ogden 1978). The changes in the femoral head become visible within two years of reduction (Gage & Winter 1972; Thomas et al. 1982).

TYPE I. Transient ischaemic necrosis of the femoral head

Radiology: the epiphysis shows fragmentation of the ossification centre of the femoral head. The metaphysis shows no changes. Re-ossification of the epiphysis occurs within a few months. Salter et al. (1969) described this situation as temporary irregular ossification of the centre of the femoral head (case 6).

Deformity: the residual deformity can consist of minimal loss of epiphyseal height or slight enlarging of the femoral head.

Cause: transient occlusion of the medial femoral circumflex artery.

TYPE II. Lateral ischaemic necrosis of the femoral head

Radiology: changes in the lateral aspect of epiphysis and metaphysis. The lateral aspect of the epiphysis is irregular and cystic radiolucencies develop in the metaphysis. In some cases a bony bridge can form between the ossification centre of the femoral head and the metaphysis.

Deformity: in the latter case lateral epi-metaphyseal fusion results, with normal growth on the medial side of the growth plate. The residual deformity is shortening of the femoral neck with a valgus position of the femoral head in relation to the femoral neck and relative overgrowth of the greater trochanter. The latter, however, remains at a lower level than the femoral head (case 7).

Cause: probably occlusion of the vessels extending on the postero-lateral side: the postero-lateral retinacular arteries.

TYPE III. Total ischaemic necrosis of the femoral head

Radiology: severe changes throughout the epiphysis and metaphysis and irregular demarcations of the growth plate. The ossification centre of the femoral head does not appear until a year after reduction, or even later. If a femoral centre is present at the time of reduction, it does not increase in size during the first year after reduction (Salter et al. 1969). The entire epiphysis is irregular and fails to attain its normal height; increased density and fragmentation occur.

Deformity: an extremely shortened femoral neck with marked varus position an extremely deformed femoral head and considerable relative overgrowth of the greater trochanter, which is at a higher level than the femoral head.

Cause: prolonged total occlusion of the medial femoral circumflex artery.

TYPE IV. medial ischaemic necrosis of the femoral head

Radiology: irregularity of the medial aspect of epiphysis and metaphysis. On the medial side a bony bridge between the two parts forms in isolated cases.

Deformity: in the presence of a bony bridge varus deformity develops with relative overgrowth of the greater trochanter, which remains at a lower level than the femoral head. If the bony bridge is localized more anteriorly, then increased anteversion occurs; if it is localized more posteriorly there is diminished anteversion.

Cause: occlusion of the vessels on the postero-medial side: the postero-medial retinacular arteries.

TYPE V. Central ischaemic necrosis of the femoral head

Kalamchi & McEwen (1980) likewise distinguish four types but instead of the above type IV with irregularities on the medial side of epiphysis and metaphysis they define a type which entails changes in the central part of the epiphysis. These changes lead to a shortened femoral neck and relative overgrowth of the greater trochanter, which attains the same level as the femoral head.

Premature osteo-arthritis develops in 80% of the cases in which the epiphyseal plate is affected (Cooperman et al. 1980).

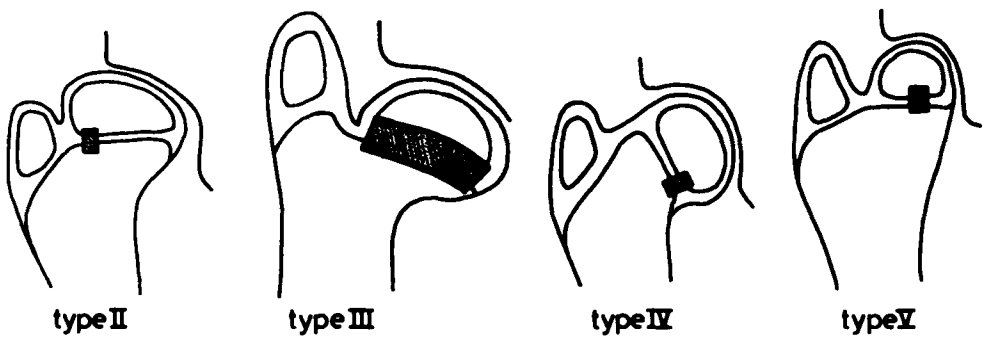


Fig. 44 Classification of ischaemic necrosis of the femoral head. Type II through V. (For type I see case 6).

X.3.5 Ischaemic necrosis of the femoral head after treatment

In the treatment of congenital hip dislocation it is often difficult to estimate the extent to which ischaemic necrosis results from the reduction or rather from the immobilization after reduction. As a result of differences in criteria applied, failure to recognize type I as ischaemic necrosis of the femoral head and failure of a gradation of the severity of necrosis it is rarely possible to compare the results of different therapies in terms of ischaemic necrosis of the femoral head.

Adduction contracture plays an important role in the pathogenesis of ischaemic necrosis of the femoral head. Salter et al. (1969) demonstrated in experiments on pigs that immobilization of the hindlegs in abduction can cause slight circulatory disturbances even in the absence of adduction contracture. When the same immobilization was combined with artificially induced adduction contractures, severe ischaemic necrosis of the femoral head developed in all cases. After abolition of the adduction contracture by open adductor tenotomy, immobilization in forced abduction caused no ischaemic necrosis of the femoral head.

The above investigators compared children with congenital hip dislocation treated by manual reduction, with children in whom manual reduction had been preceded by traction and, in a large number of cases, by adductor tenotomy. The rate of ischaemic necrosis of the femoral head was 30% in the former and 15% in the latter group. The temporary disorders of ossification diminished from 15% to 6%.

It was demonstrated experimentally in dogs that the blood flow unmistakably diminishes in the Lorenz position but is hardly influenced in the human position (Law et al. 1982).

After manual reduction and subsequent immobilization in extreme abduction, the various therapists reported a high rate of ischaemic necrosis of the femoral head: between 50% and 60% (Bost et al. 1948; Bösch 1952; Kaiser 1958; Esteve 1960; Mittelmeyer 1961; Dooley 1964; Cooperman et al. 1980). The Lorenz position entailed a much higher risk of necrosis than the Lange position (Gage & Winter 1972; Tönnis 1978), but the latter position entailed a higher risk than immobilization in the human position (Tönnis 1978; Salter et al. 1969). The duration of immobilization had no effect on the rate of ischaemic necrosis of the femoral head (Tönnis 1978; Buchanan et al. 1981).

Attempts were made to reduce this high rate of ischaemic necrosis of the femoral head by changes in treatment. Open reduction of the hip-joint entails a lower risk of necrosis than manual reposition; after open reduction the rate of necrosis varies from 0% to 40% (Massie & Howarth 1951; Scaglietti & Calandriello 1962; Jäger et al. 1972; Salter & Dubos 1974; Ferguson 1982; Simons 1980).

Longitudinal traction prior to reduction caused a decrease in the rate of ischaemic necrosis of the femoral head (Crego & Schwartzmann 1948; Gage & Winter 1972; Buchanan et al. 1981; Langenskiöld & Paavilainen 1982). It was found that the rate of necrosis diminished significantly when the dislocated hip in the frontal plane came level with or lower than the normal hip (Gage & Winter 1972; Buchanan et al. 1981). Longitudinal traction up to 1.3 kg during at least three weeks improved the prognosis only in infants younger than a year (Weiner et al. 1977). Traction preceding open reduction also led to better results (Langenskiöld & Paavilainen 1982).

In extension-reduction treatment the legs are first pulled into extension and then flexed to 90°, slowly abducted and then immobilized in an abduction apparatus. Ischaemic necrosis of the femoral head occured in 4% of these cases (Krämer 1975; Tönnis 1978). Craig (1954) described "guided abduction", in which the legs are first brought into marked flexion and then slowly abducted. This treatment is also known as "overhead traction" because the feet are suspended above the head. Traction is slight and in fact intended only to neutralize the weight of the legs. When the legs are quickly abducted, however, ischaemic necrosis of the femoral head nevertheless develops in more than 50% of cases (Tönnis & Kuhlman 1969), whereas after slow, cautious abduction necrosis rates of 15% (Tönnis 1978; Mittelmeyer et al. 1981), 4.9% (Bartolomaeus et al. 1971) and 1.5% (Lilienberg 1972) can be achieved.

To summarize: causes of ischaemic necrosis of the femoral head are forced reduction and immobilization in extreme abduction of the hips in the presence of an adduction contracture. Abolition of the adduction contracture (whether by surgery or by conservative measures such as traction) and slow relaxation of the remaining soft tissues exert a favourable influence on the rate of necrosis in the treatment of congenital dislocation of the hip.

X.3.6 Treatment of ischaemic necrosis of the femoral head

Type I ischaemic necrosis of the femoral head disappears spontaneously without severe deformity. In types II, IV and V, but especially in type III, relative overgrowth of the greater trochanter occurs. When the apex of the greater trochanter is localized 5 mm above the upper boundary of the femoral head, a positive Trendelenburg test occurs in 50% of the cases. This test is positive in all cases when this distance exceeds 14 mm (Langenskiöld 1982). Relative overgrowth of the greater trochanter can be reduced by 50% by epiphysiodesis of its growth plate. The remaining growth takes place subperiosteally (Langenskiöld & Salenius 1967). Because the ossification centre of the greater trochanter is very small prior to the age of five years, it is advisable to postpone epiphysiodesis of the greater trochanter (if necessary) until the age of five to six years (Langenskiöld 1982). Above the age of eight years the greater trochanter shows only subperiosteal growth (Gage & Cary 1980).

Once the apex of the greater trochanter is localized 5 mm above the upper boundary of the femoral head, this procedure cannot be expected to reverse a positive Trendelenburg test. If necessary, the greater trochanter can be displaced distally in these cases. In cases of ischaemic necrosis of the femoral head with fusion of its growth plate, a difference in leg length is to be expected. This applies in particular to type III necrosis. It may be necessary in these cases to perform an epiphysiodesis on the contralateral distal femoral growth plate. In type II necrosis the valgus position of the femoral head may lead to subluxation, and this may be an indication for an intertrochanteric (derotational) varus osteotomy.

Transmetaphyseal removal of a bony bridge (Visser & Nielsen 1981) is technically very difficult and entails a grave risk of perforation in the joint; for the femoral head this technique is therefore not recommendable.

CHAPTER XI

PERSONAL OBSERVATIONS

XI.1 PATIENTS

Fifty-three patients with 68 hip dislocations were treated at the Orthopaedic Department of the Groningen University Hospital from 1969 to 1979. Infants with congenital dislocation of the hip who were younger than three months and children older than three years were not included in the series because they were treated in accordance with a different treatment plan. Patients initially treated elsewhere were likewise excluded. The minimal follow-up period after reduction was three years so that sufficient insight could be gained into the development of the acetabular angle. In order to eliminate ischaemic necrosis of the femoral head, a follow-up of up to two years after discontinuation of all treatment is required.

All children were re-examined after establishing that their medical and radiological records were complete. Bilateral congenital dislocation of the hip proved to be present in 15 patients. The left hip was dislocated in 35 and the right in 33 cases. The average age at presentation was ten months; the youngest patient was three months and the oldest was 28 months of age (fig. 45). During the period 1969-1979, no patients aged between 28 and 36 months received initial treatment for congenital dislocation for congenital dislocation of the hip in the Groningen University Hospital.

Of the abovementioned 53 patients, 10 were boys and 43 were girls. Five had been born in breech presentation. Twenty patients had a positive family history of congenital hip dislocation: eight in the first, five in the second and seven in the third degree. The interval between the institution of treatment and the final examination ranged from 3 to 13 years (average 7½ years).

XI.2 PHYSICAL EXAMINATION PRIOR TO TREATMENT

Data on the presence or absence of abduction limitation, a positive Galeazzi sign and duck-like waddle were carefully recorded. The presence or absence of an additional thigh fold was not consistently mentioned. The Trendelenburg test was not performed in a large number of cases, either because the patients were not yet able to stand or because they were insufficiently cooperative for this test.

All dislocated hips showed a limitation of abduction. The Galeazzi sign was positive in all except one of the patients with a unilateral dislocation. In this case the abduction limitation of the contralateral hip was as marked as that of the dislocated hip. On the antero-posterior pelvic roentgenogram the non-dislocated hip showed a very steep acetabulum. A duck-like waddle was observed in 14 cases.

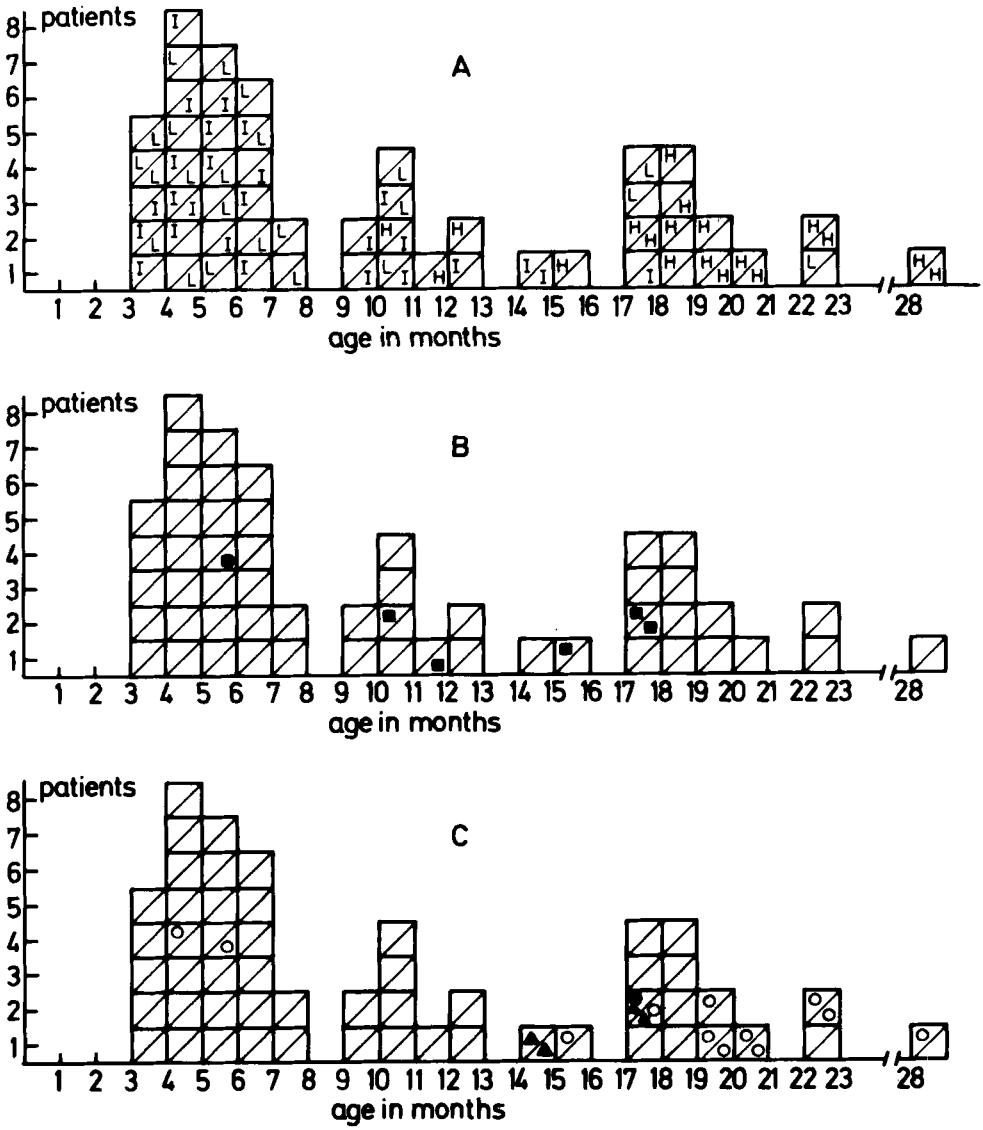


Fig. 45 A. Age at presentation at the out-patient clinic. L = low dislocation. I = intermediate dislocation. H = high dislocation. Each square represents a patient, with the left hips to the left and right hips to the right of the diagonal line. Bilateral congenital dislocation of the hip exists in 15 patients. B. Six hips could not be reduced by skin traction in balanced suspension: three left and three right hips. Open reduction marked with ■. C. Intertrochanteric derotational varus osteotomy (▲) was performed in four instances, Salter osteotomy (O) in 12 cases and Chiari osteotomy (◐) in one.

XI.3 INITIAL ANTERO-POSTERIOR ROENTGENOGRAMS OF THE PELVIS

An antero-posterior roentgenogram of the pelvis was made of each patient suspected of congenital hip dislocation at the first presentation at the out-patient clinic. For this purpose the patient was placed supine on the table with the lower legs dangling over the edge to ensure neutral rotation. When a flexion contracture was present in the hip, a small pillow was placed beneath the knees to abolish the increased lumbar lordosis. The roentgen tube was focused on the symphysis.

Dislocation of the hip-joint was diagnosed only if the medial part of the metaphysis of the proximal femur was localised laterally to Perkins' line. The dislocations were radiologically subdivided into high (case 1), intermediate (case 2) and low dislocations (case 3) (see Chapter VIII.2). The dislocation was high in 19 cases (12 on the left and 7 on the right), intermediate in 26 (14 on the left and 12 on the right) and low in 23 (9 on the left and 14 on the right). High dislocations were observed only in patients older than nine months (fig. 45A).

The ossification centre of the femoral head was present bilaterally in 30 patients. In three cases it was invisible in the dislocated but visible in the contralateral hip. Bilateral radiological absence of the ossification centre was recorded in 20 cases. Seventeen of these patients were less than eight months old; of the remaining three (aged 9, 17 and 18 months respectively) one (17 months old) had bilateral hip dislocation; in the other two patients the ossification centre was also absent on the non-dislocated side.

XI.4 REDUCTION PHASE OF TREATMENT

All patients were hospitalized for skin traction in balanced suspension. After one week vertical traction in which the hips were flexed 90°, controlled symmetrical abduction was effected on the basis of the tension in the adductors.

The traction period for patients with a high dislocation averaged 7½ weeks. The average age at diagnosis of patients with a high dislocation was 17½ months. The traction period for patients with an intermediate dislocation was 5½ weeks. The average age at diagnosis of these patients was 7 months. The traction period for patients with a low dislocation averaged 4½ weeks. The average age at diagnosis of these patients was 8 months. For bilateral dislocations the traction period was adjusted to treat the side with the highest dislocation.

In three patients with four high dislocations a period of 2-3 weeks' cross traction was followed by reduction of three of the four high dislocations.

In six dislocated hips traction in suspension was not followed by reduction (the left hip was involved in three cases, and the right hip in the other three). Three patients had bilateral hip dislocations and in one patient open reduction of both hip-joints was performed (table II) (fig. 45B).

XI.5 RETENTION PHASE OF TREATMENT

Immediately after reduction the hips of 42 of the 53 patients were immobilized for three months in a bilateral hip spica plaster cast in the Lorenz position. After open

reduction of unilateral dislocations immobilization in the Lange position followed. A bilateral hip spica plaster cast with the hips in the Lorenz position was used in bilateral hip dislocations in which one hip was reduced functionally and the other operatively. After open reduction of a bilateral dislocation the hips were immobilized in the Lange position. In eight cases the hips were immobilized for three months in the Lange position immediately after reduction. In three patients this followed open reduction (bilateral in one); in the remaining five cases this followed closed reduction of low dislocations. Three patients were immobilized in a Craig splint immediately after closed reduction (low dislocation in all these cases). Fifteen patients were subsequently treated in a bilateral hip spica plaster cast for nine months, 24 for six months and 12 for three months.

When immobilization in a bilateral hip spica plaster cast was started in the Lorenz position, it was followed after three months by a cast in the Lange position in 37 of the 42 cases; three months later this was replaced by immobilization in a modified Lange position in 15 cases. Of eight patients who had started in a Lange position for three months, two were given a bilateral hip spica plaster cast in the modified Lange position for the next three months.

Of the 50 patients initially immobilized in a bilateral hip spica plaster cast, 43 were subsequently treated day and night in a splint, until the acetabular angle normalized or until a supplemental operation on the proximal end of the femur or acetabulum was performed.

A Hilgenreiner splint was used in 26 cases and a Craig splint in 17, both for an average of six months. In 23 of these cases this was followed by an average of $4\frac{1}{2}$ months during which a splint was only applied at night.

XI.6 DEVELOPMENT OF THE ACETABULAR ANGLE

On all antero-posterior pelvic roentgenograms on which the symphysio-ischial angle and the ratio of the right and left obturator foramen were within normal limits, the acetabular angles were measured. The patients were divided into two groups: a group reduced before and a group reduced after the age of one year. Lindstrom et al. (1979) demonstrated that reduction of a congenital hip dislocation before the age of one year is followed by more rapid improvement of the acetabular angle than reduction after this age.

The first group comprised 43 reduced hip dislocations; in 40 of these an acetabular angle of less than 20° developed before the third year of life (fig. 46). The remaining three hip-joints showed no improvement of the acetabular angle during at least one year. Two of these joints were treated by a Salter Osteotomy (patients 24 and 25; table III); the third (case 9) is also being considered for this procedure.

In the second group of 25 hip dislocations reduced after the age of one year, 12 hip-joints developed an Ac-angle of 20° or less without an operation; the period required for this ranged from one to eight years (fig. 47). Eleven of these patients had a unilateral hip dislocation.

Thirteen hips were operated on before an Ac-angle of 20° or less had developed (fig. 48). Involved were six patients with bilateral hip dislocations; three of them

underwent a Salter pelvic osteotomy of both hips, one had a Salter osteotomy only on the left (case 4), one under went a bilateral intertrochanteric derotational varus osteotomy (case 8) and one had a bilateral intertrochanteric derotational varus osteotomy as well as a Chiari osteotomy on the left and a Salter osteotomy on the

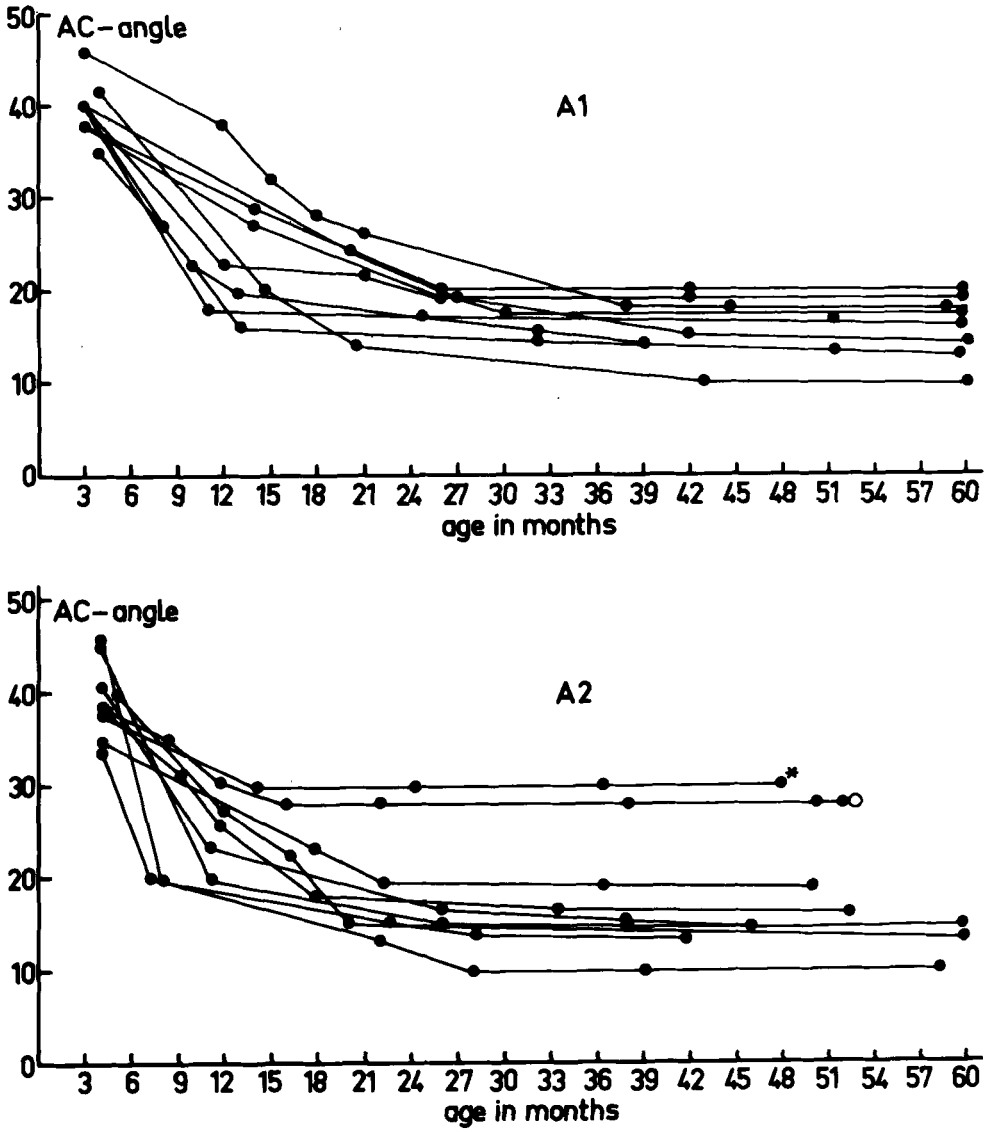


Fig. 46 In 40 out of 43 dislocated hips reduced within the first year of life the acetabular angle diminished to less than 20° before the third year of life; the remaining three hip-joints showed no improvement of the acetabular angle during at least one year. Two of these hip-joints were submitted to Salter osteotomy (O), (A2, B1); the third is likewise being considered for a Salter operation (*), (A2).
A1, A2. Reduction between three and twelve months.

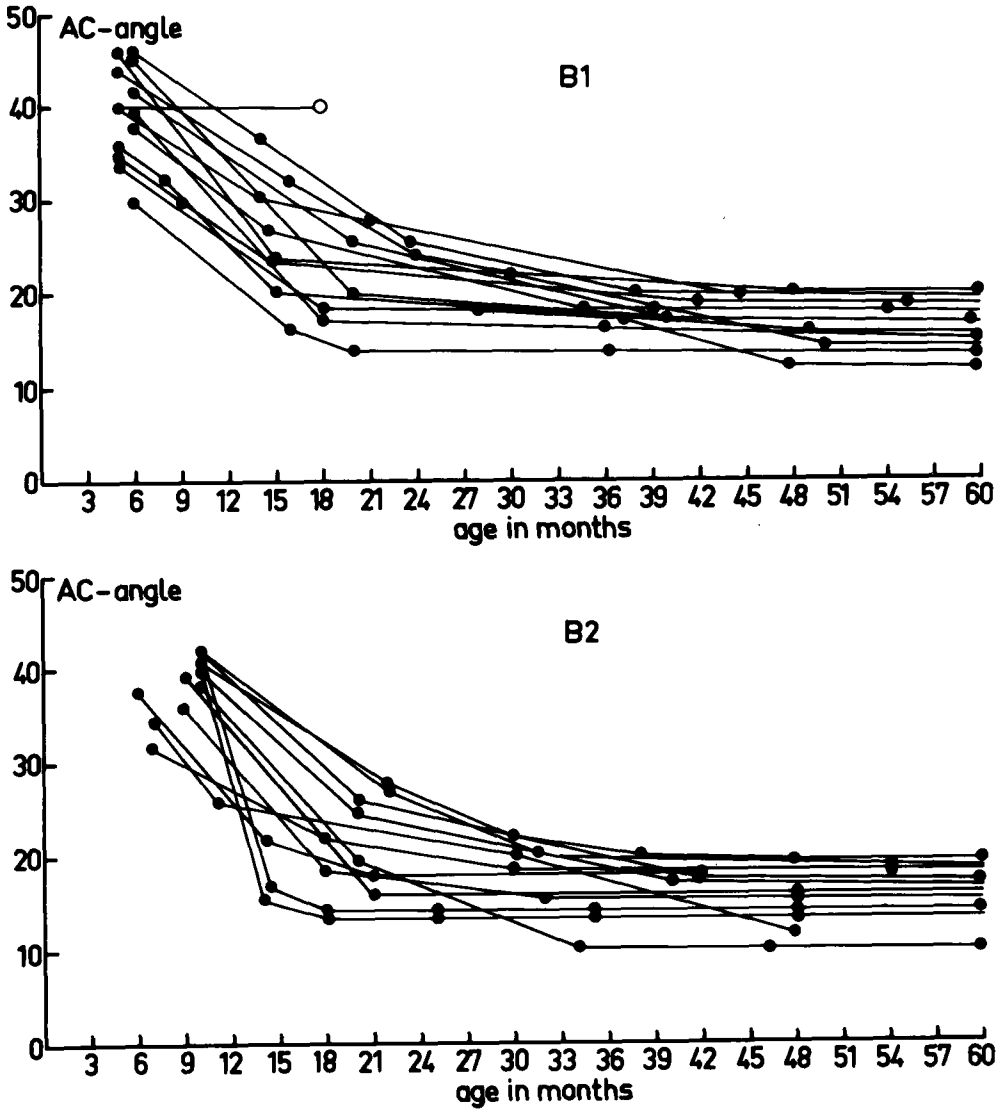


Fig. 46 B1, B2. Reduction between three and twelve months.

right (case 11). Two patients with a unilateral hip dislocation underwent a Salter osteotomy (case 5). In this group the operations performed were four intertrochanteric derotational varus osteotomies, ten Salter osteotomies and one Chiari osteotomy (tables III and IV).

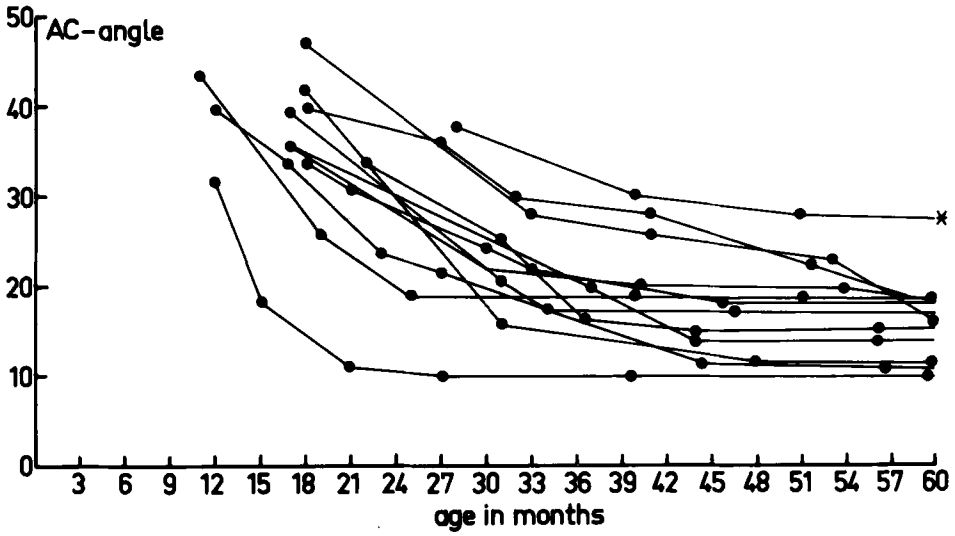


Fig. 47 In 12 of the 25 dislocated hips reduced above the age of one year the acetabular angle normalized without surgical intervention; in one case this did not happen until after eight years (*).

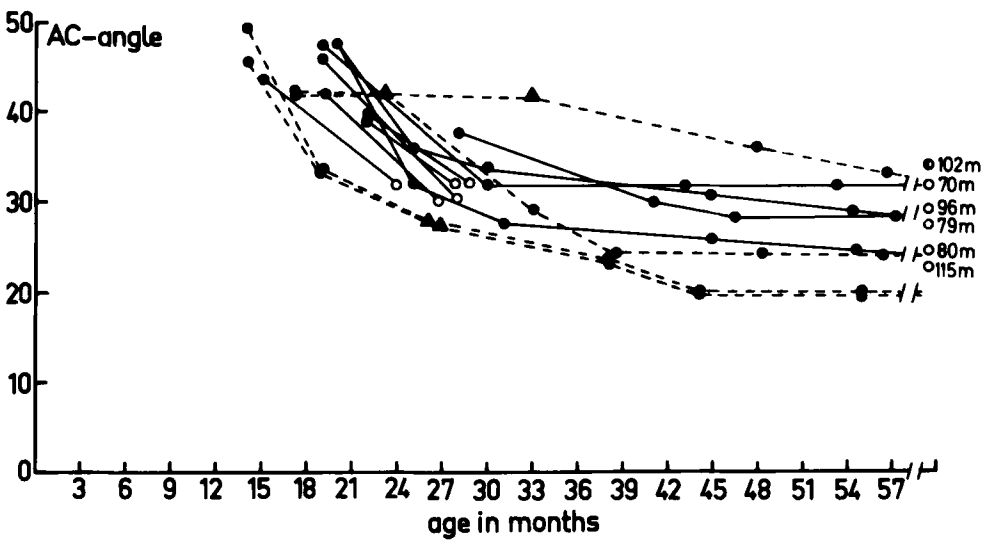


Fig. 48 Of the 25 dislocated hips reduced above the age of one year 13 were operated on before a normal acetabular angle had developed: Salter's pelvic osteotomy (O), Chiari's pelvic osteotomy (◐) or intertrochanteric derotational varus osteotomy (▲).

XI.7 COMPLICATIONS OF TREATMENT

XI.7.1 Unsuccessful functional reduction and redislocation (fig. 45B)

An open reduction was performed in a total of six cases: three on the left and three on the right (table II). Five involved a high and one a low dislocation. In three cases obstruction was caused by an inverted acetabular labrum and a hypertrophic ligament of the head. In one case, an hour-glass configuration of the capsule and a hypertrophic ligament of the head impeded functional reduction, and in one case an hour-glass configuration of the capsule with a hypertrophic ligament of the head and an inverted labrum were responsible. In one case a hypertrophic ligament of the head was the sole factor impeding adequate reduction after four weeks of traction in abduction. At operation the labrum was not inverted, nor did the capsule show an hour-glass configuration. In this case a congruent joint would probably have developed with continued traction and retention of the hips in the most stable position, without any operation.

XI.7.2 Operations to improve the acetabulo-femoral relation (fig. 45C; tables III and IV)

Thirteen pelvic osteotomies were performed: twelve according to Salter and one according to Chiari (8 on the left and 5 on the right side). In six instances the operation was performed within three years of reduction. One of these six hips was operated on because no improvement of the acetabular angle was seen one year after reduction despite abduction treatment in a plaster cast and a splint. In the remaining five hips congenital dislocation had been diagnosed between the 14th and the 23rd month of life. It was nevertheless expected that functional treatment would not sufficiently correct the Ac-angle in these cases. In a number of these cases functional treatment might have been followed by adequate correction of the Ac-angle. The maximal correction of the Ac-angle after a Salter osteotomy was 12°; in 11 cases the Ac-angle was 20° or less after a Salter osteotomy. In one patient (patient 24, right hip; case 10) submitted to a Salter osteotomy at the age of 18 months, the Ac-angle was reduced from 40° to 28°. During growth the angle further diminished to 23°. A Chiari osteotomy was performed in one case (patient 16, left hip; case 11), but the osteotomy was too steep and a deformed femoral head resulted. Pain in this hip developed at a very early age.

Two patients were submitted to a bilateral intertrochanteric derotational varus osteotomy before the age of three years. The indication for this operation was increased anteversion and valgus position in one case (patient 5, case 8) and sufficient improvement of the Ac-angle in the other (patient 16, case 11). Each of the four hips resumed a valgus position after the operation. In the first patient the Ac-angle normalised after the operation, and in the second bilateral pelvic osteotomies were required to correct the Ac-angle.

TABLE II **OPEN REDUCTION**

PATIENT NUMBER	AGE AT DIAGNOSIS	DISLOCATION		DURATION OF TRACTION	OPEN REDUCTION	OBSTRUCTION	ACETABULAR LABRUM REMOVED	SUPPLEMENTAL OPERATIONS
		LEFT	RIGHT					
7	15 m	H*	—	6 w	left	— inverted labrum — hypertroph. lig. of the head	yes	Salter osteotomy
15	10 m	H*	I	10 w	left	— hourglass capsule — inverted labrum — hypertroph. lig. of the head	no	none
16	17 m	H*	H*	7 w	left	— hourglass capsule — hypertroph. lig. of the head	no	intertrochanteric derotational varus oesteotomy and Chiari osteotomy
					right	— inverted labrum — hypertroph. lig. of the head	no	intertrochanteric derotational varus osteotomy and Salter osteotomy
24	5 m	I	L*	4 w	right	— hypertroph. lig. of the head	no	Salter osteotomy
33	11 m	—	H*	6w (C)	right	— inverted labrum — hypertroph. lig. of the head	no	none

* = open reduction
m = months
w = weeks
H = high dislocation
I = intermediate dislocation
L = low dislocation
C = with cross traction

Six of the 68 hip-joints required open reduction because skin traction in balanced suspension had failed to achieve reduction.

TABLE III **PELVIC OSTEOTOMY**

PATIENT NUMBER	AGE AT DIAGNOSIS	DISLOCATION		OSTEOTOMY SIDE	AGE AT OPERATION	TYPE OF PELVIC OSTEOTOMY	ACETABULAR ANGLE BEFORE OPERATION	ACETABULAR ANGLE AFTER OPERATION
		LEFT	RIGHT					
3	20 m	H	H	left right	79 m 80 m	Salter Salter	28° 24°	20° 16°
7	15 m	H	—	left	24 m*	Salter	32°	20°
16	17 m	H	H	left right	102 m 115 m	Chiari Salter	30° 24°	22° 20°
22	19 m	H	H	left right	28 m* 27 m*	Salter Salter	30° 30°	18° 18°
24	5 m	I	L	right	18 m*	Salter	40°	28°
25	4 m	I	L	left	53 m	Salter	28°	18°
39	19 m	H	—	left	70 m	Salter	32°	20°
40	28 m	H	H	left	96 m	Salter	28°	18°
45	22 m	H	H	left right	29 m* 28 m*	Salter Salter	32° 32°	20° 20°

* = osteotomy within 3 years of reduction
m = months
H = high dislocation
I = intermediate dislocation
L = low dislocation

A pelvic osteotomy was performed on 13 of the 68 hip-joints.

TABLE IV INTERTROCHANTERIC DEROTATIONAL VARUS OSTEOTOMY

PATIENT NUMBER	OSTEOTOMY SIDE	AGE AT DIAGNOSIS	DISLOCATION		AGE AT OPERATION	ACETABULAR ANGLE BEFORE OPERATION
			LEFT	RIGHT		
5	left right	14 m	I	I	26 m 27 m	28° 28°
16	left right	17 m	H*	H*	33 m 23 m	42° 42°

* = open reduction
m = months
H = high dislocation
I = intermediate dislocation

Two patients underwent a bilateral intertrochanteric derotational varus osteotomy.

XI.7.3 Ischaemic necrosis of the femoral head

Type I ischaemic necrosis of the femoral head developed in two cases, in one (case 6) it occurred on the non-dislocated side. Spontaneous recovery followed within a few months. Both patients had a unilateral high dislocation on the left, reduced by traction. One patient (case 7) developed type II necrosis. This patient had a unilateral low dislocation on the left, reduced within four weeks by traction which was followed by abduction in a Craig splint for 4½ months.

XI.7.4 Other complications

In two cases a supracondylar femoral fracture occurred, two and three weeks respectively after removal of the hip spica. These were non-dislocated fractures which showed complete consolidation after four weeks plaster cast immobilization.

XI.8 FINAL EXAMINATION

The mobility of the hip-joints was tested in all children; the parents were asked whether the child complained of pain in the inguinal region and/or thighs.

If no recent respresentative antero-posterior pelvic roentgenogram and Ripp-stein anteversion roentgenogram were available, they were performed.

XI.8.1 Clinical results

None of the children examined limped. One child (patient 16, case 11) complained of pain in the left thigh. Flexion of the hip-joint in this case was limited to 90°, with 40° medial and 0° lateral rotation. Adduction and abduction of this hip were both 30°. This was the only hip-joint with pain and disturbed mobility. Extension, flexion, adduction and abduction of the remaining hip-joints were within normal limits (see Chapter VII.5). The rotational arcs with the hip-joints extended were symmetrical in 52 children, only the abovementioned patient showing asymmetry. In 24 children the arcs of medial and lateral rotation were equal and amounted to about 50°. Seven children had about 60° medial and 40° lateral rotation. At physical examination 15 children showed about 70° medial and 30° lateral rotation; six showed about 80° medial and 20° lateral rotation. Examined while standing up, eight children showed infacing patellae, in one case without compensatory lateral torsion in the leg. Infacing patellae was observed only in cases with 70° of 80° medial rotation.

	MEDIAL ROTATION	LATERAL ROTATION
24 children	50°	50°
7 children	60°	40°
15 children	70°	30°, infacing patellae in 5
6 children	80°	20°, infacing patellae in 3

XI.8.2 Radiological results

An ischiometer was used to measure the Ac-angle, CE-angle and neck-shaft angle on the latest antero-posterior pelvic roentgenogram. The anteversion of the femoral neck was measured on the Rippstein anteversion roentgenogram. Rippstein's conversion table (1955) was used to convert the projected values of the neck-shaft angle and the angle of anteversion to real values. The sphericity of the femoral head was determined with the aid of a Plexiglas disc showing concentric circles differing 2 mm in diameter (Mose 1964). This disc was placed on the femoral head, and the difference in sphericity could thus be determined with an accuracy of 2 mm (fig. 22). The contours of the growth plate of the femoral head were given special attention to see whether a bony bridge was present.

In two cases (cases 9 and 10) the Ac-angle was still too large and the CE-angle still too small. For femoral anteversion the following values were accepted as normal: $\leqslant 40°$ at the age of 4 to 8 years; $\leqslant 30°$ at the age of 8 to 12 years; $\leqslant 25°$ at the age of 12 to 16 years. All children showing infacing patellae at clinical examination showed increased anteversion in both hips. The age group 4 to 8 years included five children with increased anteversion of the femoral neck in both hips and one with increased anteversion in one hip (case 10). Three of these children showed infacing patellae. The age group 8 to 12 years included six children with increased anteversion in both hips. Four showed infacing patellae, in one case without compensatory lateral torsion in the legs. The age group 12 to 16 years included one case of increased anteversion, likewise with infacing patellae. Of the 12 children with increased anteversion in both hips, only four had had bilateral congenital hip dislocations; the remaining eight therefore also showed increased anteversion in the non-dislocated hip.

The real neck-shaft angle exceeded 145° in both hip-joints in two patients (cases 8 and 11). Two hip-joints showed disturbed sphericity of the femoral head: one after a Chiari osteotomy (case 11) and one with type II ischaemic necrosis of the femoral head and a lateral bony bridge (case 7). A discreet enlarged femoral head without loss of sphericity was observed in two patients (cases 6 and 10).

XI.8.3 Classification of results

A classification of results should faithfully reflect the therapeutic aims envisaged, which were:

— achieving reduction
— preventing redislocation
— avoiding ischaemic necrosis of the femoral head
— optimalization of the acetabulo-femoral relation.

Failure to achieve reduction or the development of redislocation constitutes a poor result, as also does the development of ischaemic necrosis of the femoral head other than type I. Quantitation of the acetabulo-femoral relationship without CT-scan is possible only in the frontal plane. An evaluation of results should take into account that the skeletal development was still incomplete in all our patients.

Osteo-arthritis based on a disturbed acetabulo-femoral relation had not yet had time to become manifest. In this context a complaint of pain in the hip-joint already constituted a poor result.

With the above considerations in mind, we believe the following classification of results in the treatment of congenital hip dislocation to be realistic in view of the still incomplete skeletal development in these patients.

A result is described as **poor** if one or more of the following criteria applies:

clinical examination	pain presence of contractures leg length difference in excess of 1 cm limp
radiological examination	redislocation ischaemic necrosis other than type I loss of sphericity of the femoral head Ac-angle $>20°$ CE-angle $<20°$

A result is described as **good** if all the following criteria apply:

clinical examination	absence of pain absence of contracture leg length difference $\leqslant 1$ cm absence of limp
radiological examination	congruent joint no or type I ischaemic necrosis spherical femoral head Ac-angle $\leqslant 20°$ CE-angle $\geqslant 20°$

This classification is a composite of Severin's (1971) radiological classification and a clinical classification. The good results correspond with Severin's groups I and II, and poor results with Severin's groups III through VI.

A good result was obtained in 64 of the 68 hip-joints treated, and a poor result in four (cases 7, 9, 10 and 11). The poor results in case 7 should probably be ascribed to too rapid abduction treatment in the reduction phase, leading to type II ischaemic necrosis of the femoral head. The poor results in cases 9 and 10 were caused by an excessively large Ac-angle; further improvement is possible. The poor result in case 11 was due to a too steep Chiari pelvic osteotomy.

XI.8.4 Summary

The study comprised 53 patients with 68 congenital hip dislocations in whom an abduction limitation was clinically diagnosed while on the roentgenogram the medial part of the femoral metaphysis was localised laterally to Perkins' line. The

dislocations were radiologically divided into high (19), intermediate (26) and low dislocations (23). High dislocations were found only in children older than nine months. The traction period averaged 7½ weeks for high, 5½ weeks for intermediate and 4½ weeks for low dislocations. The male:female ratio was 1:4. There was no significant difference between left and right. Skin traction in balanced suspension failed to achieve reduction in six cases. Abduction treatment in a bilateral hip spica plaster cast and a splint was started in the majority of cases with the legs immobilized in a hip spica in the Lorenz position. Severe ischaemic necrosis of the femoral head (type II) developed in only one case. Temporary irregular ossification (type I) was found in two cases. In 43 of the 46 children whose treatment was started within the first year of life a normal Ac-angle developed without surgical intervention. Thirteen of the 22 hip-joints treated in children older than one year required supplemental operations to improve the acetabulo-femoral relation.

Twelve of the 53 children underwent a total of 23 operations (6 open reductions, 4 intertrochanteric derotational varus osteotomies, 12 Salter osteotomies and 1 Chiari osteotomy). The increased anteversion in 13 children was associated with infacing patellae in eight cases (without compensatory lateral torsion in the legs in one case).

The ultimate result was good in 64 and poor in four of the 68 congenital hip dislocations treated. Two of the four poor results are capable of subsequent improvement.

XI.9 ACHIEVEMENT OF THE AIMS ENVISAGED

- Reduction was achieved by skin traction in balanced suspension in 62 cases. This method of reduction failed in six cases, which required subsequent open reduction.
- Redislocation in the retention phase did not occur in any of the patients.
- Irreversible damage of the femoral head occurred as a result of ischaemic necrosis of the femoral head in one case, and after a Chiari osteotomy in one case.
- A normal AC-angle developed before the third year of life without surgical intervention in 40 of the 43 hip-joints reduced prior to the age of one year. Twelve of the 25 hip-joints treated after the first year of life developed a normal AC-angle without surgical intervention. The total number of operations comprised six open reductions, 12 Salter osteotomies, one Chiari osteotomy and four intertrochanteric derotational varus osteotomies.

CHAPTER XII

SUMMARY AND CONCLUSION

SUMMARY

A prerequisite for the development of congenital dislocation of the hip is ligamentous laxity of the hip-joint, which is demonstrable shortly after birth when the hip can be easily dislocated and reduced. This situation is described as dislocatable hip. Ligamentous laxity naturally tends to disappear, and 90% of all dislocatable hips in fact stabilize spontaneously. No dislocation develops unless an exogenous factor is involved. In infants born in breech presentation the hyperextension of the knees with the resulting increased tension in the hamstrings plays a role. During or shortly after birth, the deflexion of the hip-joint causes an increased tension in the relatively shortened iliopsoas muscle, as a result of which the hip can be dislocated in postero-superior direction. By the time the infant is two months old secondary changes (more specifically restricted abduction) become more pronounced. It may therefore be stated that contracture of the iliopsoas muscle is one of the causes, and restricted abduction a consequence of congenital dislocation of the hip. The degree of dislocation is determined by a balance between the degree of ligamentous laxity and the influence of exogenous factors. When the infant starts to stand and walk, its body weight also begins to function as a deforming exogenous factor.

When dislocatable hips are not treated immediately after birth, the frequency of congenital dislocation of the hip at the age of three months amounts to 1-2 per 1000 neonates. The male:female ratio is 1:4.

The secondary changes in the osseous structures of the hip-joint should always be studied three-dimensionally. Apart from conventional antero-posterior pelvic roentgenograms, CT-scans can enhance spatial insight. The secondary changes manifest themselves in an enlarged neck-shaft angle, increased femoral anteversion, an increased inclination of the acetabulum and possibly also in diminished acetabular anteversion. In view of the high radiation load involved, examination by CT-scan is not yet a routine procedure in congenital hip dislocation. Radiological examination is usually confined to an antero-posterior pelvic roentgenogram on which the acetabular angle, the neck-shaft angle and the CE-angle can be measured. These are all values projected in a frontal plane. To determine the real values the degree of acetabular and femoral torsion has to be known. With the aid of the CT-scan the torsion of the acetabulum and of the femoral neck as well as their summation - the instability index - can be measured without difficulty. By conventional techniques only femoral torsion can be determined. The most widely used procedure is the biplanar technique, but this entails the risk of a by no means inconsiderable measuring error.

Functional treatment of congenital dislocation of the hip comprises closed reduction which, slowly and in a controlled way, reverses the pathogenetic mechanism of the dislocation. The influence of the iliopsoas muscle is eliminated by flexing the hips 90° with the aid of skin traction in balanced suspension. Next, the adduction contracture is abolished by slow abduction. At 90° flexion and 90° abduction of the hip-joint reduction is achieved via the anteriorly directed vector of the resulting force of the adductors.

After reduction efforts are made to restore the anatomical architecture of the hip-joint by means of the inductive action of the well-centred femoral head in the acetabulum. On the basis of myogenetic conditions, the most stable position is the Lorenz position. However, in order to ensure an optimal inductive action of the femoral head on the acetabulum, the head must be optimally centred both in the frontal and in the transverse plane. This is ensured by 45° flexion, 30° abduction and 20° medial rotation of the hips or by 90° flexion, 30° abduction and neutral rotation (human position) for immobilization.

In patients up to three years old, reduction can be achieved by traction methods in some 90% of cases. After reduction of the femoral head the decision to perform a pelvic osteotomy to improve the covering of the femoral head should be postponed three years, because during this period considerable improvement of the acetabular angle can be expected to occur with growth. After reduction within the first year of life a normal acetabular angle develops in most cases without surgical intervention. After the first year of life this happens much less frequently. When a pelvic osteotomy is required, the Salter osteotomy is the operation of choice as long as there is adequate congruence between femoral head and acetabulum. It should be realized that the maximal correction of the acetabular angle to be achieved by this osteotomy does not exceed 10-12°.

Spontaneous correction occurs during growth in some 80% of patients with pathologically increased femoral anteversion. This is most pronounced during the first few years after reduction and is very limited after the age of eight years.

A serious complication which may occur in treatment of congenital hip dislocation is ischaemic necrosis of the femoral head. The deformity of the proximal end of the femur can be predicted from the degree of damage of the epiphyseal plate. This complication occurred in only one of the 68 functionally treated congenital hip dislocations.

Evaluating on the basis of strict criteria, the result of functional treatment of congenital dislocation of the hip can be described as good in 64 of the 68 hips and poor in four; two of these four poor results are capable of subsequent improvement.

CONCLUSION

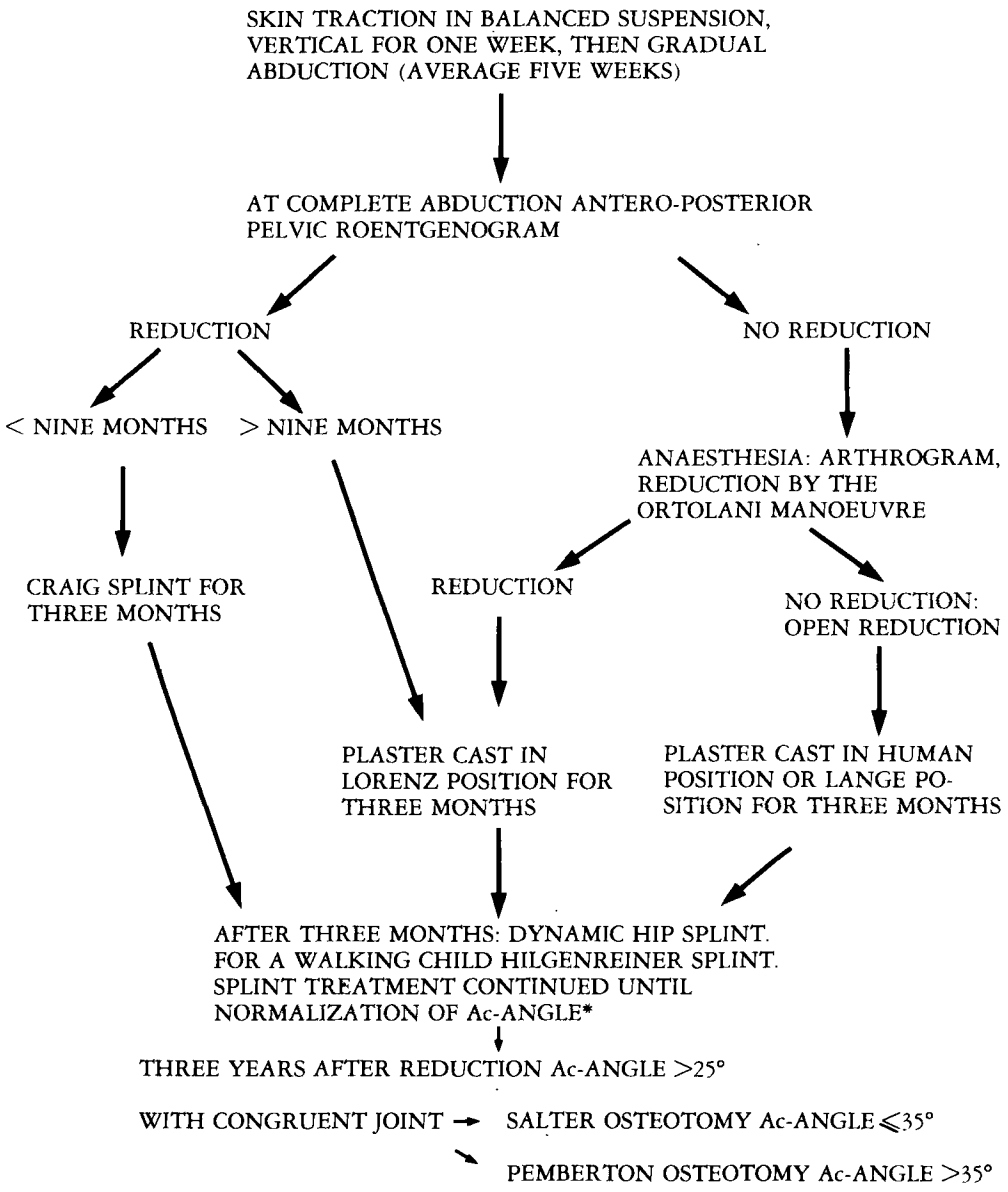
Functional treatment of congenital dislocation of the hip as described in this thesis is a simple, safe method. During the reduction phase the hips are flexed to eliminate the influence of the iliopsoas muscle; subsequent abduction of the hips should be effected very gradually to prevent ischaemic necrosis of the femoral head. The

pectineus-adductor muscles play an important role both in reduction and in the pathogenesis of ischaemic necrosis of the femoral head.

Up to the age of three years reduction is achieved by skin traction in balanced suspension in 90% of cases. On the basis of myogenetic conditions the Lorenz position is the most stable position for immobilization after reduction. This position entails no increased risk of necrosis after gradual abduction. A less extreme position can be chosen when the contractures are less marked and reduction is quick and easy. When no further risk of redislocation exists the femoral head should be optimally centred in the acetabulum in the frontal as well as in the transverse plane, preferably with the aid of a splint which allows mobility in the hip-joint within certain limits. After reduction of the femoral head at least three years should be allowed to pass before a decision is made concerning a pelvic osteotomy to improve the covering of the femoral head.

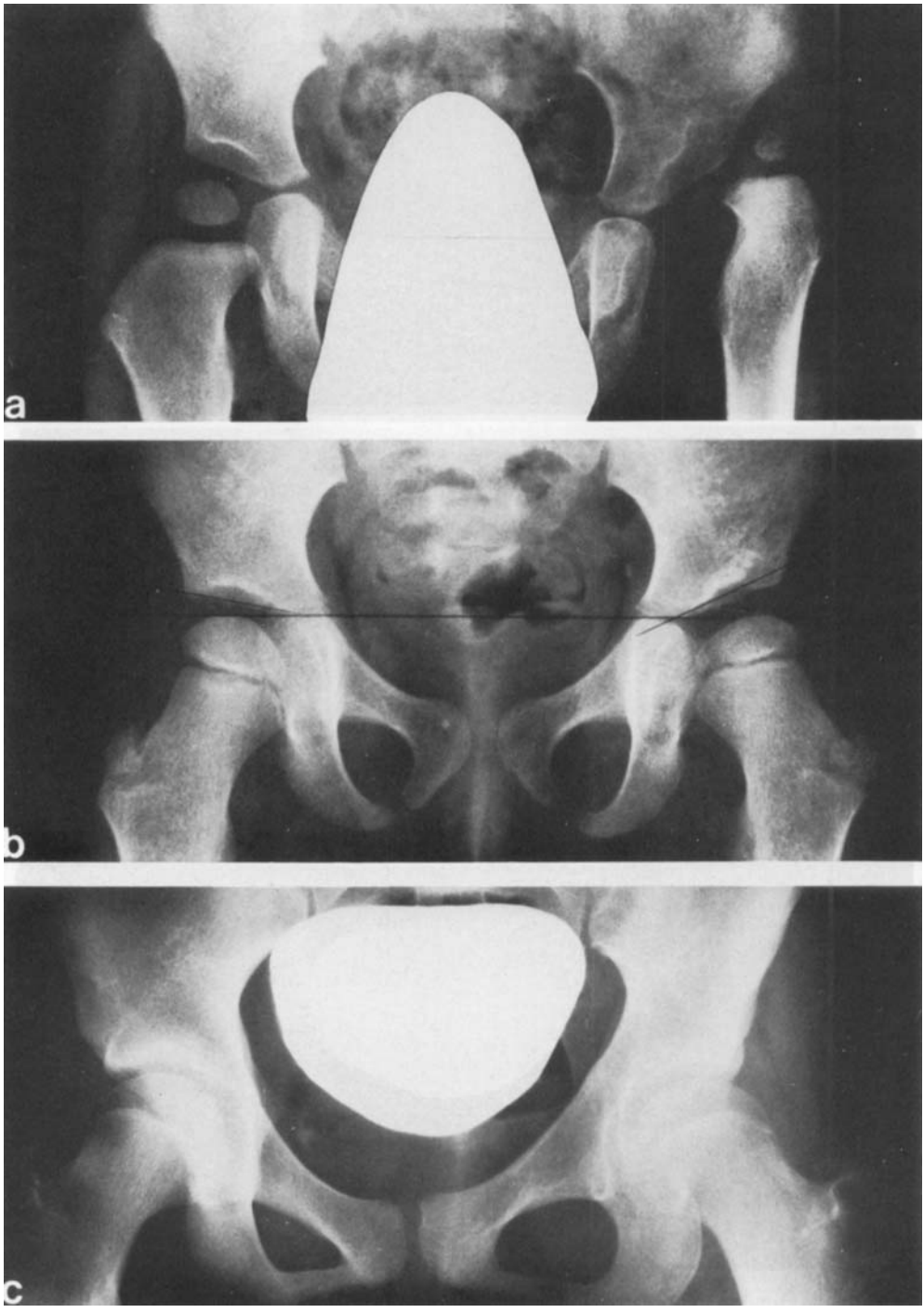
DIAGRAM OF TREATMENT PLAN

On the basis of experience gained in the functional treatment of congenital dislocation of the hip we use the following treatment plan in children from the age of three months until the age of three years.

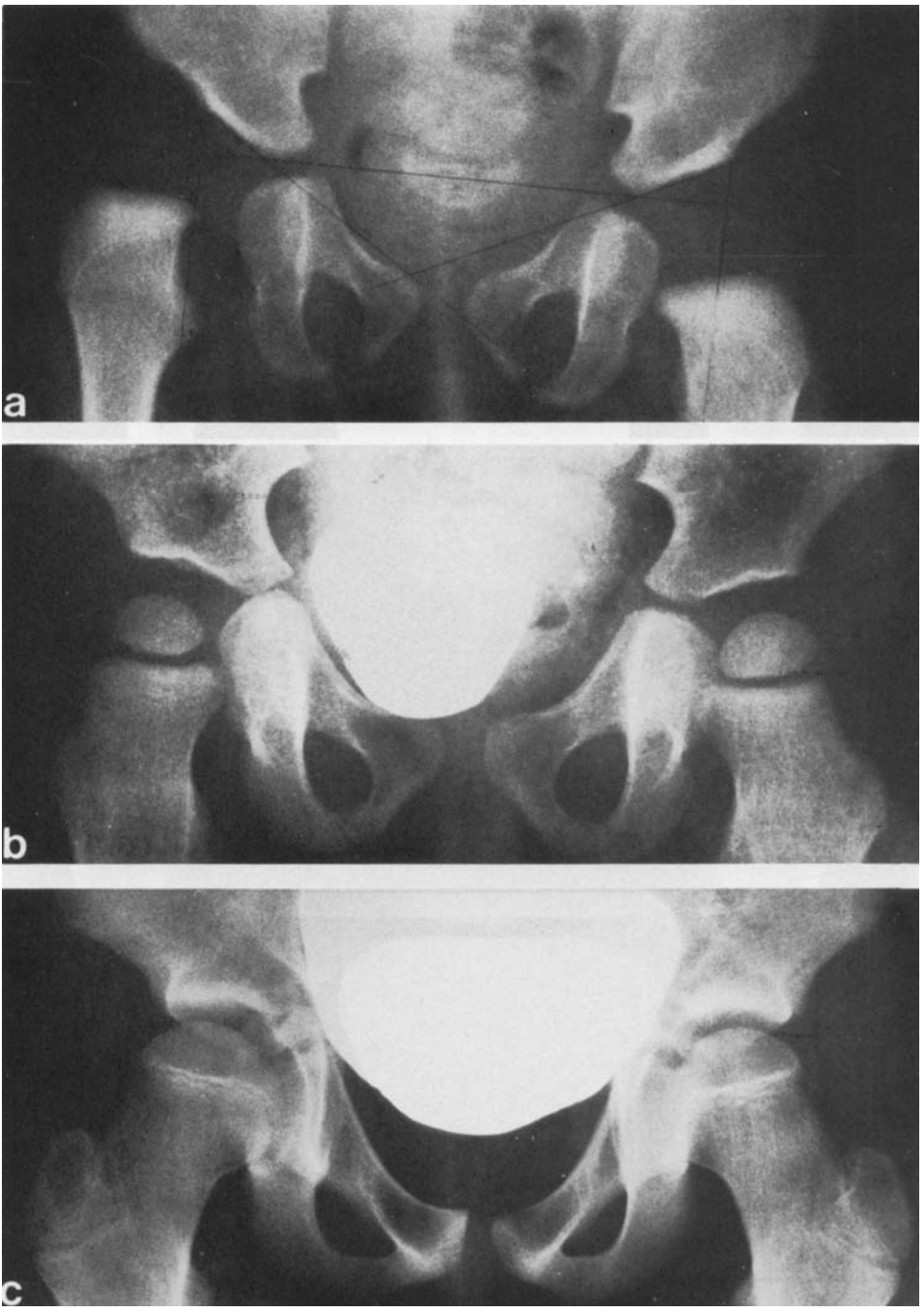


* If there is no improvement of the acetabular angle after one year splint treatment, the splint is abandoned.

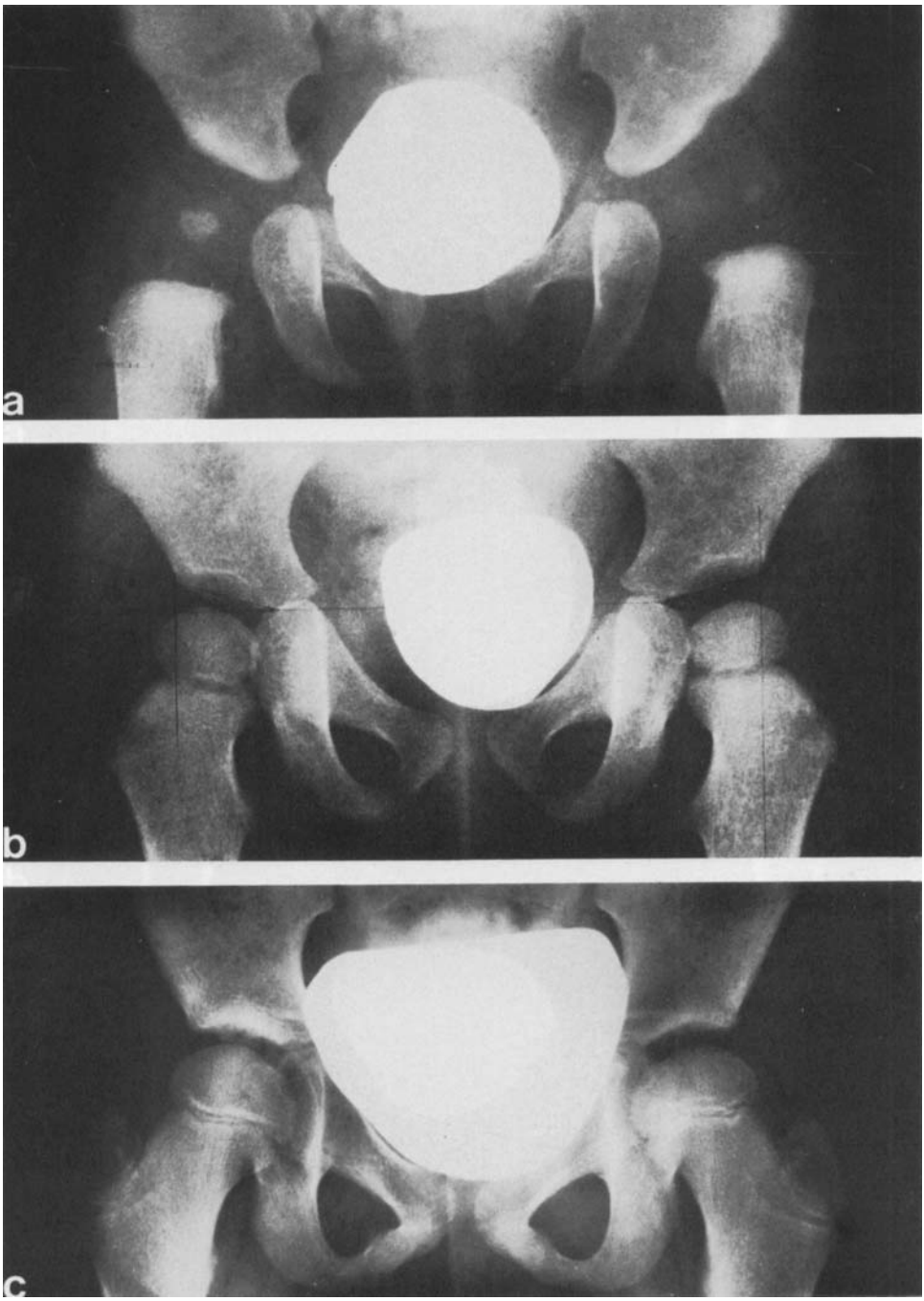
CASE REPORTS



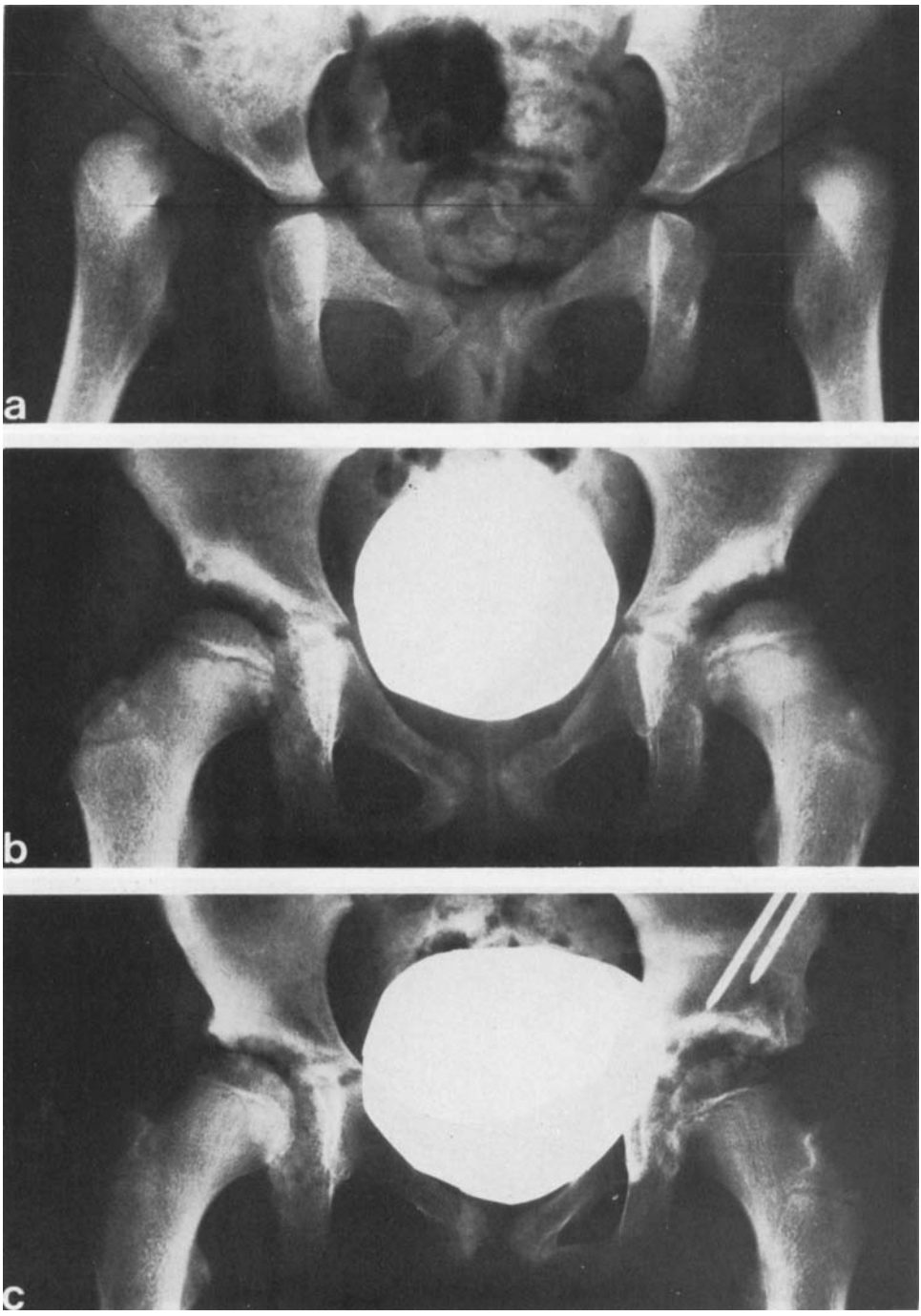
Case 1 a) 18 months, high dislocation left hip. b) 3½ years. c) 13 years. Treatment: 10 weeks traction, 6 months bilateral hip spica plaster cast, 20 months Hilgenreiner splint (only at night for 9 months).



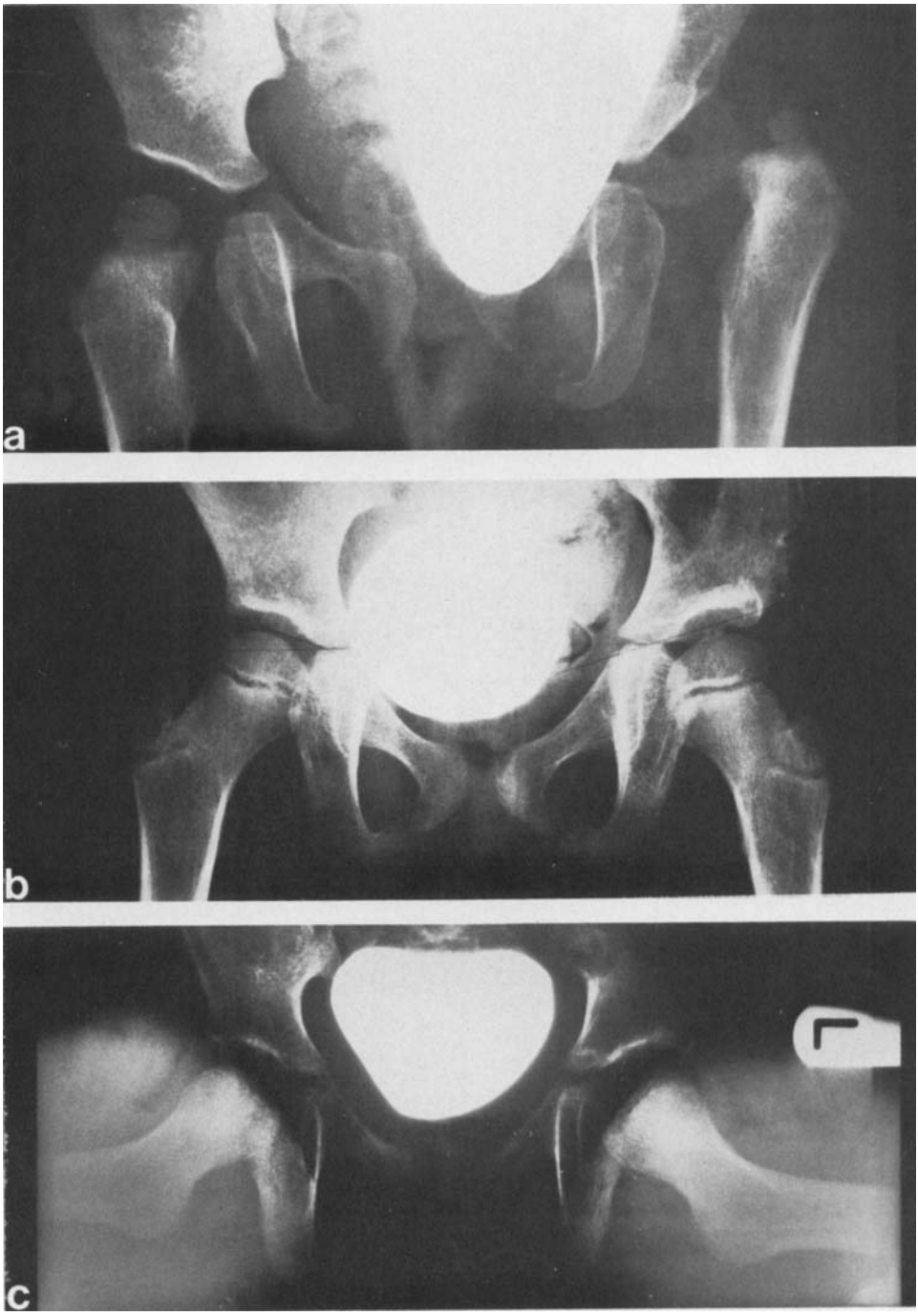
Case 2 a) 5 months, intermediate dislocation right hip. b) 24 months. c) 10 years. Treatment: 5 weeks traction, 9 months bilateral hip spica plaster cast, 20 months Hilgenreiner splint (only at night for 12 months).



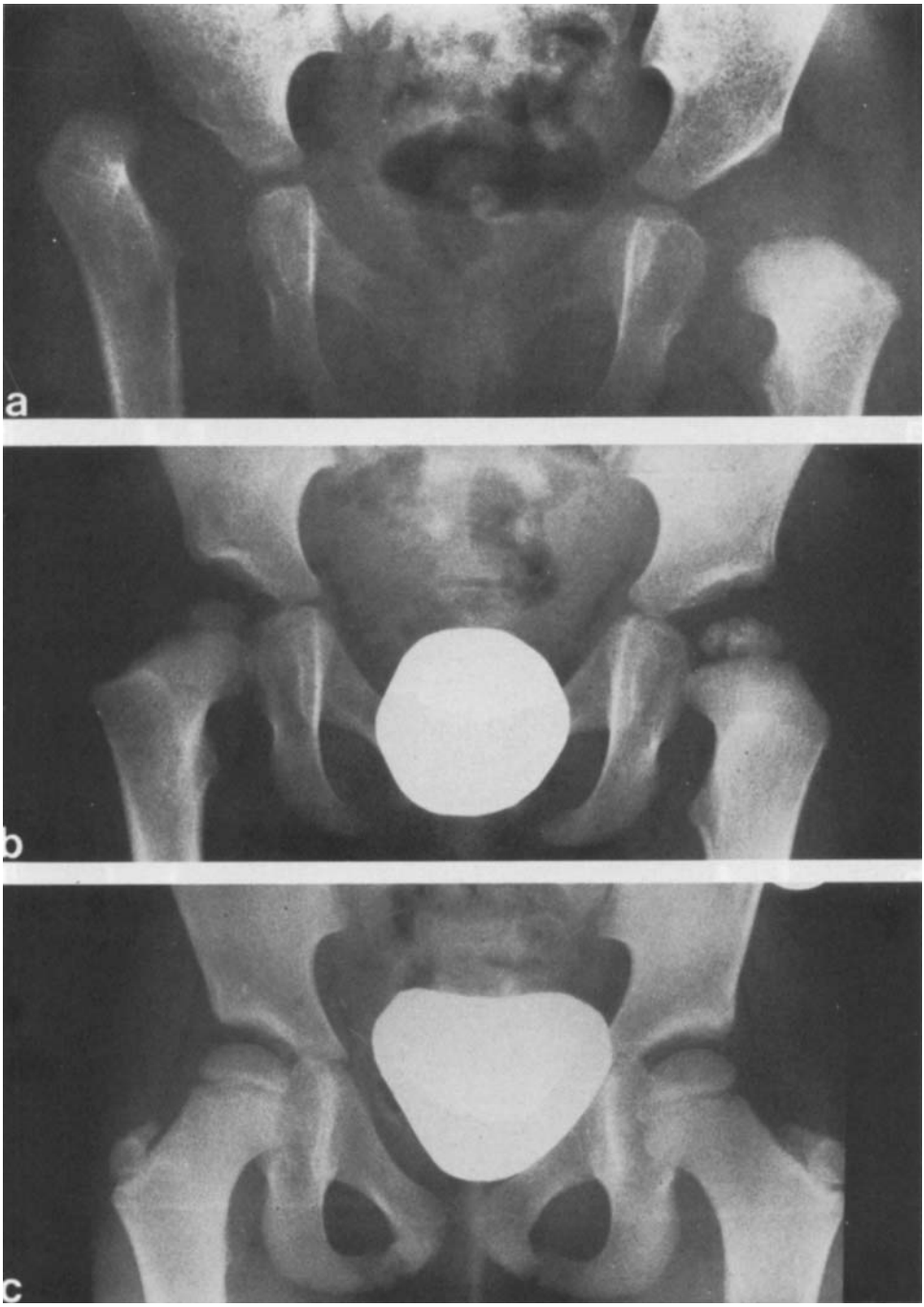
Case 3 a) 4 months, low dislocation left hip. b) 24 months. c) 7½ years. Treatment: 4 weeks traction, 6 months bilateral hip spica plaster cast, 12 months Hilgenreiner splint (only at night for 3 months).



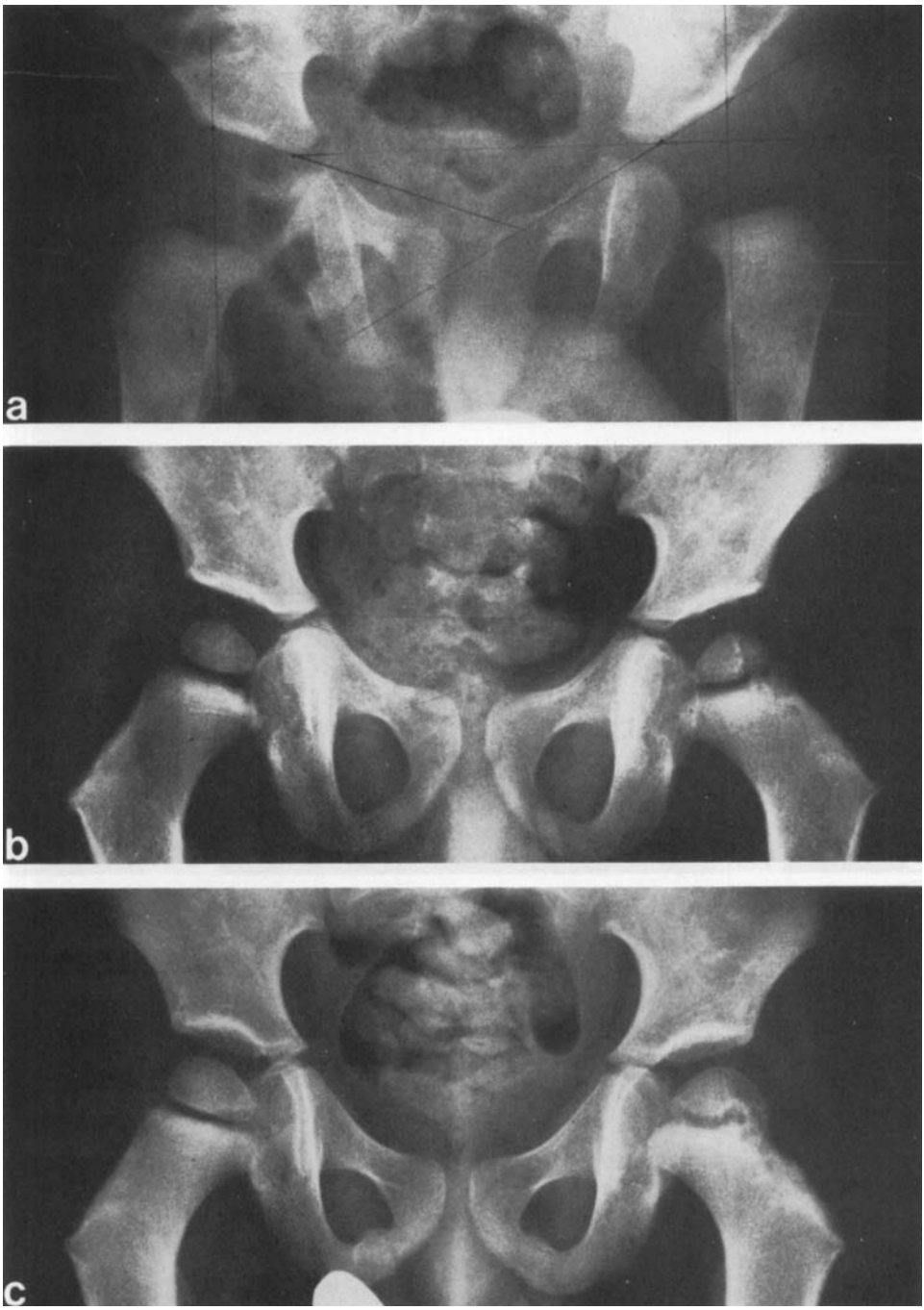
Case 4 a) 28 months, bilateral high dislocation. b) 7½ years. c) 10 years. Treatment: 8 weeks traction, 9 months bilateral hip spica plaster cast, 6 months Hilgenreiner splint, Salter osteotomy on the left at the age of 8 years.



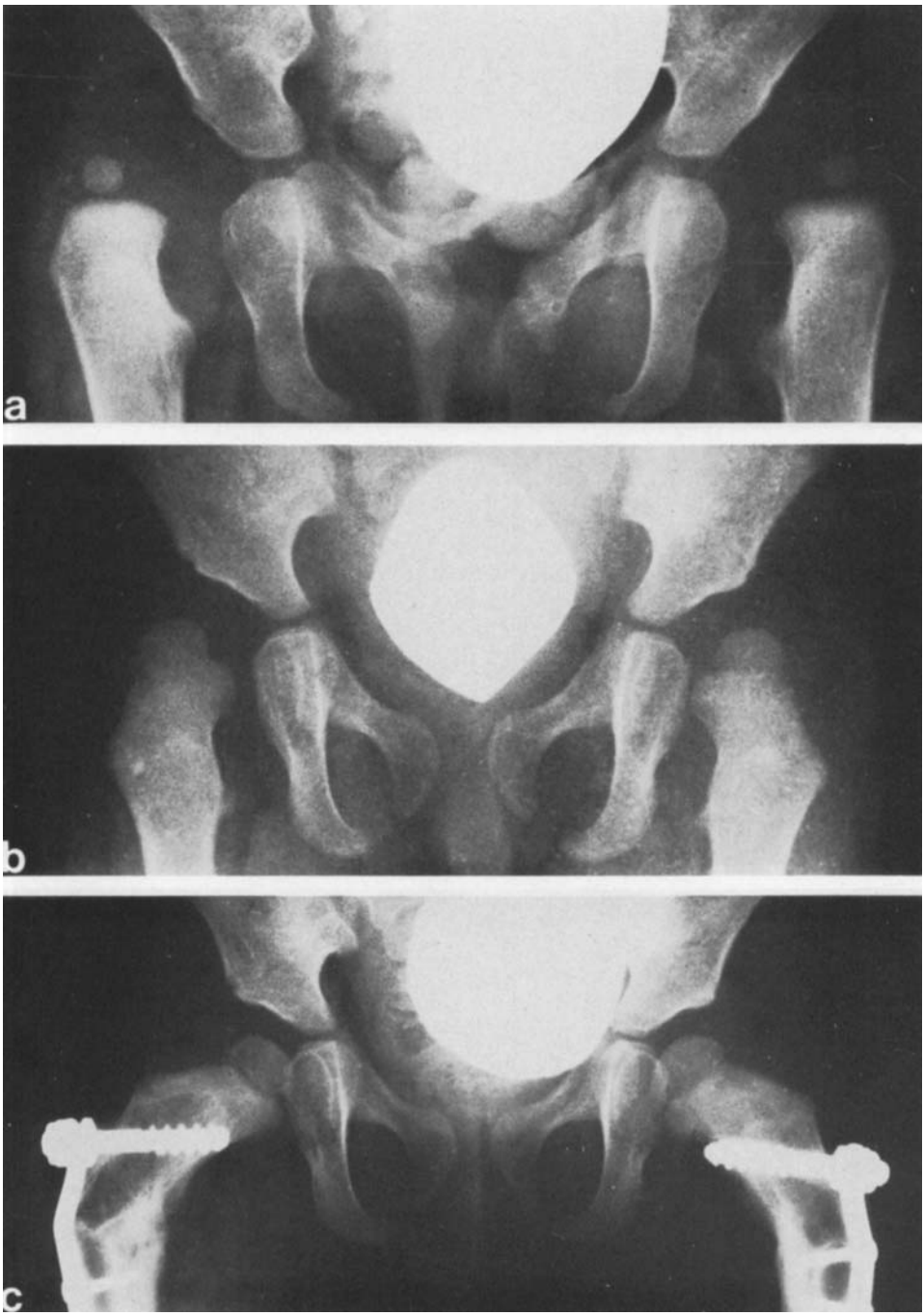
Case 5 a) 15 months, high dislocation left hip. b) 10 years. c) anteversion roentgenogram. Treatment: 6 weeks traction, open reduction left hip, 6 months bilateral hip spica plaster cast, Salter osteotomy on the left at the age of 24 months.



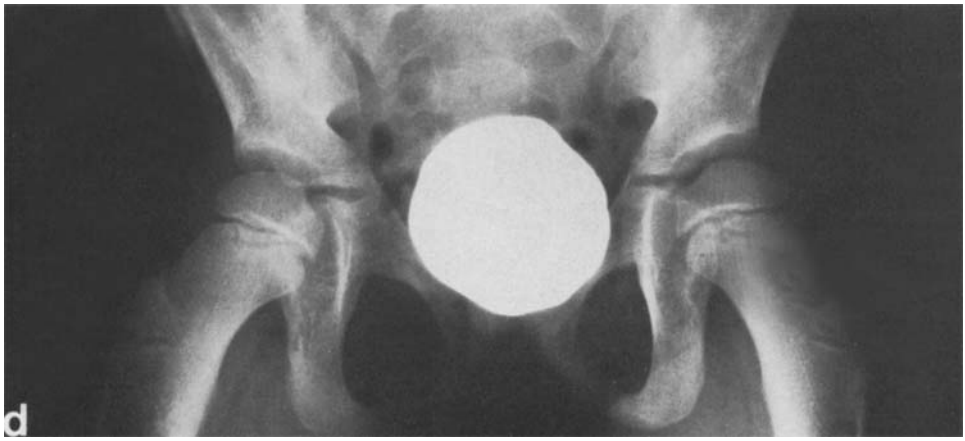
Case 6 a) 18 months, high dislocation right hip. b) 33 months. c) 7 years. Treatment: 6 weeks traction, 9 months bilateral hip spica plaster cast, 12 months Hilgenreiner splint. Complication: type I ischaemic necrosis of the contralateral femoral head, residual abnormality discreetly enlarged femoral head.



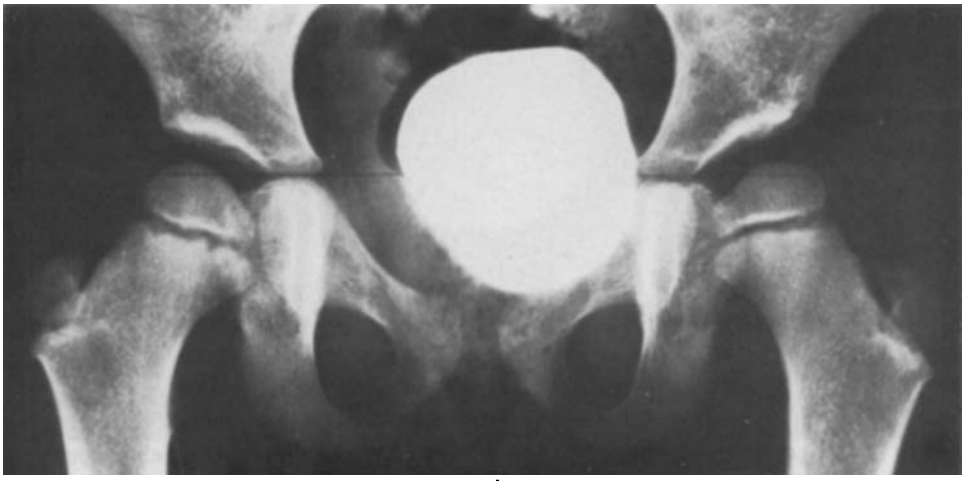
Case 7 a) 7 months, low dislocation left hip. b) 30 months. c) 4 years. Treatment: 4 weeks traction, 3 months Craig splint. Complication: type II ischaemic necrosis of the left femoral head with lateral bony bridge.



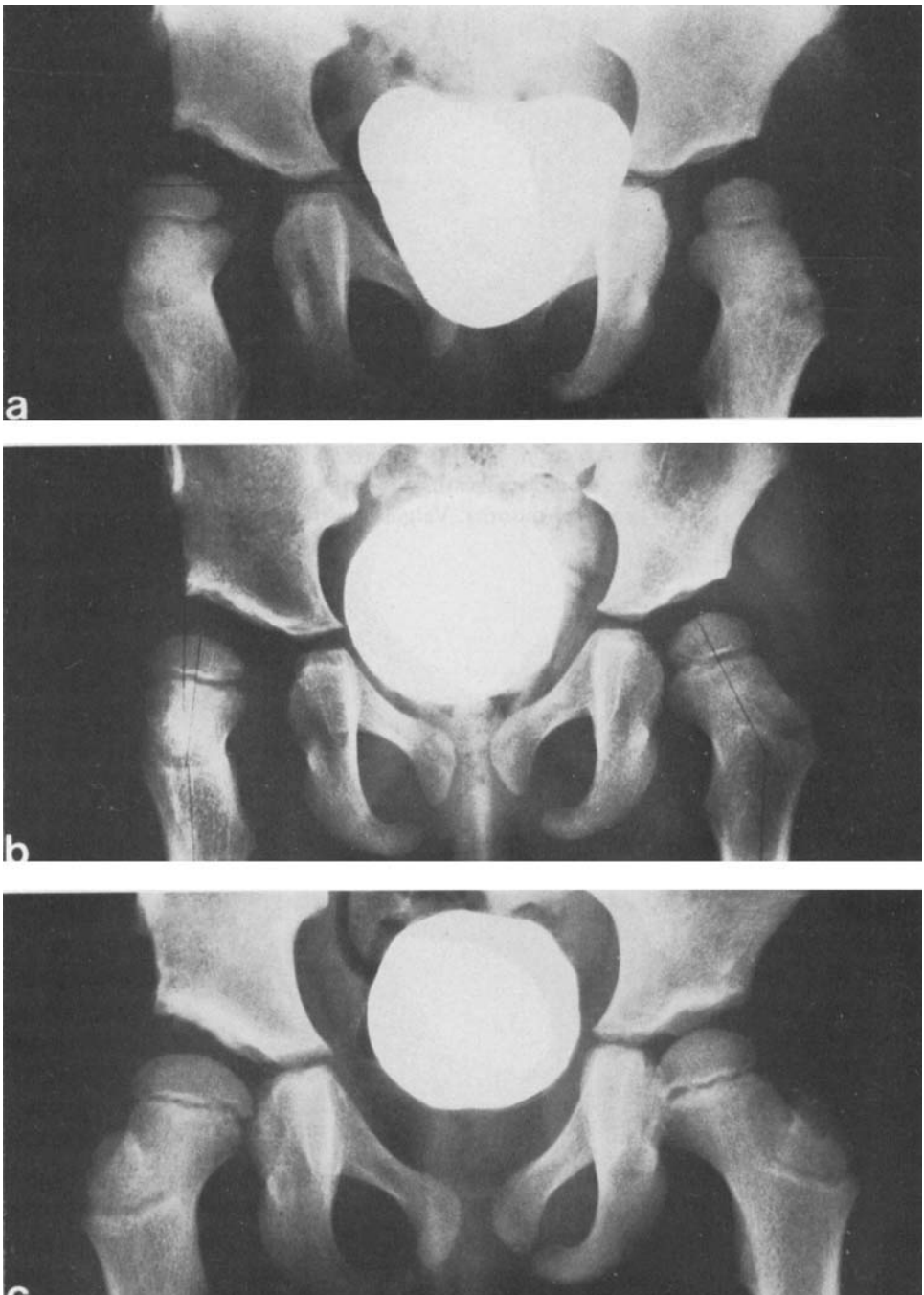
Case 8 a) 14 months, bilateral intermediate dislocation. b) 25 months. c) 32 months.



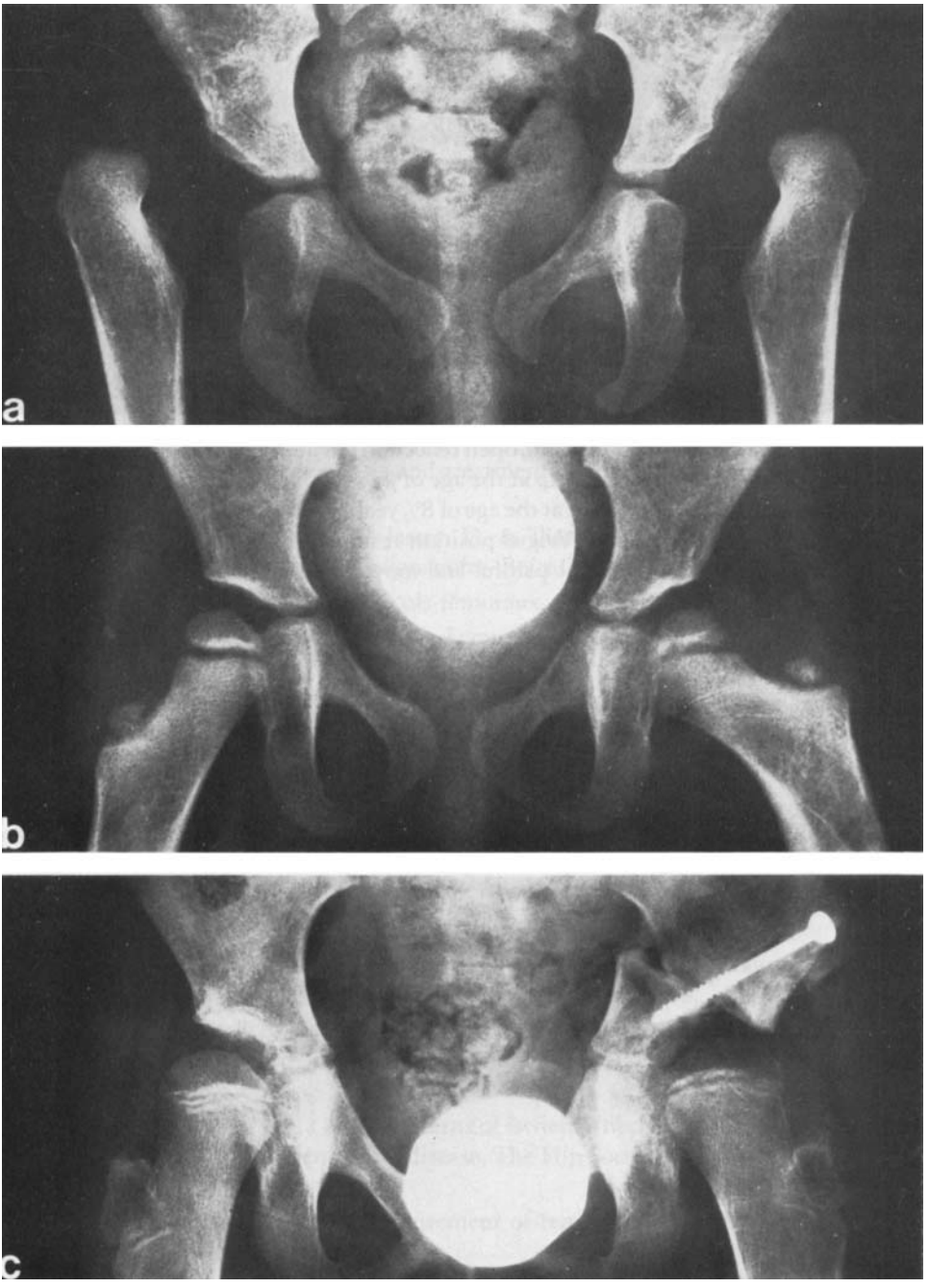
d) 6½ years. Treatment: 7 weeks traction, 3 months bilateral hip spica plaster cast, 3 months Craig splint. Intertrochanteric derotational varus osteotomy on the left at the age of 26 months, on the right at the age of 27 months. Valgus position resumed. Neck-shaft angle larger than normal on both sides.



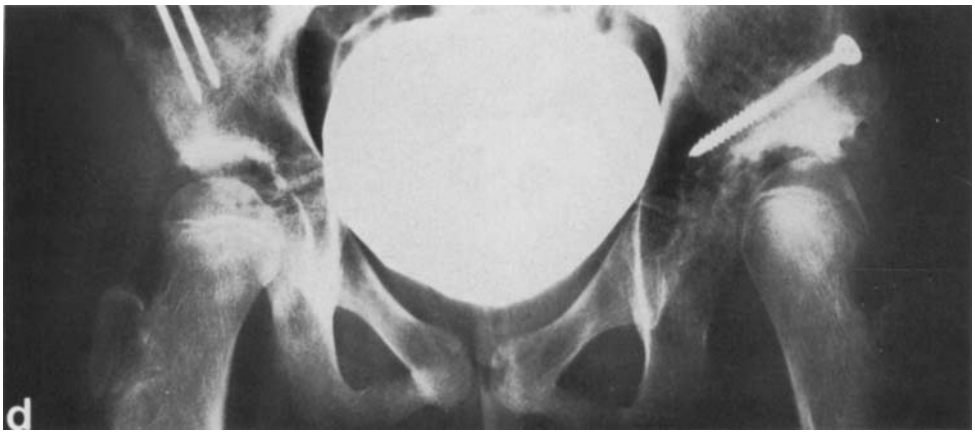
Case 9 Four years. Intermediate dislocation left hip at 4 months. Treatment: 8 weeks traction, 3 months bilateral hip spica plaster cast, 9 months Craig splint; no improvement of the acetabular angle.



Case 10 a) 30 months. b) 3 years. c) 5½ years. Treatment: bilateral hip dislocation at the age of 5 months treated by 4 weeks traction, open reduction of the right hip, 6 months bilateral hip spica plaster cast, 5 months Hilgenreiner splint, Salter osteotomy on the right at the age of 18 months. Increased anteversion on the right with slow spontaneous correction. Right femoral head discreetly enlarged. Acetabular angle too large.



Case 11 a) 17 months, bilateral high dislocation. b) 4 years. c) 8½ years.



d) 10 years. Treatment: 7 weeks traction, open reduction left and right hip, intertrochanteric derotational varus osteotomy right hip at the age of 23 months and left hip at the age of 33 months. Chiari osteotomy on the left at the age of 8½ years; Salter osteotomy at the age of 9½ years. Chiari operation too steep. Valgus position resumed; neck-shaft angle larger than normal on both sides. Left hip-joint painful and movements restricted.

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