# Long-term results after closed reduction of late-detected hip dislocation

## 60 patients followed up to skeletal maturity

Terje Terjesen[1] and Vera Halvorsen[2]

[1]Department of Orthopaedics, Rikshospitalet University Hospital, NO-0027 Oslo, [2]Orthopaedic Centre, Ullevål University Hospital, NO-0407 Oslo, Norway
Correspondence TT: terje.terjesen@rikshospitalet.no
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**Background** This retrospective study was undertaken because there is limited knowledge about the long-term results after closed reduction of late-detected hip dislocation. The aims were to evaluate the outcome after skeletal maturity and to find predictive factors for good and poor results.

**Patients and methods** The material included 60 patients (78 hips, 53 girls) treated during the period 1958–62. The primary treatment was skin traction for 36 (16–76) days. Closed reduction was performed in all hips except 4 that needed open reduction. The mean age at reduction was 20 (4–65) months. Hip spica plaster was worn for 9 (6–20) months. Within 3 years of the start of treatment, derotation femoral osteotomy was performed because of increased femoral anteversion in 35 patients. Later, 28 patients underwent additional surgery on the femur or acetabulum to improve femoral head coverage. Radiographs at the time of diagnosis and during follow-up to skeletal maturity were assessed. The average age of the patients at the most recent follow-up was 26 (15–42) years.

**Results** The femoral head coverage normalized during the primary treatment and then decreased somewhat during the remaining growth period. The dysplasia of the acetabulum improved markedly during the first year after reduction. It continued to improve, but to a much lesser degree, until 8–10 years of age. A satisfactory radiographic outcome at skeletal maturity (Severin grades I and II) was obtained in 63% of the hips. Early derotation osteotomy of the femur did not improve the outcome. Avascular necrosis of the femoral head occurred in 14% of the hips. Risk factors for unsatisfactory outcome at skeletal maturity were high initial dislocation, steep acetabulum 1 year after reduction, reduced femoral head coverage at age 8–10 years, and avascular necrosis.

**Interpretation** The specific risk factors and the radiographic outcome—with satisfactory long-term results in nearly two-thirds of the patients—would be valuable for comparison with outcome studies after more modern treatment regimes.

The initial treatment of late-detected congenital or developmental hip dislocation in children under 2 years of age, with preliminary traction followed by closed or open reduction, has been largely unchanged over the last 5 decades whereas surgery has become more usual in older children. There has, however, been less agreement concerning surgical intervention after the initial treatment.

Many studies have been published on the short-term results after treatment for hip dislocation, but there have been few studies in which the patients have been followed up until skeletal maturity (Smith et al. 1968, Malvitz and Weinstein 1994, Angliss et al. 2005). Such a long follow-up is necessary because there is a trend towards deterioration during the last part of the growth period (Gibson and Benson 1982, Blockey 1984). Furthermore, long-term results are necessary to find


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the factors that contribute to good or poor final outcome.

Some decades ago, most patients in Norway with late-detected congenital or developmental hip dislocation were treated in our department (at that time Sophies Minde Orthopaedic Hospital). The treatment regime was quite uniform with a relatively long period of preliminary traction, closed reduction, and relatively long immobilization in hip spica plaster. Moreover, the radiographs were not routinely discarded after 10 years, as happens in most other hospitals. These favorable conditions made it possible to undertake the present retrospective radiographic study on late-detected hip dislocation. We evaluated the long-term outcome after closed reduction and subsequent operative procedures. We wanted particularly to find predictors, at the time of diagnosis and later during the growth period, for satisfactory and less satisfactory outcome.

## Patients and methods

Based on the diagnosis card index at our department during the period 1961–62, we searched the files of case records and radiographs for patients with late-detected hip dislocation. Patients were included in the study if they met the following criteria: no associated anomaly, no neuromuscular disorder, no previous treatment in other hospitals, patient age at diagnosis under 5 years, and radiographs available from the start of treatment to skeletal maturity. Patients with acetabular dysplasia only or slight subluxation were not included. With these criteria, 60 patients with 78 affected hips were included. There were 53 girls and 7 boys, with a mean age of 18 (2–60) months. The primary treatment of 51 hips was during the period 1961–62 and the remaining 27 hips had had their primary treatment during the period 1958–60.

63 hips had total dislocation and 15 had pronounced subluxation with femoral head coverage of less than 50%. The condition was unilateral in 42 patients and bilateral in 18; the left side was affected slightly more often than the right side (41 versus 37).

All the patients were first treated with skin traction in order to ease the subsequent reduction. Traction was longitudinal with the hips in abduction. Internal rotation was often added during the last part of the traction period. The average time in traction was 36 (16–76) days. Closed reduction under general anesthesia was performed in 74/78 hips. Open reduction was necessary in 3 patients (4 hips) because closed reduction could not be achieved. The mean age at reduction was 20 (4–65) months. 45 patients were younger than 24 months at the time of reduction.

After the hips had been reduced, a hip plaster spica was used for a mean period of 9 (6–20) months. The position of the hips in the spica was slight flexion, quite pronounced abduction (usually about 60º), and slight internal rotation. The knees were included in the plaster in moderate flexion. The spica was changed every 3 months.

Early derotation osteotomy of the femur was performed within 3 years of hip reduction in 35 patients (bilaterally in 12). The indication for operation was increased anteversion, which was considered to be present if internal hip rotation was markedly increased and external rotation was decreased and if there was better femoral head coverage on a radiograph taken with the legs internally rotated. A transverse osteotomy just distal to the lesser trochanter was carried out with a Gigli saw. The distal fragment was rotated externally by an average of 50º (40–60) and no varus was added to the osteotomy. Fixation was secured with a 4-hole straight steel plate, which was removed after approximately 1 year. When both legs were operated on, there was an interval of 2–3 weeks between the operations.

Because of residual subluxation, acetabular dysplasia, or increased femoral anteversion surgical interventions were performed later than 3 years after hip reduction in 27 patients (32 hips) at a mean patient age of 11 (5– 21) years. The procedures were proximal femoral osteotomy, acetabular shelf operation, and pelvic osteotomy.

All the patients were followed until skeletal maturity. 40 patients were followed beyond 20 years of age. The reasons could be abnormal or suspicious radiographic findings or that the patients requested further follow-up because of hip complaints. Another reason was that some of the patients had undergone a follow-up examination at the age of 25–30 years as part of a survey on long-

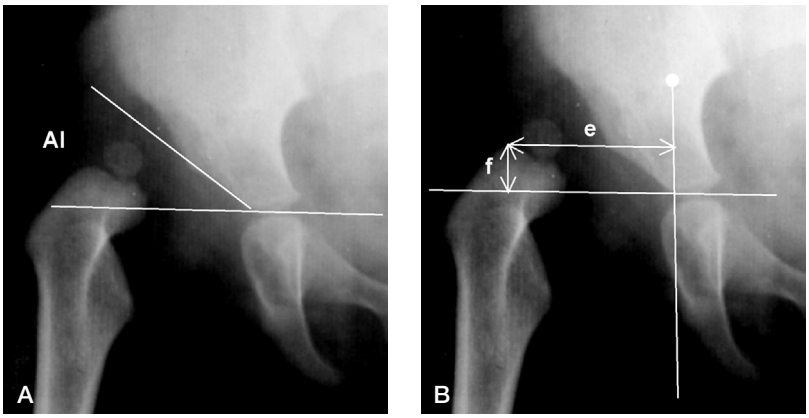


Figure 1. Radiographic measurements. Panels A and B show the primary radiograph of a 15-month-old girl with a dislocated right hip. AI is the acetabular index. The lateral (e) and vertical (f) metaphyseal distances are indicated.

term results. None of the patients were called for additional follow-up in connection with the present study.

### *Radiographic evaluation*

Conventional anteroposterior radiographs of the pelvis were taken with the child in the supine position. Care was taken to position the child correctly with the legs parallel and—as far as possible—to avoid rotation of the pelvis and hips. The film-focus distance was 115 cm. The following 6 radiographs were used for measurements: the primary radiograph, the radiographs taken 1 year and 3 years after reduction, those taken at 8–10 years of age and after skeletal maturity at the age of 15–20 years, and the last radiograph in those older than 20 years. All the radiographic measurements were performed by one of the authors (TT) with long experience in such measurements.

On the primary radiographs, the acetabular index (AI) was measured according to Kleinberg and Lieberman (1936) (Figure 1). The proximal displacement of the femur was measured as the vertical metaphyseal distance from the lateral and proximal corner of the femoral metaphysis to Hilgenreiner's line (Terjesen et al. 1989). When the metaphyseal corner was proximal to Hilgenreiner's line, this distance was given a negative sign. The lateral metaphyseal distance was measured parallel to Hilgenreiner's line, from the lateral metaphyseal corner to the inferior bony margin of the acetabular roof.

If the capital epiphysis of the femur was visible and was more than 10 mm in diameter, the migration percentage (MP) was measured (Reimers 1980) (Figure 2). When the lateral tangent of the femoral head was medial to Perkins' line, MP was termed 0%. When the medial tangent of the femoral head was lateral to Perkins' line, the MP was termed 100%. If MP is less than 33%, the hip is located. When MP is 33–89% the hip is subluxated, and 90–100% means total dislocation.

The AI could not be measured on the 15–20-year radiographs because the triradiate cartilage of the pelvis was no longer visible. Instead, the acetabular angle of Sharp (1961) was measured (Figure 2). The center-edge angle (CE angle) (Wiberg 1939) was included in the measurements from 3 years after reduction.

Assessment of avascular necrosis of the femoral head (AVN) was performed according to the method of Bucholz and Ogden (Thomas et al. 1982).

The radiographic outcome at age 8–10 years, 15–20 years, and later was evaluated using the classification of Severin (1941). Severin I means a normal hip with a CE angle above 15º in young children (< 13 years of age) and above 20º in adolescents above 14 years and in adults. Severin grade II means minor changes in the proximal femur or acetabulum, and has the same limit for the CE angle as grade I. Severin grade III is acetabular dysplasia with CE angles of less than 15º and 20º, respectively. Severin IV is subluxation, which for

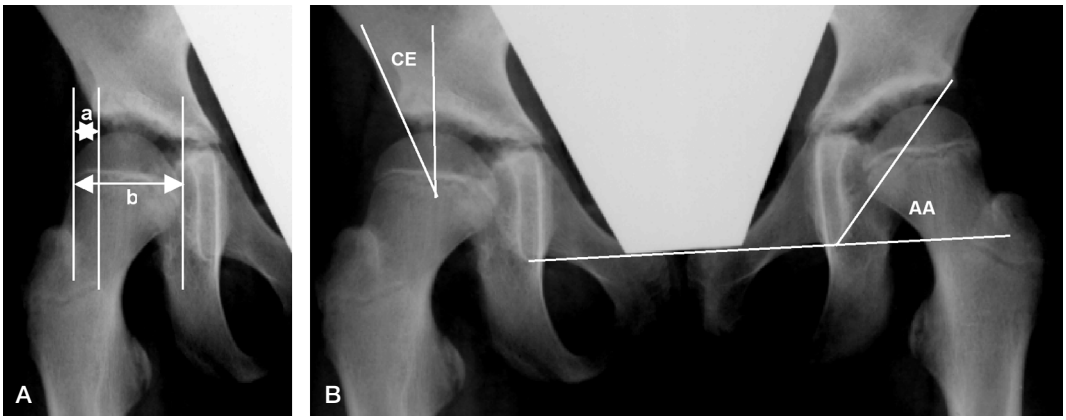


Figure 2. Radiograph of the same patient as in Figure 1 at the age of 9 years. Migration percentage (panel A) is a/b × 100 and indicates the percentage of the femoral epiphysis lateral to the lateral rim of the acetabulum. CE is center-edge angle and AA is acetabular angle (panel B).

the purposes of present study was defined as a CE angle of less than 10º and MP above 33%. Severin V is redislocation. We also simplified the Severin classification into 2 grades: satisfactory outcome when the Severin grade was I or II, and unsatisfactory outcome when the Severin grade was III–V.

Osteoarthrosis was defined according to Jacobsen and Sonne-Holm (2005). A minimum joint space width of less than 2.0 mm in the upper, weight-bearing part of the joint was the criterion for osteoarthrosis.

### *Statistics*

SPSS was used for the statistics. Categorical data were analyzed with the chi-square test. Continuous results were analyzed using the t-test for independent samples and the paired-samples t-test. Differences were considered significant when the p-value was below 0.05.

## Results

The mean follow-up period was 24 (12–39) years and the average age of the patients at the most recent follow-up was 26 (15–42) years. The mean migration percentage (MP) was 94% at the time of diagnosis, showing that most of the hips were totally dislocated. 1 year after reduction, the MP had decreased markedly and all the hips were located. The MP increased significantly during all time intervals later in the growth period (Table 1).

The mean acetabular index was 36º initially (Table 1), indicating pronounced acetabular dysplasia. There was no significant difference between patients 24 months of age or older at reduction and those younger than 24 months. During the first year after reduction, there was a marked improvement of the dysplasia with a mean decrease in AI of 14º (2–25). The decrease was significantly greater in patients less than 24 months of age at reduction than in the older patients (mean reduction 16º and 12º). Later, the decrease continued, but much more slowly than during the first year (Table 1).

Using the Severin classification for radiographic outcome, 81% of the hips had a satisfactory result with Severin grades I–II at the age of 10 years (Table 2). At skeletal maturity, the proportion of satisfactory results had decreased to 63%. The rate of subluxation (Severin IV) had not increased from 10 years of age to maturity. There was a trend towards better results when age at reduction was under 18 months, than in older patients (p = 0.06, Fisher's exact test).

### *Early derotation osteotomy*

Early derotation osteotomy of the femur was performed in 35 patients (47 hips). The mean age at the time of operation was 3.5 (2–6) years. The mean preoperative MP was 15% (0–40). Approximately 1 year postoperatively, the mean MP was 13% (0–29), a slight but statistically significant decrease (p = 0.04). The pre- and postoperative AI were 22º (10–30) and 20º (10–29) (p = 0.003).

**Table 1. Radiographic measurements in 60 patients (78 abnormal hips and 42 normal hips) with late-detected hip dislocation. Results are given as mean (SD)**

| Parameter | Measurement time | | | | |
|---|---|---|---|---|---|
| | Primary radiograph | 1-year follow-up | 3-year follow-up | Age 8–10 years | Age 15–20 years |
| Abnormal hips | | | | | |
| lateral metaphyseal distance (mm) | 31 (5.3) | | | | |
| vertical metaphyseal distance (mm) | –2 (6.0) | | | | |
| acetabular index (degrees) | 36 (3.6) | 22 (4.7) | 19 (5.0) | 18 (5.7) | |
| migration percentage (%) | 94 (14) | 3 (7.1) | 15 (11) | 22 (11) | 25 (8.4) |
| center-edge angle (degrees) | | | 20 (7.4) | 20 (7.2) | 22 (8.6) |
| acetabular angle (degrees)[a] | | | | 49 (2.7) | 43 (3.6) |
| Normal hips | | | | | |
| lateral metaphyseal distance (mm) | 22 (2.7) | | | | |
| vertical metaphyseal distance (mm) | 8 (1.6) | | | | |
| acetabular index (degrees) | 23 (5.4) | 16 (4.5) | 16 (5.1) | 13 (5.0) | |
| migration percentage (%) | 11 (11) | 2 (5.0) | 11 (8.0) | 16 (7.6) | 18 (5.2) |
| center-edge angle (degrees) | | | 24 (5.0) | 25 (6.8) | 28 (5.8) |
| acetabular angle (degrees) [a] | | | | 48 (3.7) | 41 (3.7) |

[a] according to Sharp.

**Table 2. Radiographic results according to the Severin classification**

| Severin groups | Age 8–10 years (78 hips) | | Age 15–20 years (78 hips) | |
|---|---|---|---|---|
| | n | % | n | % |
| I and II | 63 | 81 | 49 | 63 |
| III | 7 | 9 | 22 | 28 |
| IV and V | 8 | 10 | 7 | 9 |

To evaluate the effect of early femoral osteotomy on outcome, we compared the 25 hips with early osteotomy and no later surgery with the 21 hips that had not undergone surgical treatment. There was no significant difference in Severin results at skeletal maturity.

### *Later surgical treatment*

27 patients (32 hips) underwent surgical treatment more than 3 years after reduction, at a mean age of 11 (5–21) years. 22 of these hips had undergone early femoral osteotomy and 10 hips had not had any early operation. The indications for late surgical correction were residual subluxation in 18 hips, persistent acetabular dysplasia in 13, and increased femoral anteversion in 1 hip. Proximal femoral osteotomy with varus and derotation was performed in 14 hips, acetabular shelf operation (Figure 3) using the technique of Spitzy (1924) in 14 (combined with femoral osteotomy in 2 hips), and pelvic osteotomy with the technique of Salter (1961) in 4 hips.

The mean preoperative MP was 32%, and, 1 year postoperatively, had decreased to 22% ($p = 0.001$). The criterion for good effect would be a reduction in MP of more than 10% (Kalen and Bleck 1985). Using this criterion, a good effect was obtained in 4 of the 14 femoral osteotomies, in 10 of the 14 shelf operations, and in 3 of the 4 Salter osteotomies. The results were better in the acetabular procedures than in the femoral osteotomies ($p = 0.03$). The age at operation was lower in the hips with good effect of the operation. 3 of the 4 patients with a good result after femoral osteotomy were 6 years of age.

Because of a poor result after the first late operation, an additional surgical procedure was performed at a mean age of 14 years in 6 hips (femoral osteotomy in 5 hips and acetabular shelf in 1). Using the same criterion of 10% reduction in MP, none of these operations had a good effect on femoral head coverage. 1 hip was reoperated a second time, with a combined femoral osteotomy and acetabular shelf, and the effect of this operation was good.

When comparing the 32 hips with late surgical correction with the 46 hips with no late opera-

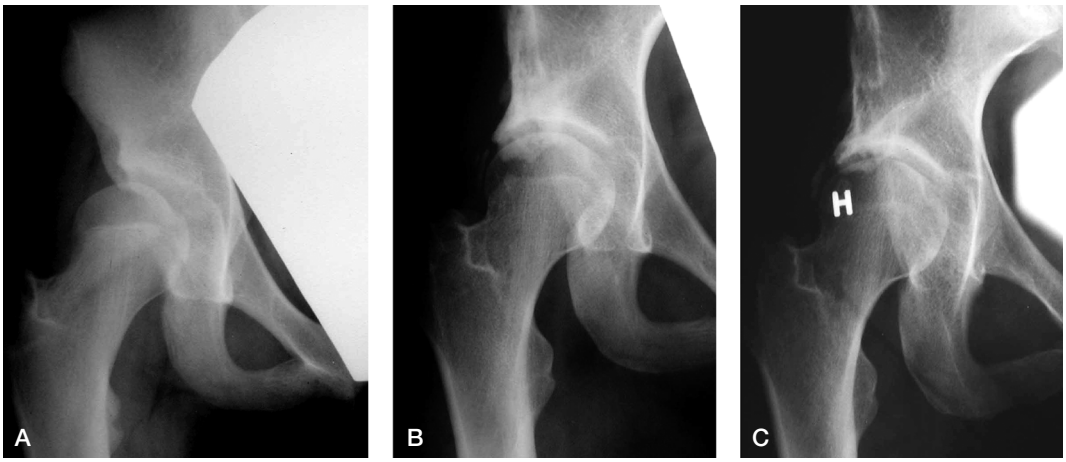


Figure 3. Radiographs of a girl with a Spitzy shelf operation at the age of 12 years. Panel A shows acetabular dysplasia of the right hip before the shelf procedure was performed. Panel B, taken at the age of 17 years, indicates that the operation has given an adequate acetabular roof. Panel C shows no signs of osteoarthrosis at the age of 33 years.

tions, there were no significant differences in radiographic parameters at the time of diagnosis. 3 years after reduction, femoral head coverage was significantly reduced in the hips with late surgical correction but there was no significant difference at skeletal maturity, indicating that the late surgical procedures had been effective in improving the coverage. The radiographic outcome at skeletal maturity tended to be better in hips with no late surgery (Severin I–II in 33/46 hips vs. 16/32; p = 0.06).

### *Complications*

Redislocation occurred in 2 patients (3 hips) during the first months after the initial reduction, and was treated with new closed reduction in one hip and open reduction in the two others. No serious complications occurred after the 47 early femoral osteotomies.

Complications after the late surgical procedures included postoperative wound infection after 3 shelf operations. Deep infection developed in two of these patients, resulting in osteoarthrosis and poor outcome. In the third case the infection healed after antibiotics and wound debridement, and the outcome was good.

AVN occurred in 9 patients (11 hips; 14%). There was involvement of the epiphysis only (grade 1) in 3 hips and more serious involvement of parts of the physis in the remaining 8 hips. The radiographic outcome at maturity was satisfactory (Severin I–II) in the 3 hips with epiphyseal involvement alone, but in only 1 of the 8 hips with physeal involvement.

### *Risk factors for unsatisfactory radiographic outcome*

Risk factors for unsatisfactory radiographic outcome were evaluated by computing the various clinical and radiographic variables according to good radiographic result (Severin I–II) and unsatisfactory results at skeletal maturity. Risk factors for unsatisfactory outcome were residual subluxation (p = 0.001) and avascular necrosis of the femoral head (p = 0.003). Of the radiographic measurements at diagnosis (Table 3), high dislocation (smaller vertical metaphyseal distance) was the only risk factor for unsatisfactory outcome. At the 1-year follow-up, acetabular dysplasia (less reduction in AI during the first year after reduction) was a risk factor. At the age of 8–10 years, acetabular dysplasia and reduced femoral head coverage were significant risk factors.

The following parameters had no significant influence on the radiographic results at skeletal maturity: sex, affected side, bilateral or unilateral involvement, and dislocation vs. subluxation. Nor was increased age at hip reduction a significant risk factor, irrespective of whether the age limit was 12 months, 18 months, or 24 months. The mean age at reduction was 19 months in the satisfactory hips and 23 months in the unsatisfactory hips (p = 0.1).

**Table 3. Radiographic parameters at the time of diagnosis and follow-up according to the** outcome at skeletal maturity. Satisfactory outcome corresponds to Severin groups I–II; unsatisfactory outcome corresponds to Severin groups III–V. Results are given as mean (SD)

| Radiographic parameter | Radiographic outcome at age 15–20 years<br>Satisfactory (Severin I–II) | Unsatisfactory (Severin III–IV) | P-value |
|---|---|---|---|
| At diagnosis | | | |
| Lateral metaphyseal distance (mm) | 30 (5.3) | 32 (5.0) | 0.07 |
| Vertical metaphyseal distance (mm) | 0 (5.6) | –4 (6.0) | 0.01 |
| Acetabular index (degrees) | 36 (3.8) | 36 (3.4) | 0.9 |
| Migration percentage (%) | 94 (15) | 96 (11) | 0.5 |
| 1-year follow-up | | | |
| Acetabular index (degrees) | 21 (4.7) | 23 (4.6) | 0.05 |
| Reduction in AI (degrees) | 15 (4.8) | 13 (5.2) | 0.04 |
| Migration percentage (%) | 3 (6.7) | 5 (7.8) | 0.3 |
| 3-year follow-up | | | |
| Acetabular index (degrees) | 19 (5.1) | 20 (4.7) | 0.4 |
| Migration percentage (%) | 13 (9.7) | 18 (13) | 0.07 |
| Center-edge angle (degrees) | 21 (7.2) | 20 (7.9) | 0.5 |
| Age 8–10 years | | | |
| Acetabular index (degrees) | 16 (4.8) | 20 (6.4) | 0.005 |
| Migration percentage (%) | 19 (8.1) | 26 (13) | 0.03 |
| Center-edge angle (degrees) | 22 (6.6) | 18 (7.8) | 0.03 |

### *Development of the hips after skeletal maturity*

Follow-up had been extended after a patient age of 20 years in 40 patients (52 hips). The mean age of these 40 patients at the most recent follow-up was 30 (21–42) years. The mean MP was 23% (8–37) in the affected hips and 16% (6–32) in the normal hips. The corresponding CE angles were 22º (-8–40) in the affected hips and 29º (17–40) in the normal hips. At the latest follow-up, the results according to the Severin classification were satisfactory in 26 hips and unsatisfactory in 26 hips.

Osteoarthrosis had developed in 7 patients (8 hips) who were older than 20 years. There was a relationship (p = 0.05) between the occurrence of degenerative changes and age, as osteoarthrosis had developed in only 1 of the 26 hips at the age of 21–29 years, in 5 of 21 hips at 30–39 years, and in 2 out of 5 hips at the age of 40–42 years. Thus, osteoarthrosis had occurred in 7/26 hips with longer follow-up than 30 years.

Risk factors for osteoarthrosis in the 26 hips with a follow-up of more than 30 years were residual subluxation (p = 0.001), avascular necrosis (p = 0.002), and the following radiographic parameters: higher AI 1 and 3 years after reduction, and reduced femoral head coverage 3 years after reduction.

## Discussion

During the first part of the last century, when the treatment was closed reduction without preliminary traction, the long-term outcome of late-detected hip dislocation was usually poor, with only 12–15% satisfactory radiographic results (Severin 1941, Smith et al. 1968). Avascular necrosis (AVN) was one of the main reasons for the poor results. The results improved after the introduction of new concepts to avoid AVN: traction, gentle reduction, and avoidance of extreme positions in the hip spica (Salter et al. 1969, Gage and Winter 1972).

The radiographic classification of Severin (1941) has been widely used by others, which has made comparison of different studies easier. Although traction had been used in only a small proportion of the patients, Malvitz and Weinstein (1994) reported good long-term outcome (Severin I–II) after closed reduction in 46% of the patients. Somewhat better results (53% satisfactory) were obtained by Blockey (1984) using traction and closed reduction plus derotation osteotomy 7 months later. In Oxford, the “direct approach” to hip dislocation was introduced by Somerville and Scott (1957), consisting of preliminary traction,

closed reduction or open reduction with excision of the limbus, and derotation osteotomy some weeks later. Angliss et al. (2005) described 147 patients with this treatment. The outcome at skeletal maturity was rather poor with 31% good results, 39% dysplastic Severin III hips, and 29% subluxation or dislocation.

Gibson and Benson (1982) reported a deterioration of the radiographic results from 5 years after reduction to skeletal maturity, and we found the same. There were more Severin III hips at the 15–20-year follow-up than at age 8–10 years, and less Severin I–II hips. One reason for this difference is the criterion for satisfactory results according to Severin, which is a CE limit of 15º at age 10 years and of 20º at maturity. If a CE limit of 20º were to be used at the 10-year follow-up, our satisfactory results would decrease from 81% to 60%. We consider that it would be rational to modify the Severin criteria and use a limit of 20º at all follow-up examinations.

The main characteristics of our patient material were relatively long traction time, closed reduction in almost all patients, a long time in plaster spica, and often early derotation osteotomy. In comparison with previous long-term studies, our result with 63% Severin I–II hips seems somewhat better. However, our treatment policy has changed over the years and now involves shorter time in traction, no internal rotation during traction, open reduction more often, and a shorter time in hip spica. In patients 3 years of age and older, preliminary traction is not used, and open reduction is combined with femoral shortening osteotomy and acetabular osteotomy.

Because the treatment concepts have changed considerably, the present study is now almost historical. Nevertheless, the results are valuable because no previous long-term study on the present treatment regime has, to our knowledge, been published. Our radiographic results over many years represent a valuable resource for comparison in order to evaluate whether or not, and to what degree, modern treatment concepts will give better long-term outcome for the patients.

### *Acetabular development*

The acetabular index showed a marked decrease of 14º the first year after the start of treatment, in accordance with previous studies (Cherney and Westin 1989, Race and Herring 1983). The decrease was somewhat less in patients above 2 years of age than in those who were younger, in accordance with the findings of Lindstrom and Ponseti (1979). This shows a pronounced capacity for improvement of the acetabulum, even when age at reduction is over 2 years. After the first year the decrease in AI continued, but at a much slower rate, confirming the experience of others that a slow but steady improvement of the acetabulum takes place up to 6–8 years after reduction (Lindstrom and Ponseti 1979, Zionts and MacEwen 1986). Harris et al. (1975) reported that the acetabulum will develop normally if concentric reduction is obtained before the age of 4. This contrasts with the opinion of Salter (1961) that after 1.5 years of age normal osseous development of the acetabulum is no longer assured.

### *Early derotation osteotomy*

Since most dysplastic hips have increased femoral anteversion, Somerville and others believed that early correction of the anteversion would give more concentric position of the femoral head and would thus ensure better development of the hips (Somerville and Scott 1957, Blockey 1984). Influenced by this concept, it was common policy in our department to perform early derotation of the femur, although the osteotomies were not performed 1–2 months after reduction as recommended by Somerville, but usually after 1–2 years. In many cases there was increased valgus; thus, addition of varus would seem necessary. However, Gibson and Benson (1982) found that inclusion of varus in the derotation did not influence the outcome.

Somerville and Scott (1957) thought that persistent anteversion was the commonest cause of recurrent subluxation. This would make early femoral derotation a prophylactic procedure. Ponseti (1966) believed, however, that early derotation did not prevent late subluxation and this was confirmed in later long-term studies (Angliss et al. 2005) as well as in the present study. According to Salter (1961), increased anteversion and valgus will resolve spontaneously if the hip remains concentrically reduced. Moreover, Tönnis (1994) has warned against varus femoral osteotomies because this could lead to unfavorable long-term results

with tilting of the femoral head into valgus (subcapital coxa valga) and repeated subluxation.

Based on our findings, it seems reasonable to conclude that early femoral osteotomy was unnecessary in the majority of the patients, because the results at maturity were no better than those in hips where no derotation had been carried out. Many years ago we stopped doing derotation osteotomies as was done almost routinely during the study period.

### *Late surgical procedures*

The reason for late surgical intervention was residual acetabular dysplasia with or without subluxation. The frequency of late operations was 41%, which is in accordance with rates from 20% to more than 60% in previous studies; there seems to be no clear difference in frequency whether primary open or closed reduction has been performed (Zionts and MacEwen 1986, Williamson and Benson 1988, Forlin et al. 1992, Yamada et al. 2003, Angliss et al. 2005).

The late operations had good effect, with improvement of the femoral head cover and Severin groups I–II at maturity in half of the hips. Although reliable conclusions can hardly be drawn from 32 hips, the results were less satisfactory after femoral osteotomy alone, which is in agreement with the findings of Gibson and Benson (1982). In our patients, there was a trend towards better effect when an acetabular procedure alone or in combination with femoral osteotomy had been performed.

What is the optimal age for late procedures? Lindstrom and Ponseti (1979) recommended delaying surgical intervention until about 8 years of age, to give the acetabulum a chance of spontaneous improvement with growth. However, Lalonde et al. (2002) reported that combined acetabuloplasty and femoral osteotomy gave better results when performed at a younger age (2–8 years) than when performed later, and Tönnis (1993) maintained that the best age for correction of the acetabular roof is 4–5 years. In the present study the hips with unsatisfactory outcome showed reduced femoral head cover at age 8–10 years, but not 3 years after reduction. Thus, 5–6 years appears to be a suitable age for late correction.

Is there still a place for shelf procedures? Good results in 60–85% of cases after relatively short follow-up have been reported (Bjøro 1956, Wilson 1974, Wainwright 1976) but there seems to be a gradual failure of the operation with time. Summers et al. (1988) had a mean follow-up of 16 years and found good results in 59% of cases, which is consistent with the good effect in 10 of the 14 hips in this study. Our results might have been better if prophylactic antibiotics had been used in the 2 cases of deep infection.

If late surgical correction is necessary, our present policy is to perform femoral osteotomy (with shortening, derotation, and varus as required) combined with pelvic osteotomy. However, in children above 10 years of age and adolescents, we still prefer the shelf operation according to Spitzy. This is because it is a relatively easy and safe technique and because more modern—but technically difficult—pelvic osteotomies have not been evaluated with sufficiently long follow-up to allow us to conclude that they lead to better results.

### *Risk factors for unsatisfactory outcome*

Smith et al. (1968) maintained that anything other than perfect reduction was a risk factor for poor long-term prognosis. In older studies, better results were found when treatment started under 3 years of age and worse results above 4 years of age (Severin 1941, Smith et al. 1968). We found no significant relationship between the age at reduction and radiographic outcome at maturity, in agreement with Blockey (1984), Forlin et al. (1992), and Yamada et al. (2003). Others have reported better results in younger patients. Malvitz and Weinstein (1994) had better results in younger patients irrespective of whether the age limit was 12 months or 18 months.

High dislocation (increased proximal displacement of the femur) was a significant risk factor in the present study, in accordance with the findings of some other studies (Malvitz and Weinstein 1994, Angliss et al. 2005). However, others did not find any radiographic risk factors at diagnosis (Ferris et al. 1991, Forlin et al. 1992).

Varying rates of severe AVN (grades 2–4) from 0% to approximately 20% have been reported (Smith et al. 1968, Gibson and Benson 1982, Malvitz and Weinstein 1994, Blockey 1984, Berkeley et al. 1984, Salter and Dubos 1974), which is in accordance with the rate of 10% in our study. According to a review article by Gabuzda and Ren-

shaw (1992), there is no significant difference in the rate of AVN between closed and open reduction. AVN was a significant risk factor for unsatisfactory development in our study, in agreement with previous experience.

Acetabular dysplasia and less reduction of the AI during the first year after reduction were risk factors in our study, which is in keeping with some other reports (Gibson and Benson 1982, Malvitz and Weinstein 1994) but not with others (Ferris et al. 1991, Forlin et al. 1992). At 8–10 years of age, persistent acetabular dysplasia and reduced femoral head cover were risk factors, supporting previous experience (Cooperman et al. 1983, Malvitz and Weinstein 1994, Angliss et al. 2005). This indicates that surgical correction should take place before this age.

### *Development of the hips after skeletal maturity*

Residual subluxation was found to be a risk factor for the development of osteoarthrosis in previous long-term studies (Malvitz and Weinstein 1994, Angliss et al. 2005), and this was confirmed with the present patients. The occurrence of osteoarthrosis is relatively rare before the age of 30 years. Thus, only studies with really long follow-up can provide reliable information about the rate of osteoarthrosis. Malvitz and Weinstein (1994), with a mean patient age of 31 years, found that the rate of osteoarthrosis increased from 4% between the ages of 20 and 29 years to 29% between 30 and 39 years, and 42% in patients over 40 years of age. Angliss et al. (2005), with a similar long follow-up, reported moderate or severe osteoarthrosis in 40% of 191 hips. Thus, new treatment methods must give a rate of moderate to severe osteoarthrosis of less than 40% at the age of ~40 years in order to represent a true improvement in the treatment of late-detected hip dislocation.

### *Contributions of authors*

TT: reviewed the literature, planned and executed the study and wrote the manuscript. VH: participated in planning and performing the study and revised the manuscript.

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