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ORIGINAL PAPER

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Avascular necrosis after surgical treatment for developmental dysplasia of the hip

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Abstract We reviewed the medical records of 101 patients with developmental dysplasia of the hip who were treated with Dega's (102 hips), or Salter's (42 hips) osteotomy preceded by open reduction and femoral intertrochanteric osteotomy. The minimal follow-up was 17 years. At the last follow-up, there were proximal femoral growth disturbances in 52 hips (36%). In 20 hips, the disturbances were graded as mild and in six as severe. We found significantly better clinical and radiological results in hips without avascular changes. Risk factors for the development of avascular necrosis were: involvement of the left side and surgical treatment initiated after 2 years of age without pre-operative traction and without femoral shaft shortening. We found that the incidence of avascular necrosis increased with the length of follow-up. The avascular necrosis influenced both clinical and ra-diological results.

Résumé Nous avons examiné les registres médicaux de 101 malades avec une dysplasie congénitale de la hanche qui ont été traitée par ostéotomie de Dega (102 hanches) ou Salter (42 hanches) précédé par réduction ouverte et ostéotomie fémorale intertrochantérienne. Le suivi minimal était de 17 ans. Àu dernier recul il y avait des troubles de croissance des fémurs proximaux dans 52 hanches (36%). Dans 20 hanches les troubles ont été notés comme discrets et en six comme sévères. Nous avons trouvé des résultats cliniques et radiologiques bien meilleurs dans les hanches sans troubles vasculaires. Les facteurs du risque pour le développement d'une nécrose avasculaire étaient: l'affection du côté gauche, le traitement chirurgical commencé après l'âge de 2 ans sans traction préopératoire et sans raccourcissement de la diaphyse fémorale. Nous avons trouvé que la fréquence des nécroses avasculaires a augmenté avec la durée d'observation. La nécrose avasculaire a influencé les résultats cliniques et radiologiques.

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Introduction

Avascular necrosis (AVN) is a serious complication to the treatment of developmental dislocation of the hip (DDH). It can also occur in the contralateral normal hip during the course of treatment [4, 6, 8, 9]. The major causes are excessive pressure on the cartilaginous femoral head and compression or occlusion of the epiphyseal blood supply.

Several factors are associated with AVN: immobilisation in excessive abduction; patient age, with avascular necrosis being more common in older children [10, 11, 18]; surgery for redislocation; and failure of previous closed treatment [2, 8, 24]. A factor in the variation of the reported prevalence is the question of what exactly is classified as AVN. Salter et al. [18] outlined five criteria for the diagnosis: failure of the ossified nucleus to appear for 1 year or more; failure of the nucleus to grow for 1 year or more; broadening of the femoral neck; increased radiographic density followed by fragmentation of the epiphysis; and residual deformity after ossification is complete.

Patterns of avascular involvement of the epiphysis and growth plate have been classified by several authors [4, 7]. Vascular changes may not be evident until 6–11 years after the reduction and rates of growth disturbances with less than 10 years of follow-up must be regarded as preliminary findings and may not reflect the true prevalence. Therefore, the purpose of our study was to determine the incidence and sequelae of AVN with a minimum of 15 years' follow-up.

Materials and methods

We retrospectively reviewed the medical records of 256 patients who underwent pelvic osteotomies for the treatment of DDH before 1985. Patients with neuromuscular or connective tissue disorders as well as patients with septic arthritis of the hip were excluded. One hundred and one patients with 144 hips involved who had reached skeletal maturity were available for follow-up. There were 88 girls and 13 boys with 66 unilateral (51 left and 15 right hips) and 39 bilateral cases. Mean age at the time of the diagnosis was 19 (3–108) months; mean age at time of surgery was 35 (20–108) months. Mean follow-up was 21 (17–32) years.

The height of the original dislocation was classified according to Tönnis [23]. The measurement was done from the ossification centre of the femoral head to the superolateral corner of the true acetabulum. There were only eight hips with no displacement (grade 0), in which cases the only abnormality was the acetabular dysplasia. In 39 hips, there was lateral displacement of the ossification nucleus, but still level with the acetabulum (grade 1). The majority of cases (67 hips) presented a high dislocation where the ossification centre was above the lateral corner of the ace-tabulum (grade 4). The remaining 30 hips with the femoral head at the level of the acetabular corner were classified as grade 3.

Eighty-six hips (60%) had no previous treatment and the surgical procedure was performed shortly after the diagnosis of DDH was established. The remaining 58 hips were operated on after previous unsuccessful conservative treatment. The conservative treatment included flexion-abduction devices (12 hips) or closed reduction (46 hips) and immobilisation. The mean age at the time of closed reduction was 13 (7–38) months. Pre-operative traction was used in 87 hips.

In 102 hips, Dega's trans-iliac osteotomy was performed and in 42, Salter's innominate osteotomy. An open reduction and femoral intertrochanteric osteotomy preceded all pelvic osteotomies. Femoral shaft shortening was not performed as a standard procedure but only used to restore Shenton's line. Clinical assessment at the final follow-up was performed using McKay criteria with Barret's modification [1, 16].

We also evaluated the radiographs taken pre-operatively, 6 months after surgery and at the last follow-up. Quantitative measurement of the acetabular index (AI) in skeletally immature patients (pre-operative and post-operative radiograms) and Sharp's acetabular angle (AA) in skeletal mature patients (follow-up examination) was done. Due to the significant number of high dislocations, we were unable to measure the centre-edge angle of Wiberg before surgery. However, we analysed this angle on the post-operative and final radiographs, which were also screened for abnormalities of the femoral head, neck and acetabulum, as well as for signs of avascular necrosis. We used Mose's templates [17] to measure Wiberg's centre-edge angle and the sphericity of the femoral head. The obtained results were classified according to Severin [20].

Subluxation of the hip was defined as an interruption of Shenton's line or a lateral shift of the femoral head with more than 12 mm between the medial aspect of the femoral head and the lateral aspect of the "teardrop figure". In accordance with the method of Mose [17], the femoral head was considered "perfect" if its outline was covered by the same circle of the template, "regular" if its outline was in the zone limited by two concentric circles, "irregular" in the zone limited by three circles and "very irregular" in the zone limited by four or more concentric circles. Femoral head growth disturbances were described using the classification system by Bucholz and Ogden [4].

All analysed variables showed a non-parametric distribution. Statistical significance was evaluated using the Mann-Whitney test. Chi-squared test was used for qualitative data. Spearman correlation co-efficients were used to examine the correlation between two factors. A value of $p<0.05$ was considered statistically significant.

Results

We observed no case of pre-operative femoral head AVN. At the last follow-up, however, we found proximal femoral growth disturbances in 52 hips (36%). The most frequent was type I [4]. Mild changes were observed in 20 hips. We found type II deformation in 12 hips and type III in 14 hips. The most severe, type IV, was noted in six hips.

In order to assess the influence of AVN on proximal femoral development and to analyse AVN risk factors, we divided our patients into two sub-groups: whether they had signs of AVN or not. Clinical results according to McKay classification [16] are shown in Table 1. Differences between the groups were statistically significant ($p=0.04$). Radiographic results according to Severin's criteria [20] are presented in Table 2. Differences between groups were also statistically significant ($p=0.02$).

Finally, we evaluated factors that affected the final results. Gender, height of the original dislocation, type of surgery, time of initial diagnosis and conservative treatment as well as the length of conservative treatment showed no significant correlation with the incidence of AVN. The left hip joint, surgical treatment initiated after 2 years of age, pre-operative traction and femoral shaft shortening were, however, found as significant risk factors for AVN development (Table 3).

Premature triradiate cartilage closure was observed in five hips; it did not influence acetabular development. We

Table 1 Clinical results using McKay's classification in patients with and without avascular necrosis (AVN) of the hip

McKay's classification	Hips with AVN (n=52)	Hips without AVN (n=92)
Very good	15	52
Good	16	21
Satisfactory	14	16
Poor	6	3

Table 2 Radiological findings according to Severin's criteria. *AVN* avascular necrosis

Findings according to Severin's criteria	Hips with AVN (n=52)	Hips without AVN (n=92)
Very good	10	35
Good	20	40
Satisfactory	12	13
Poor	10	4

Table 3 Risk factors for the development of avascular necrosis (AVN) (type I–IV) in developmental dislocation of the hip (DDH). *AC* acetabular

Factor	Type I	Type II	Type III	Type IV	Overall	*p* value
Left	9	12	9	5	35	
Right	9	2	3	3	17	
						0.05
Pre-op. traction	2	2	3	1	8	
Without pre-op. traction	18	10	11	5	44	
						0.01
Operation before 2 years of age	2	0	3	1	6	
Operation between 2 and 3 years of age	10	7	3	4	24	
Operation after 3 years of age	6	8	7	1	22	
						0.04
Femoral shaft shortening	6	2	2	1	11	
Without femoral shaft shortening	11	12	12	6	41	
						0.001
Correction of AC angle more than 15°	11	9	7	7	34	
Correction of AC angle less than 14°	7	5	5	1	18	
						0.03

observed no transitory hip joint stiffness or septic problems.

Discussion

AVN of the hip remains the most serious complication after treatment of DDH. There is universal agreement that alteration of the blood supply to the femoral head causes this complication [2, 8, 9, 18], but there is still uncertainty as to incidence and pre-disposing factors. In the earliest studies, the incidence varied from 0% [5] to 67% [6]. Our findings are similar to those reported by Brougham et al. [3] and Thomas et al. [22], whereas others have reported lower figures [2, 11, 21, 25]. This discrepancy might be due to several factors.

Firstly, the main problem may be associated with the classification systems and the strictness with which the criteria are interpreted. Some authors [21, 23] suggested that the actual prevalence of growth disturbances may vary less than the criteria with which they are defined. For example, Mau et al. [15] reported only two instances of AVN, but 16 of 33 patients were noted to have "transient roentgenographic changes in the femoral heads". Similarly, Zionts and MacEwen [25] identified major AVN in approximately 5% of their patients, but also noted "temporary irregular ossification" in one third. Secondly, the prevalence of growth disturbances goes up with the length of the follow-up, since many changes become apparent relatively late. Studies with longer follow-up even after conservative treatment [14] or isolated open reduction report a higher rate of AVN [12]. Thirdly, different regimes of conservative and surgical treatment may influence the prevalence of AVN. It is impossible to compare angles and tension of applied traction, as well as force and technique used to perform a closed reduction. As for the surgical technique, the most important is not the method of osteotomy but the surgeon's skills. We found no significant difference in the rate of AVN in relation to surgical technique.

Pre-operative traction and femoral shortening are the most frequently recommended procedures to decrease the prevalence of AVN and improve likelihood for a successful treatment [8, 13, 18, 22, 24]. Femoral shortening may benefit younger children who have an open reduction. This operation acts more effectively than a soft-tissue release. In the literature, femoral shortening is preferred in patients older than 3 years. The rate of AVN after femoral shortening is lower than after pre-operative traction alone. It has been reported [19] that, in children over the age of 3 years, pre-operative traction before an open reduction yields a poorer result than after femoral shortening. Retrospective studies have suggested that traction before open reduction in children younger than 3 years helps to decrease the prevalence of AVN if femoral shortening is not performed [13, 24]. In an older child, excessive femoral epiphysis compression seems best avoided by femoral shortening. The efficacy of pre-operative traction alone remains questionable in this age group.

We were not able to evaluate the effect of traction or femoral shortening in our series, since both techniques were used in the majority of cases. We found, however, after statistical analysis, that neither traction (p=0.04) nor femoral shortening (p=0.001) could prevent growth disturbances in the femoral head. Unfortunately, we were unable to assess whether traction was administered properly. In other studies [7, 8], there has been a positive correlation between the incidence of AVN, inadequate pre-reduction traction and extreme positions of immobilisation.

We were unable to show the importance of traction duration, which has been stated by others [24]. We did not assess the role of extreme positions of immobilisation known to produce AVN, since the necessity for such a position was taken as an indication for open reduction. We found that the lowest rate of AVN was achieved when surgical treatment was initiated before the age of 2 years. In the age group between 2 and 3 years, and after 3 years of age, the overall rate of AVN was similar but the sequelae more severe. The oldest children had only types

II and III changes of AVN. This finding is in accordance with other studies [8, 10].

Even though the type of method of pelvic osteotomy did not influence AVN rate, good pre-operative planning and a proper surgical technique may be vital in order to avoid AVN. We found that in hips that required acetabular angle correction of more than 15°, the incidence of AVN was twice as high as in the remaining group. In children with a more dysplastic acetabulum, surgery is a bigger challenge and requires a more experienced surgeon.

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