AVASCULAR NECROSIS FOLLOWING CLOSED REDUCTION OF CONGENITAL DISLOCATION OF THE HIP

REVIEW OF INFLUENCING FACTORS AND LONG-TERM FOLLOW-UP

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We studied the pathogenesis, incidence and consequences of avascular necrosis in 184 children treated for congenital dislocation of the hip. Of 210 hips, 99 (47%) had some evidence of avascular necrosis (total 81, partial 18). The incidence was not influenced by the age at reduction, the duration of traction or the use of adductor tenotomy. Patients treated by closed reduction without preliminary traction did not have a higher incidence of avascular necrosis.

At long-term clinical and radiological review of 81 hips, early avascular necrosis significantly increased the chance of a poor outcome but did not predispose to acetabular dysplasia. If review includes minor forms of avascular necrosis, then this condition is common after closed reduction. Its presence is an important determinant of long-term radiological and clinical outcome.

Avascular necrosis following the treatment of congenital dislocation of the hip continues to contribute to poor results. The reported incidence varies between nil (Crego and Schwartzmann 1948) and 67% (Esteve 1960). The use of preliminary traction (Salter, Kostuik and Dallas 1969; Gage and Winter 1972; Weiner, Hoyt and O'Dell 1977; Ishii and Ponseti 1978; Buchanan, Greer and Cotler 1981), adductor tenotomy (Salter et al 1969; Ishii and Ponseti 1978), and immobilisation in the 'human' position (Dooley 1964; MacKenzie, Seddon and Trevor 1960; Salter et al 1969; Gage and Winter 1972) have all been suggested to decrease the incidence of avascular necrosis. Pre-operative coronal traction with abduction of the limb to 90° has been reported to be associated with an increased risk of avascular necrosis in those treated by closed reduction (Fogarty and Accardo 1981).

We have reviewed a series of children with congenital dislocation of the hip treated by closed reduction. The incidence of avascular necrosis and the influence of associated factors and treatment variables have been

assessed, and the long-term effects of avascular necrosis on the radiological and clinical outcome have been investigated.

MATERIAL AND METHODS

Assessment of avascular necrosis. We reviewed the clinical and radiological records of all children with congenital dislocation of the hip who underwent closed reduction at the Royal Children's Hospital, Melbourne, between 1970 and 1985. This allowed for a minimum of two years follow-up to observe the development of avascular changes in the femoral head and neck (Gage and Winter 1972; Fisher and Cary 1978). Twenty-five children with neuromuscular disorders, teratological dislocations, congenital subluxation, or who had initially been treated elsewhere, were excluded, as were 33 other children with inadequate radiographs.

A total of 184 children with 210 hip dislocations have been reviewed. There were 158 girls and 26 boys with 158 unilateral and 26 bilateral dislocations. The mean age at reduction was 14 months (range 1 to 55). Preliminary traction had been used in 168 hips for a mean of 12 days (range 1 to 28) and an adductor tenotomy was performed in 71 hips. The side involved, the degree of abduction in traction and the preliminary use of an abduction device were recorded.

Using the criteria of Salter et al (1969) and Gage and Winter (1972), total or partial avascular necrosis was assessed from the serial radiographs of each child. We

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Fig. 1a

Fig. 1b

Figure 1a – Boy of two years six months, who had left CDH, showing total avascular necrosis of both hips 12 months after closed reduction of the left hip. Figure 1b – At 11 years six months, there is a good radiological outcome in both hips, after a Salter osteotomy on the left for persistent acetabular dysplasia.

Fig. 2

Girl of 14 years, with a good radiological outcome after total avascular necrosis of the left hip following closed reduction.

also assessed, as additional evidence of vascular changes, medial metaphyseal beaking, localised metaphyseal rarefaction and sclerosis, cystic changes within the epiphysis with later evidence of coxa magna, and physeal cupping and rarefaction.

Long-term radiological follow-up. Eighty-four children (98 hips) were over eight years of age at the latest radiological review. The median age was 13 years (range 8 to 20). There were 70 unilateral and 14 bilateral dislocations, 67 in females and 17 in males. The overall appearances of the hips at review were graded by the criteria of Thomas et al (1989), which are a modification of Severin's classification (1941) also including changes in the femoral head and neck and the degree of subluxation.

Acetabular dysplasia was defined as a centre–edge angle of less than 15° between the ages of seven and 15 years, a centre–edge angle of less than 20° at over 15 years or the necessity for a containment procedure. This definition avoids the difficulties of using the acetabular index over the age of eight, as Hilgenreiner's line is difficult to define in this age group (Fredensborg 1976; Tönnis 1976).

Long-term clinical follow-up. Of the 114 children (133 hips) treated from 1970 to 1980, 71 children (81 hips)

were seen (62%). The median follow-up time was 12 years (range 6 to 17). There were 57 females and 14 males, 51 with unilateral and 10 with bilateral dislocations. At clinical review, each child was assessed for the presence or absence of pain, stiffness, limp, Trendelenburg's sign, leg length discrepancy and range of movement at the hip. An overall clinical grade was given (see Table III), based on a modification of McKay's criteria (1974). The ranges of movement recorded were flexion, abduction, adduction, and total rotation, either in flexion or extension, whichever was larger.

We used chi-squared statistical analysis, with Yates' correction where necessary, for categorical data, and Mann-Whitney analysis or Student's *t*-test for continuous data.

RESULTS

Incidence of avascular necrosis. Of the 210 hips studied, 99 showed radiological evidence of avascular necrosis (47%); 81 hips had total involvement (39%) and 18 had partial involvement (9%). One child, with a unilateral dislocation, developed total avascular necrosis in the

Fig. 3

Girl of 14 years with a poor radiological outcome after total avascular necrosis of the left hip.

Table I. The influence of various factors on the incidence of avascular necrosis (AVN)

		Number of hips			Significance of difference
		Total	With AVN	% AVN	
Age at closed reduction	< 12 months	95	46	48.4	p = 0.84 p = 0.39
	> 12 months	115	53	46.1	
	Total	210	99	47.2	
Sex	Male	36	20	55.6	p = 0.35
	Female	174	79	45.4	
Side	Left	134	62	46.3	p = 0.85
	Right	76	37	60	
Previous abduction device	Yes	40	19	47.5	p = 0.45
	No	170	80	47.1	
Traction	None	42	19	45.2	p = 0.63
	60°	86	38	44.2	
	90°	82	42	51.2	
Duration of traction	< 5 days	57	32	56	p = 0.16 p = 0.41
	> 5 days	152	67	44	
	Overall	168	80	47.6	
Adductor tenotomy	Yes	71	37	52.1	p = 0.38
	No	139	62	44.6	

previously normal contralateral hip (Fig. 1). A recent study in our department on avascular necrosis after the open reduction of congenital hip dislocation showed total involvement in 29% and partial in 8% (Thomas et al 1989).

We found no significant correlation of the incidence with sex, side, age at reduction, duration of traction, degree of abduction in traction, adductor tenotomy, or the use of a previous abduction device (Table I). There were, however, trends to a higher incidence of avascular necrosis in males and in right-sided dislocations but these were not significant. There was also a trend to a higher incidence in those treated in traction with 90° abduction (44% against 51%) but this was not significant (p = 0.45). The incidence of avascular necrosis in those treated without traction (45%) was approximately the same as those treated with traction (48%); it was similar in those treated without an adductor tenotomy (45%) and those who had a tenotomy (52%).

Radiological grade. At follow-up, 72 hips were graded (Table II) as good (Fig. 2), 14 as fair and 12 as poor (Fig. 3). There was a highly significant association between

Table II. Criteria for final radiological grade and the results in 98 hips

Result	Criteria	Hips	
		No AVN	AVN
Good 73.5%	1 Spherical shape or minimal irregularity 2 mm on Moses' rings 2 None or minimal coxa magna < 20% increase in diameter of the femoral head 3 None or minimal neck changes, broadening only 4 Minimal uncovering, centre-edge angle 15 to 20 degrees (All four features must be present)	50	22
Fair 14.3%	1 Spherical shape or irregularity 2 to 4 mm on Moses' rings 2 Coxa magna < 20% 3 Neck changes, shortening (articulo-trochanteric distance > 50% of unaffected side) and/or valgus tilt of epiphysis 4 Uncovering, centre-edge angle 10 to 15 degrees (three features must be present)	3	11
Poor 12.2%	1 Flattened epiphysis 2 Coxa magna > 20% 3 Neck changes, shortening (articulo-trochanteric distance < 50% of unaffected side) and/or varus angulation 4 Uncovering, centre-edge angle < 10 degrees. (two features must be present)	0	12

Table III. Criteria

		Hips	
Final clinical grade		No AVN	AVN
Excellent 42%	Painless No limp Negative Trendelenburg Combined ROM > 300 degrees	25	9
Good 40.7%	Painless Normal gait or slight limp Negative Trendelenburg or delayed Positive Trendelenburg Combined range > 200° < 300°	17	16
Fair 12.3%	Painless or occasional ache Limp and/or Trendelenburg sign and/or Combined range > 150° < 200°	5	5
Poor 5%	Pain (exercise related or interfering with function) and/or Positive Trendelenburg sign and/or Presence of fixed deformity and/or Combined range < 150°	0	4

Table IV. Relation of degree and extent of avascular necrosis to the final radiological outcome

Avascular necrosis (total)	Radiological outcome			
	Good	Fair	Poor	Unknown
Minimal changes (4)	2	1	1	0
Epiphyseal only (24)	22	2	0	0
Metaphyseal only (2)	0	2	0	0
Epiphyseal and metaphyseal (18)	10	5	3	0
Physeal involvement (4)	1	0	2	1

avascular necrosis and the final radiological grade ($p < 0.001$, Table V). All 12 hips with poor radiological grade had had avascular necrosis as had 11 of the 14 hips with a fair radiological grade.

The late influence of avascular necrosis. We assessed the area of the femoral head and neck involved by avascular necrosis and related it to subsequent appearances in those with adequate serial radiographs. The commonest residual deformity was coxa magna, seen in 18 of 45 hips (40%) with avascular necrosis. The initial changes were most commonly seen in the epiphysis (49%); changes in both epiphysis and metaphysis were seen in 31% (Figs 4 and 5). In four hips, early changes were only visible retrospectively; two hips showed mainly metaphyseal changes (Fig. 6). Epiphyseal involvement with metaphyseal changes, or later evidence of physeal involvement correlated with a high risk of a poor radiological outcome ($p = 0.05$).

In three of the four children with physeal involvement, this was on the lateral side (Fig. 7) and produced the type II changes of Kalamchi and MacEwen (1980).

Forty-four hips (44.9%) were dysplastic and in 27 of

these, containment procedures had been performed (24 Salter osteotomies, two femoral osteotomies and in one hip both Salter and femoral osteotomies). We found no correlation between avascular necrosis and residual dysplasia ($p = 0.90$, Table V). Containment procedures had been performed equally in hips with or without avascular necrosis.

Clinical grading. In all, 77 hips were clinically excellent or good; four hips were poor (Table III). There was a significant association between avascular necrosis and final clinical grade ($p = 0.03$, Fig. 5, Table IV), and the poor results had evidence of avascular necrosis. Similarly, radiological grade and clinical grade were associated ($p = 0.01$): 64% of those hips with a fair or poor radiological grade had a fair or poor clinical grade; only 11% of hips with a good radiological grade were fair or poor clinically.

Pain. There was no association between avascular necrosis and subsequent hip pain ($p = 0.56$, Table V). In 17 children there were 20 painful hips; there was occasional aching in 11, pain on exercise in eight and pain sufficient to interfere with daily activities in one.

Fig. 4a

Fig. 4b

Figure 4a – Boy aged three years, two years after closed reduction for bilateral CDH. The right epiphysis is flattened, there is metaphyseal broadening and a sagging rope sign. Figure 4b – At 16 years the right hip shows moderate head deformity (2 to 4 mm), a short neck and a high trochanter. This is a fair radiological result.

Fig. 5a

Fig. 5b

Figure 5a – Girl of two years six months, who had closed reduction of bilateral CDH at 15 months, showing delay in the appearance of both epiphyses. Figure 5b – At four years, she has epiphyseal fragmentation and flattening with short broad femoral necks on both sides.

Fig. 6

Boy aged 18 months after closed reduction of bilateral CDH. There are predominantly metaphyseal changes of broadening, beaking and localised sclerosis.

Fig. 7

Girl aged eight years who had bilateral CDH showing partial closure of the lateral growth plate on the right, seven years after reduction. The epiphysis has been pulled into valgus.

Table V. The effects of avascular necrosis after closed reduction for CDH

	Effect	Statistical significance
Final radiological grade	Highly positive	$p < 0.001$
Subsequent dysplasia	Negative	$p = 0.90$
Final clinical grade	Positive	$p = 0.03$
Pain	Negative	$p = 0.56$
Trendelenburg's sign	Negative	$p = 0.72$
Range of movement at the hip	Marginally positive	$p = 0.08$

Two children required secondary operations for pain after initial containment procedures; a shelf procedure and a Sutherland osteotomy in one, and a shelf alone in the other.

Trendelenburg's sign. Eighteen children had a delayed positive Trendelenburg's sign (Hardcastle and Nade 1985) and three had a Trendelenburg gait. There was no correlation between the presence of the sign and avascular

necrosis ($p = 0.72$, Table V) or between it and the presence of hip dysplasia ($p = 0.25$).

Leg length inequality. There was inequality of leg length greater than 1.3 cm in two patients; both had avascular necrosis and had had containment procedures, one was 1.5 cm longer on the operated leg after a Salter osteotomy. The other had both Salter and femoral osteotomies and was 2.5 cm shorter.

Total range of movement. There was a tendency for the hips with avascular necrosis to be more stiff but this was not significant ($p = 0.08$).

DISCUSSION

Classifications of avascular necrosis and consequent variations in the reported incidence. We were unable to grade the majority of hips according to the classifications of Bucholz and Odgen (1978) or of Kalamchi and MacEwen (1980), and therefore used the classification into total and partial avascular necrosis suggested by Salter et al (1969) and by Gage and Winter (1972). In addition, we included both temporary ossification (Salter et al 1969) and coxa magna (Berkeley et al 1984; Gamble et al 1985) as evidence of avascular necrosis.

Several studies of avascular necrosis have been performed in Melbourne: despite this experience all the authors had difficulty in applying the criteria of partial and complete avascular necrosis to some patients. It was difficult to decide whether a minor degree of avascular necrosis was present and to differentiate partial from complete changes, especially as minor or partial necrosis may lead to significant late deformity.

We found an overall prevalence of avascular necrosis of 47% with 39% total and 9% partial involvement. The great variation in the reported ranges, from zero (Crego and Schwartzmann 1948) to 67% (Esteve 1960), suggests that the rigour of search for the diagnosis and the strictness with which the criteria are interpreted are important in determining the reported rates. The length of follow-up also influences the incidence; six to eight years may pass before premature closure of the growth plate attests to prior avascular necrosis.

Failure of preliminary traction to reduce the incidence of avascular necrosis. The incidence of avascular necrosis was approximately the same in those treated with or without preliminary traction (48% versus 45%). Patients were selected for a period of preliminary traction, before examination under anaesthesia, on the basis of the likely ease of reduction. A hip regarded as likely to reduce easily was one in a child under the age of 15 months with abduction of more than 45° and radiographs showing that the head is not widely displaced or high in relation to the acetabulum. In such a patient, under anaesthesia, provided that the head falls into the socket and is stable when the hip is abducted in flexion, a hip spica is applied. The fact that there was no increased incidence of avascular necrosis in such patients justifies our not using

preliminary traction. Of course there are other reasons for preliminary traction, such as making reduction easier. Hips which were not readily reducible under anaesthesia were subjected to a period of traction and then re-examined.

Adductor tenotomy did not influence the incidence of avascular necrosis. The incidence of avascular necrosis in patients who did not have an adductor tenotomy was 45%; in those who had a tenotomy this was 52%. These findings are at variance with those reported by Salter et al (1969) and Ishii and Ponseti (1978).

Other factors. We found no significant trends in relation to age, sex, side or previous use of an abduction orthosis. Extreme positions of immobilisation, known to produce avascular necrosis (Dooley 1964; Salter et al 1969; Gage and Winter 1972; Ogden 1974), were not employed in our series, since the necessity for such a position was taken as an indication for open reduction.

Conclusions. We found that the initial avascular appearance was unreliable in predicting the final radiological grade (Fisher and Carey 1978). However, where both the epiphysis and the metaphysis are involved, or if at any time the physis is involved, there is a risk of a poor radiological outcome. By contrast, recovery from partial avascular necrosis gave a good radiological grade in six of seven hips.

All the children who had a poor clinical grade had evidence of previous avascular changes, but acetabular dysplasia did not correlate with the overall clinical outcome or with individual signs or symptoms. The most important predeterminant of poor clinical outcome was the presence of avascular necrosis.

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