

SLIPPED UPPER FEMORAL EPIPHYSIS

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As part of the requirement for the
Part III M Med (Orthopaedics)

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ACKNOWLEDGEMENTS

I should like to thank Dr E B Hoffman for his unstinting support and enthusiasm, Mrs V Barrow for her assistance in the preparation, Mr M Wyeth for the illustrations and my wife for her assistance and support.

This dissertation is based largely on an original study performed by myself and Dr E B Hoffman of 44 patients (55 hips) with slipped upper femoral epiphysis treated at Princess Alice Orthopaedic Hospital over a 27 year period. Two papers from this work have been presented at the South African Orthopaedic Congress. The first paper entitled 'Slipped Upper Femoral Epiphysis' was presented at the 1991 congress in Johannesburg and was awarded the G T Du Toit Registrar's prize. The second paper entitled 'The Natural History of Chondrolysis in Slipped Upper Femoral Epiphysis' was presented at the 1992 congress in Cape Town. This second paper has been accepted for publication in the British Journal of Bone and Joint Surgery.

Data from this series has contributed to a study by Dr R T Loder from the University of Michigan Hospital on the seasonal incidence of slipped capital femoral epiphysis which is to be submitted for publication to the American Journal of Bone and Joint Surgery.

INTRODUCTION

Slipped upper femoral epiphysis (SUFE) is an unusual condition associated with the perplexing problem of chondrolysis and the disastrous complication of avascular necrosis (AVN). Much has been written about it since it was first described by Ambroise Pare in 1554 and much controversy still surrounds it.

Aetiology

SUFE occurs at a time of rapid growth, hormonal change and the patients with SUFE are often of a 'Dickensian' type build (ie: obese and sexually immature). These factors together with its association with abnormalities of endocrine function (eg: hypothyroidism, pituitary dysfunction, hypogonadism and cryptorchidism) suggest an endocrine basis for SUFE. Rat experiments have shown that plate strength is decreased by growth hormone and increased by oestrogens (Bright, Burstein & Elmore 1974; Harris 1950; Hillman, Hunter & Barrow 1957; Oka, Miki & Hama 1974). However most clinical studies have not shown biochemical or endocrine abnormalities in patients with SUFE except Wilcox, Weiner and Leighley (1988) who reported on a group of patients with SUFE, 25% had decreased T3, 76% had decreased testosterone and 87% had low growth hormone levels. Certainly an endocrinopathy should be considered when SUFE occurs out of the normal age range (ie: 9-16 years).

Wilson, Jacobs & Schector (1965) found that 5% of the parents of their patients with SUFE were also known to have had SUFE, suggesting a hereditary factor though the mode of inheritance is uncertain. Kelsey, Keggi and Southwick (1970) felt rather that environmental factors were more important suggested by the higher incidence in Connecticut as compared with New Mexico.

Trauma has always been implicated as a cause. Alexander's theory (1966) proposes that the reason left hips are more frequently involved is that right handed children apply more stress on their left hip than their right during writing. Decreased anteversion has been shown by Gelberman et al (1986) to be associated with SUFE. It is also of note that the peak age of incidence of epiphyseal fractures is the same as that for SUFE (Petersen & Petersen 1972). Chung, Batterman and Brighton (1976) noted that in cadaveric studies, slipping of the epiphysis could occur under physiological conditions in obese adolescents. It is more likely that it is due to normal forces acting on a weakened or altered growth plate.

SUFE is associated with synovitis. Morrissey, Steele and Gerdes (1981) identified immune complexes in the joint fluid of 10 of 12 patients with SUFE and not in many other conditions associated with synovitis.

Incidence

Loder, Aronson & Bollinger (1990) reported on the seasonal incidence of SUFE. They found that it was more prevalent during summer and attributed this to increased physical activity in that season.

The annual incidence varies from 0,71 to 3,41 per 100,000 and affects boys more often than girls (Henrickson 1969; Jacobs 1972; Kelsey, Keggi and Southwick 1970). The age range is from 9 to 16 years. Kelsey, Acheson and Keggi (1972) found that half their patients had weights greater than the 95th percentile for age.

Kelsey, Keggi and Southwick (1970) found that there was a higher incidence in Connecticut as compared to New Mexico and that it is more common in Blacks.

Radiological Diagnosis

Several radiographic methods have been described in the assessment of SUFE.

Wilson (1965) described the percentage slip on the frog lateral; the amount of slip was measured as a percentage of the width of the femoral neck at the physis. Thirty-three percent and less slips were classified as mild, 33-50% as moderate and >50% as severe. Waldenstrom (1939) and Southwick utilised the head-shaft angle on the frog lateral. Southwick subtracted the head-shaft angle of the normal from that of the slipped side and if this was greater than 30 degrees he stated that the slip was

severe and required an osteotomy. O'Brien and Fahey (1977) utilised this method but found that they were able to pin hips with head-shaft angles of up to 60 degrees and only those with an angle of greater than 60 degrees required osteotomy. Jacobs (1972) described the head-neck angle on the Smith Petersen lateral and Cohen (1986) the head-neck angle on the CT scan. Cohen stated that 'the computerized tomogram is a more accurate and reproducible method of assessing both posterior angulation and epiphyseal displacement'. Guzzanti and Falciglia (1991) reported that a standardised view on plain radiograph was as accurate as a CT scan.

The duration of slip is classified as either being acute, chronic or acute on chronic. The accepted definition of an acute slip is where there is sudden onset of symptoms of less than 3 weeks duration (Fahey and O'Brien 1965). A chronic slip is one where the history is longer than 3 weeks duration. The radiographs show signs of chronicity when the history is longer than 3 weeks (ie: resorption of bone at the antero-superior aspect of the neck and new bone formation at the postero-inferior aspect; Key 1926). However, when the history is of less than 3 weeks duration and the radiographs nevertheless show signs of chronicity then the slip is classified as being acute on chronic.

Treatment

The primary aims of treatment are to prevent further slipping and the complications of chondrolysis and avascular necrosis. Many methods of treatment are described and each has its advocates. Pinning in situ is accepted by most authors as the treatment for minor degrees of slip, although many authors (O'Brien and Fahey 1977; Nguyen and Morrisy 1990, Carney and Weinstein 1991, Aronson and Carlson 1992, Spero et al 1992) feel that it should be applied to all cases.

Walters and Simon (1980) drew attention to unrecognised pin penetration and its association with chondrolysis and concern has also been voiced about the risk of avascular necrosis following penetration of the posterior aspect of the neck (Broughton, Todd, Dunn and Angel 1988). The advent of good quality image intensification and the use of a single cannulated screw (Ward et al 1992; Aronson and Carlson 1992) have largely decreased the problem of pin penetration. Long term follow-ups of patients with severe slips treated by in-situ pinning have described how remodelling of the femoral neck may lead to good functional results with lower complication rates as compared to realignment procedures (O'Brien and Fahey 1977, Boyer and Ponsetti 1981, Carney and Weinstein 1991). However, Siegel and Kasser (1991) have shown with CT scans pre and post pinning in situ that very little remodelling actually takes place and that at 2 year follow-up, the head-neck angle is

virtually unchanged. They did state however, that their patients recovered almost a full range of movement with loss of a small degree of internal rotation and that 'in most patients, functional recovery was rapid and complete'.

There has been a resurgence of interest in the Dunn (1978) osteotomy (intracapsular cuneiform osteotomy) (Fish 1984; Broughton, Todd, Dunn and Angel 1988; Clarke and Wilkinson 1990) with low rates of avascular necrosis being reported. The rates of AVN reported in the literature range from 2,9% to 100% (Gage, Sundberg and Nolan 1978). Many authors feel that if the normal relationship of the head to the neck is not restored it will lead to osteoarthritis in moderate and severe slips (Elmslie 1933; Badgley 1948; Dunn and Angel 1978; Fish 1984). Their argument is supported in the studies by Murray (1971), Stulberg (1975) and Solomon (1976) which ascribe the deformities seen in primary osteoarthritis as being secondary to unrecognised SUFE or Perthe's disease in childhood. However, Resnick (1976) has refuted these findings saying that the tilt deformities seen in osteoarthritis are due to remodelling seen in osteoarthritis.

Other osteotomies described include a base of the neck osteotomy (Kramer, Craig and Noel 1976), the Southwick osteotomy (Southwick 1967) and the triplane osteotomy of Ireland and Newman (1978). These osteotomies are now less popular than they were previously.

Bone graft epiphyseodesis has been reported to have a very low complication rate (Weiner, Weiner, Melby and Hoyt 1984), although others do not agree (Ward and Wood 1990).

Manipulation has been used for realignment in cases of acute and acute on chronic slip. Casey, Hamilton and Bobechko (1972) reported low rates of AVN when manipulation was preceded by traction but had 5 cases of AVN out of 12 cases with manipulation alone. Griffith (1975) reported 8 cases of AVN out of 11 successfully manipulated hips.

The question of prophylactic pinning of the opposite hip often arises. Most authors agree on observation of the opposite hip (Klein et al 1953; Greenough, Bromage and Jackson 1985).

Complications

SUFE is accompanied by the perplexing problem of chondrolysis and the disastrous complication of AVN.

Chondrolysis was first described by Waldenstrom (1930) who thought it was due to a laceration of the joint capsule leading to a decrease in production of synovial fluid with resultant lack of cartilage nutrition. This was supported by Cruess (1963) who postulated that the cartilage perished as a result of interference with the production of synovial fluid, but why this should occur

in SUFE is not known. Several authors (Mankin, Sledge and Rothschild 1975; Eisenstein and Rothschild 1976; Morrissy, Kalderon and Gerdes 1981) have some evidence to suggest that it may have an autoimmune basis. The incidence in SUFE is reported to range between 1,8% and 55%. Some authors have found a higher incidence in blacks (Wilson, Jacobs and Schecter 1965; Tillema and Golding 1971; Heppenstall et al 1974), although others do not agree (Bishop 1978, Kennedy and Weiner 1990; Spero et al 1992). Its aetiology is obscure but several factors have been implicated such as cast immobilisation (Lowe 1961), heavy traction (Lowe (1961), pin penetration (Walters and Simon 1980; Ingram and Clarke 1982) and Southwick osteotomy (Frymoyer 1974).

Whether pin penetration causes chondrolysis is controversial. Stambough et al (1986) suggested that any breach of the joint space by a pin even for a short period intraoperatively may lead to chondrolysis. Zions, Simonian and Harvey (1991) however reported that a single episode of pin penetration of the joint by either a guide wire or cannulated screw, followed by immediate removal, did not lead to chondrolysis. Walters and Simon (1980) and Ingram and Clarke (1982) showed a direct relationship between persistent pin penetration and chondrolysis. Several other authors (Bennet, Koreska and Rang 1985; Greenough, Bromage and Jackson 1985; Hale and Barrett 1989) found that persistent pin penetration was not an aetiological

factor in chondrolysis.

Most authors (Maurer and Larsen 1970; Tillema and Golding 1971; Hartmann and Gates 1972; Heppenstall 1974) report that the outcome of chondrolysis in SUFE is bleak in the majority of cases with either an ankylosis occurring or an arthrodesis being required. Lowe (1970) reported recovery of joint space and movement in all 6 of his patients with chondrolysis.

Avascular necrosis is a devastating complication. Most authors agree with Howorth (1966) that it is entirely iatrogenic in aetiology. It has occurred after all forms of treatment but not in untreated cases. Manipulation has been associated with a high rate of AVN (Griffith 1975). Pin placement in the posterior superior quadrant of the head can damage the lateral epiphyseal vessels leading to AVN (Brodetti 1960; Stambough et al 1986; Tillema and Golding 1971). Osteotomies and in particular intra-capsular osteotomies have varying rates of AVN reported ie: 2,9% to 100% (Gage, Sundberg and Nolan 1978).

MATERIALS AND METHODS

In a 27 year period from 1963 to 1989, 44 patients (55 hips) with SUFE were treated at Princess Alice Orthopaedic Hospital. The average age at presentation was 13 years and 10 months (range: 8 years 8 months to 17

years and 1 month). There were 23 boys and 21 girls. Twenty-seven patients were coloured, 10 black and 7 white. The left hip was involved in 33 cases and the right in 22. Slipping was bilateral in 11 patients, 7 occurring simultaneously and 4 at an average of 13 months after the initial slip. The weights of 33 of the 44 patients had been recorded and the percentile for age was determined.

An acute slip was defined as one with a history of less than 3 weeks with no signs of chronicity on the radiographs (resorption at the anterior superior and new bone formation at the posterior inferior aspect of the neck), a chronic slip one with a history of more than 3 weeks and an acute on chronic slip one with a history of less than 3 weeks but signs of chronicity on the radiographs (Fig 1). The duration of slip was acute in 8, chronic in 41 and acute-on-chronic in 6.



Fig. 1.

A severe slip of the right hip showing chronic changes ie: resorption at the anterosuperior and new bone formation at the posteroinferior aspect of the neck.

With different laterals available, a combination of methods was used to determine the severity of the slip. The percentage slip (Wilson 1965) was determined in all cases on the available lateral (mild <33%, moderate 33% to 50%, severe >50%) (Fig. 2) If a frog lateral or acetabular oblique radiograph had been done then the head-shaft angle was determined (Southwick) (Fig. 3). The head-neck angle was determined on the true lateral (Jacobs 1986) (Fig 4) or CT scan (Cohen 1986) (Fig. 5).



Fig. 2.

A frog lateral radiograph showing Wilson's method of measuring the percentage slip



Fig. 3.

A frog lateral radiograph showing the measurement of the head-shaft angle (Southwick). The percentage slip measured 66%.



Fig. 4.

A true lateral radiograph with the measurement of the head-neck angle (Jacobs). The percentage slip measured 30%.

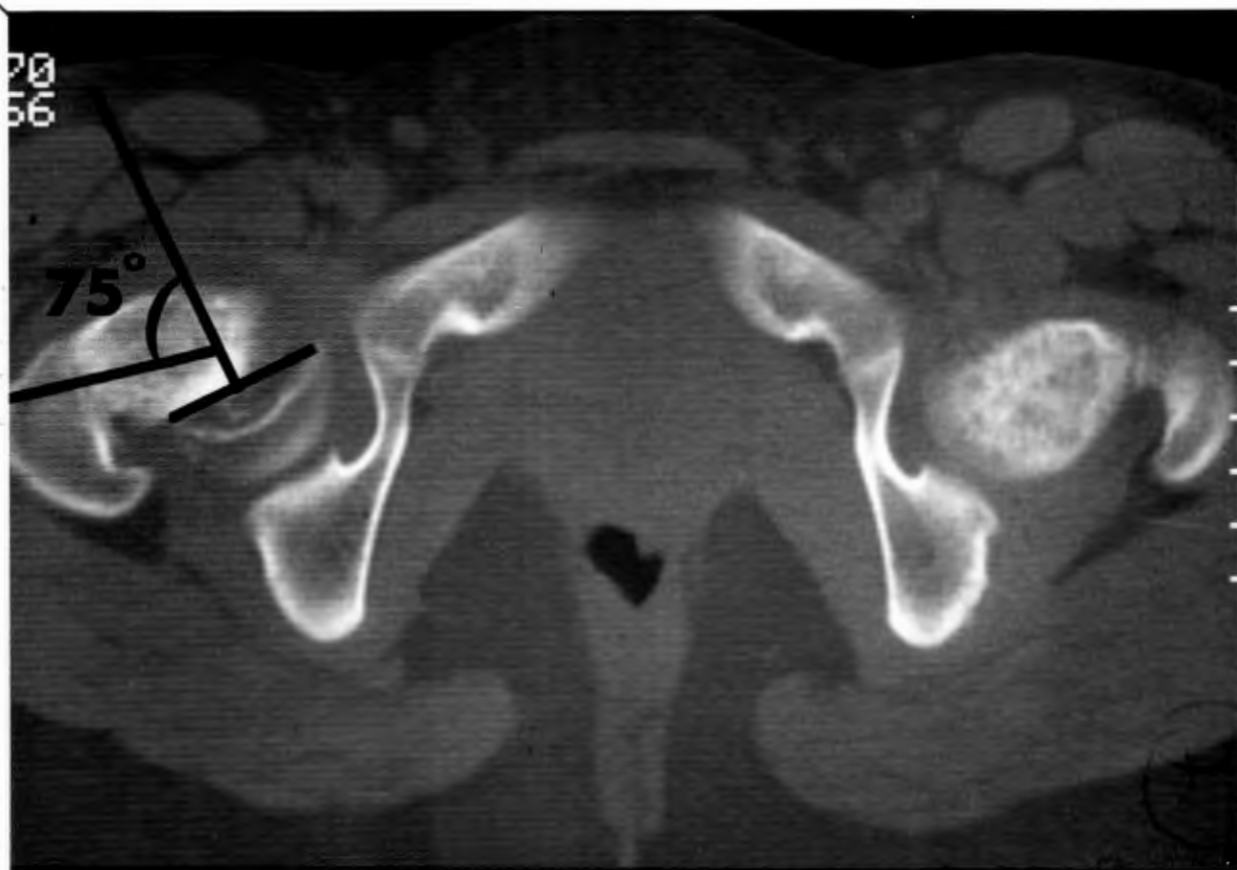


Fig. 5.

A CT scan showing the head-neck angle (Cohen).

A mild slip was with an angle of $<50^\circ$, moderate 50° to 70° and severe $>70^\circ$ (Cohen 1986). Twenty-six (47%) were mild, 24 (44%) moderate and 5 (9%) severe slips.

The follow-up of the patients with SUFE ranged from 3 to 27 years with an average of 8 years. The patients were assessed at follow-up for pain, function, gait and range of movement according to the Iowa hip rating score (Larson 1968) and antero-posterior and lateral radiographs were taken. Twenty-seven of the patients were personally reviewed by the paediatric orthopaedic consultant or the author and the other 17 assessed from the notes and radiographs. However in these 17 patients, the above 4 parameters were not all always recorded in the notes. In these cases, the range of movement was used where a full range of movement was regarded as an excellent clinical result, $>70^{\circ}$ flexion a good result, 35° - 70° a fair result and $<35^{\circ}$ flexion or ankylosis a poor result. In the cases seen, these values correlated with Iowa hip scores of $>95\%$, $>90\%$, $>70\%$ and $<70\%$ respectively. The complications were related to the type of treatment and the safest treatment to avoid the complications was determined.

The seasonal variation was determined as described by Loder, Aronson and Bollinger (1990). The date that the patients' symptoms began was determined from the date of presentation and the duration of symptoms.

The methods of treatment included pinning in situ in 40 hips, closed reduction and pinning in 3 hips, intracapsular osteotomy in 6 hips, primary extracapsular osteotomy in 5 and no treatment in one hip.

The diagnosis of chondrolysis was made when the joint space was less than or equal to 3mm (Ingram and Clarke 1982). The joint space in the chondrolysis hips ranged from 1-3mm (ave 1,8mm) and the normal hips 3,5-7mm (ave 5,1mm).

In determining pin penetration we took 2 factors into account: firstly that the pin may appear within the head on the radiograph but may actually be penetrating and secondly, that the pin may be penetrating the bony head but may be within the cartilage. The radiographs of all 44 patients were examined and the position of the tip of the pin determined using the method described by Walters and Simon (1980). This method utilises the Pythagorean theory of a right angled triangle and presumes 2 things: firstly, that the bony surface of the head is spherical (Bennet, Koreska and Rang 1984 showed using computer analysis that the femoral heads in their series deviated from a true arc of a circle by a mean of 0,43mm on the AP and 0,40mm on the lateral) and secondly, that the antero-posterior and lateral radiographs are perpendicular to each other. Three axes are defined ie: x, y and z (fig. 6a & b). The center of the axes is the center of the femoral head which is located using a template. The y axis is defined as the line bisecting the head on the AP and lateral radiographs. The x axis is perpendicular to this on the AP radiograph and the z axis perpendicular to it on the lateral radiograph. Values for x, y and z were measured for the tip of the pin and

values for z were corrected for any difference in magnification between the AP and lateral radiographs. The radius (r) was measured. Using the formula

$R = \sqrt{x^2 + y^2 + z^2}$ (where R is the distance of the tip of the pin from the center of the head) and knowing the radius, the distance that the pin was within or had penetrated the head could be determined ie: $R - r$ (Fig. 6a & b).

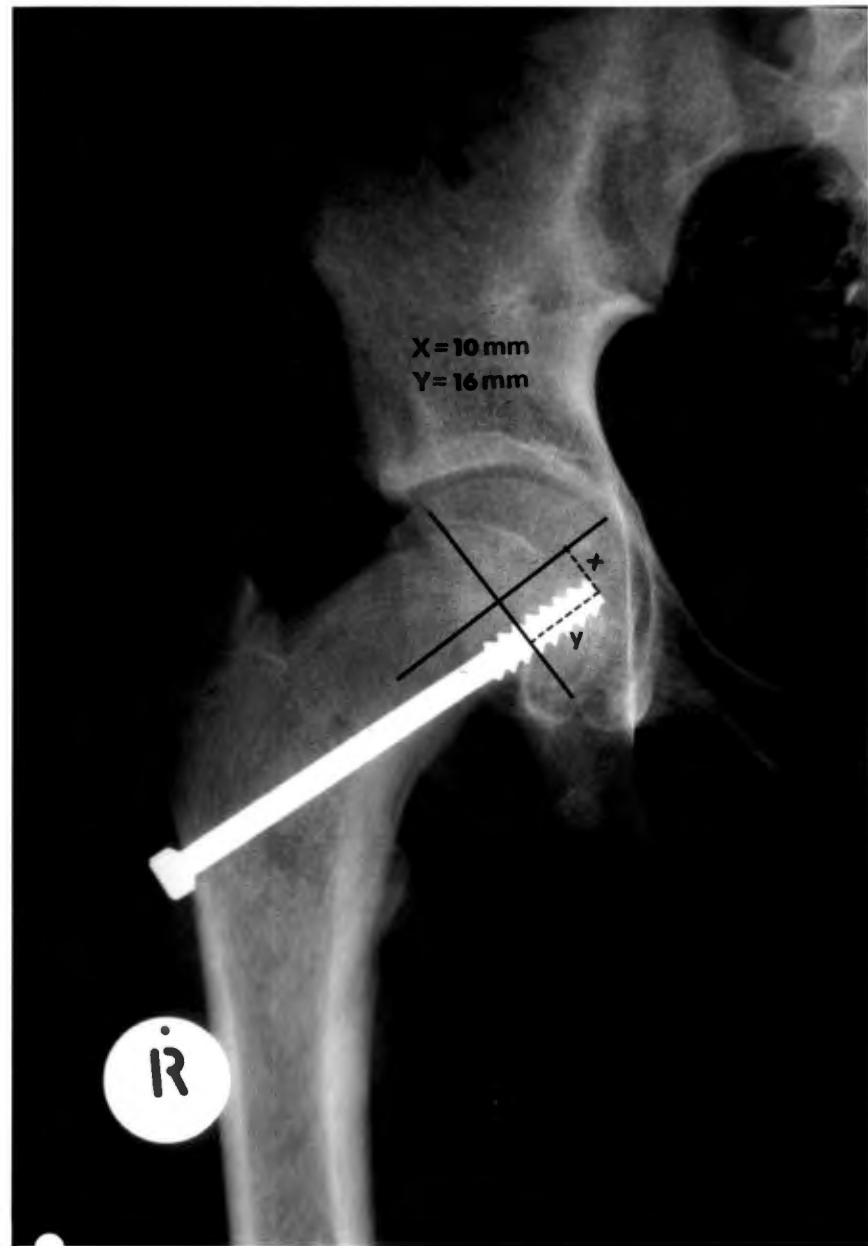


Fig. 6a.

A-P radiograph showing measurements for x and y

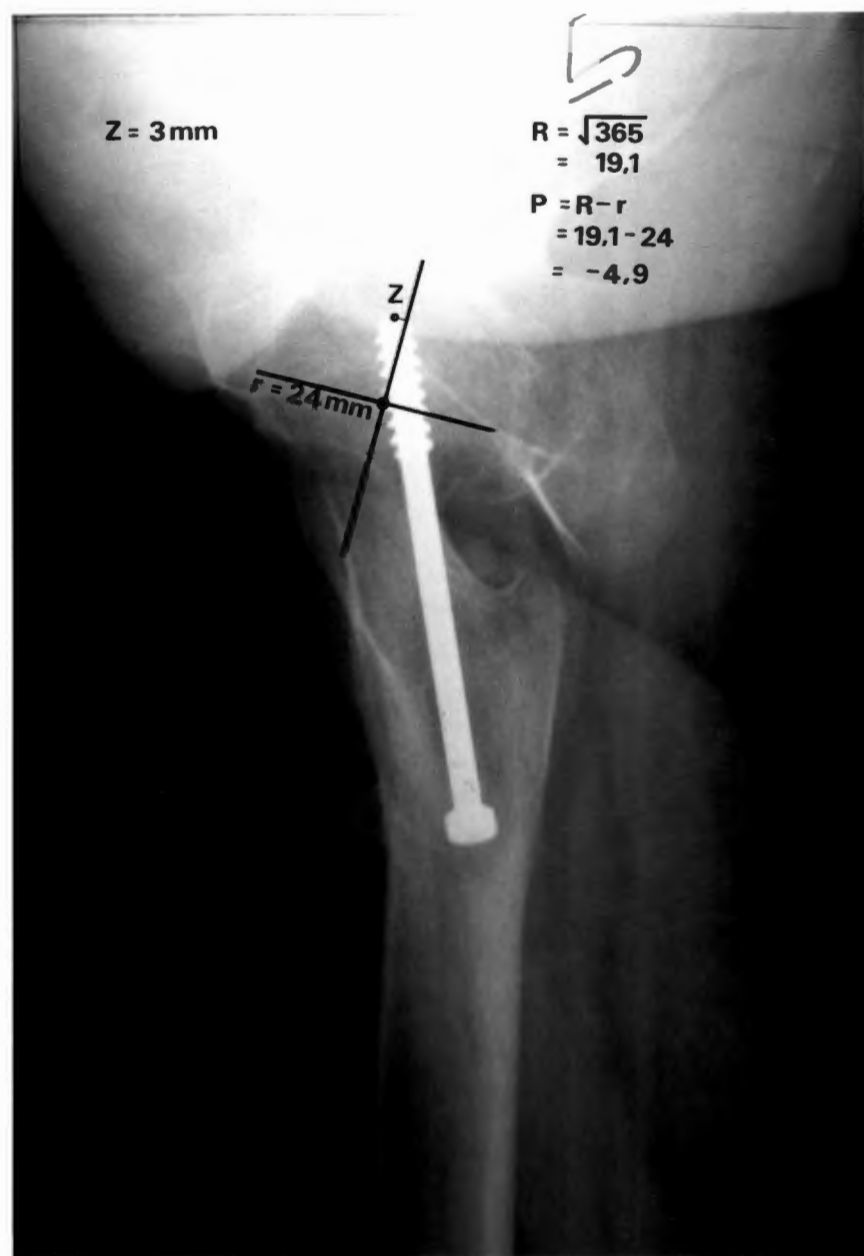


Fig. 6b.

Lateral radiograph showing z axis and measurement. The calculation shows that the tip of the pin is within the head by 4,9mm.

When Walters and Simon performed their in vitro studies with 300 different pin placements, the accuracy was within 1,5 +/- 0,5mm of the actual penetration. The accuracy was greater when a true lateral was used as compared with a frog lateral. In our series there were true laterals in 30 cases and frog laterals in 25. Only pins that were penetrating the bony head by greater than half the measured joint space were taken as actually penetrating through the cartilage into the joint (Bennet, Koreska and Rang 1984).

The course of the patients with chondrolysis was assessed from the notes and serial radiographs. At final follow-up (average 13,3 years; range 3-26 years), each patient was clinically assessed by one of the authors for pain, function and range of movement using the Iowa hip score rating scale (Larson 1968), and antero-posterior and lateral (acetabular oblique) radiographs of the hip were done. A full range of movement was regarded as an excellent clinical result (Iowa hip score >95%), >70° flexion a good result (Iowa hip score >90%), 35°-70° flexion a fair result (Iowa hip score >70%) and <35° flexion or ankylosis a poor result (Iowa hip score <70%).

RESULTS

SUFE

There were 2 patients who were excluded from the series because of abnormalities of endocrine function. One was a 15 year old coloured male who presented with bilateral chronic slipped epiphyses and who was found to have primary hypogonadism. The other was a 19 year 10 month old coloured female who presented with bilateral chronic slipped epiphyses who was found to have hypopituitarism.

There was a history of trauma in 21 slips, 6 of these were in acute slips, 3 in acute-on-chronic slips and 12 in chronic slips.

There was an almost equal distribution between the sexes, ie: 23 boys and 21 girls but there was a predominance of left hips involved ie: 33 left and 22 right.

The seasonal incidence of SUFE in our series showed that 47% of the cases occurred in the months from November to February (ie: in Summer).

The weights of the 33 patients recorded ranged from 30Kg to 94Kg with an average of 56Kg.

Of the 40 hips that had pinning in situ, 6 developed chondrolysis and 1 AVN. AVN developed in 3 out of the 6 hips that had had intracapsular osteotomies and 2 out of the 5 that had had extracapsular osteotomies. A comparative number of hips of the same severity underwent either pinning in situ or osteotomies but the number of

complications (AVN or chondrolysis) was much less in the hips pinned in situ (Tables I & II). Of the cases pinned in situ, there were 28 (70%) excellent, 6 (15%) good, 1 (2,5%) fair and 5 (12,5%) poor results. Of the cases which had osteotomies there were 2 (18%) excellent, 1 (9%) good, 2 (18%) fair and 6 (55%) poor results (Table III). The hip that had received no treatment had been a severe slip and at a follow-up of 16 and a half years had a good result .

Avascular necrosis occurred in 8 hips, 5 of them had had osteotomies and one pinning in situ. Only manipulations that resulted in reduction were included. There were 3 manipulations which resulted in reduction of which 2 developed AVN. The risk of developing AVN after manipulation was therefore 2/3.

There were 5 cases in which there was posterior penetration of the neck, by pins in 4 and by a blade plate in the 5th. AVN did not develop in any of these cases (Fig 7a & b).

Table I. Complications following pinning
in situ in 40 hips

Severity of slip	Complications	
	Chondrolysis	AVN
Mild (25)	4	1
Moderate (13)	2	0
Severe (2)	0	0
Total (40)	6 (15%)	1 (2,5%)

Table II. Complications following osteotomy
in 11 hips

Severity of slip	Complications	
	Chondrolysis	AVN
Mild (0)	0	0
Moderate (10)	0	4
Severe (1)	0	1
Total (11)	0	5 (45%)

Table III. Overall results with comparison of the different methods of treatment

Method of treatment	Result			
	Excellent	Good	Fair	Poor
Pinning in situ (40)	28 (70%)	6 (15%)	1 (2,5%)	5 (12,5%)
Osteotomy	2 (18%)	1 (9%)	2 (18%)	6 (55%)
MUA and pinning	1		1	1
No treatment		1		
Total	31	8	4	12



Fig. 7a.

A lateral radiograph showing pins penetrating the posterior aspect of the neck of the femur. AVN did not develop in this case.



Fig. 7b.

A lateral radiograph showing a blade plate penetrating the posterior aspect of the neck. AVN did not develop in this case.

CHONDROLYSIS

There were 13 patients (14 hips; 25%) with chondrolysis. Chondrolysis was diagnosed at presentation in 8 hips without any treatment having been instituted (Fig.8).



Fig. 8.

A-P pelvis radiograph of a 14 year old black female with a moderate slip of the left hip with chondrolysis at presentation.

There was persistent pin penetration in the other 6 hips (5 patients) with chondrolysis (Fig. 9). The relative distribution of sex and race of the patients, and severity of slip, duration of slip and treatment of the hips with chondrolysis is compared to those without chondrolysis in Tables IV and V.



Fig. 9.

A-P pelvis radiograph of a 10 year old girl with a moderate slip of the left hip with persistent pin penetration and chondrolysis.

Table IV. Sex and race of the patients without chondrolysis and those with chondrolysis

	Sex		Race	
	Male	Female	Coloured	Black White
<u>Without chondrolysis</u>	21	10	20	4 7
<u>With chondrolysis</u>				
1. At presentation	0	8	4	4 0
2. Associated with pin penetration	2	3	3	2 0
	(23)	(21)	(27)	(10) (7)

Table V. Severity, duration and treatment of slips in the hips without chondrolysis and those with chondrolysis

	Severity			Duration		Treatment			
	Mild	Moderate	Severe	Acute	Chronic	A/C	Pinning	Osteotomy	Nil
<u>Without chondrolysis</u>	22	16	3	5	32	4	32	8	1
<u>With chondrolysis</u>									
1. At presentation	0	6	2	1	6	1	5	3	0
2. Associated with pin penetration	4	2	0	2	3	1	6	0	0
	(26)	(24)	(5)	(8)	(41)	(6)	(43)	(11)	(1)

Chondrolysis at presentation

These 8 hips were all in female patients who were either black or coloured and who had either moderate or severe slips. In this series the risk of a black female having chondrolysis at presentation was 44% (4 of 9) and a coloured female 33% (4 of 12).

Persistent pin penetration

There were 10 hips (9 patients) with persistent pin penetration and chondrolysis developed in 6 of these. This raised the question of why persistent pin penetration does not cause chondrolysis in all hips. Table VI analyses these cases as regards sex and race. Table VII analyses these cases as regards severity of slip, duration of slip and site of pin penetration. The head was divided into quadrants: anterior superior, anterior inferior, posterior superior and posterior inferior. The site of pin penetration seemed to be the only significant factor. In 5 of the 6 hips with pin penetration and chondrolysis, the pin had penetrated the anterior superior quadrant of the head (Fig. 10). Of the 4 hips without chondrolysis, the pin had penetrated the posterior inferior quadrant in 3 (Fig. 11) and the posterior superior quadrant in the 4th.

Table VI. Sex and race of patients with persistent pin penetration with and without chondrolysis

	Sex		Race	
	Male	Female	Coloured	Black White
<u>Persistent pin penetration</u>				
1. Chondrolysis	2	3	3	2 0
2. No chondrolysis	3	1	4	0 0

Table VII. Severity and duration of slip, and site of pin penetration in hips with persistent pin penetration with and without chondrolysis

	Severity			Duration			Site of Pin Penetration			
	Mild	Moderate	Severe	Acute	Chronic	A/C	AS	AI	PS	PI
Chondrolysis	4	2	0	2	3	1	5	0	0	1
No chondrolysis	4	0	0	0	4	0	0	0	1	3

AS - Anterior superior
 AI - Anterior inferior
 PS - Posterior superior
 PI - Posterior inferior



Fig. 10.

A-P radiograph showing bilateral SUFE with bilateral pin penetration in the anterior superior quadrants with chondrolysis.



Fig. 11.

A-P radiograph of the left hip showing persistent pin penetration in the posterior inferior quadrant with no chondrolysis at 1 year.

Transient pin penetration

There were 7 hips with SUFE and 4 normal hips (prophylactic pinning) in which there was transient intra-operative pin penetration with either guide wire or pins (Table VIII). Chondrolysis did not develop in any of these cases (Fig. 12a & b). The number of cases with transient pin penetration is probably an underestimation as some cases were pinned using image intensification with no record of whether there was transient pin penetration.



Fig. 12a.

Intra-operative view of the left hip of a 15 year old boy with moderate SUFE showing transient pin penetration.

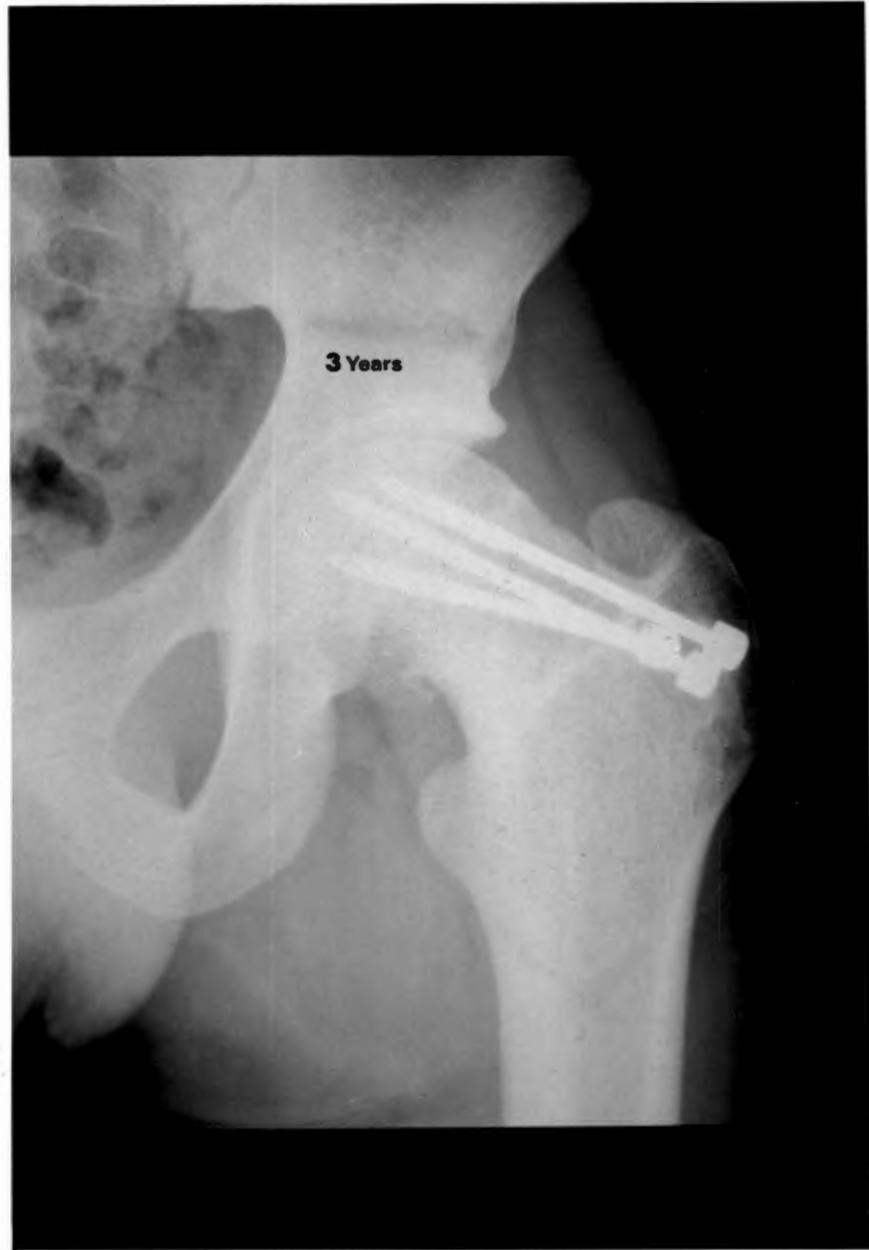


Fig. 12b.

Follow-up radiograph of patient in Fig. 12a at 3 years showing a normal joint space.

Table VIII. Sex and race of patients, and severity and duration of slips in hips with transient intra-operativ pin penetration

	Sex		Race		Severity			Duration	
	Male	Female	Coloured	Black White	Mild	Moderate	Severe	Acute	Chronic A/C
Hips with SUFE	5	2	5	1 1	2	4	1	0	6 1
Normal hips (Prophylactic pinning)	4	0	4	0 0					

Natural History of Chondrolysis

The maximum loss of range of movement (flexion of 45° flexion with a range of 20° to 90°) and maximum joint space narrowing (ave. 1,8mm; range 1-3mm) occurred within the first year of presentation. There was no correlation between the amount of joint space narrowing and the loss of range of movement. Improvement in the range of movement and joint space (follow-up joint space averaged 2,6mm; range 1-5mm) occurred up to 3 years after maximal involvement (Fig. 13a & b). Reconstitution of the joint space did not always correlate with the clinical result. Two cases with a good clinical result had no joint space recovery and of the 2 cases with an excellent clinical result, one had complete and the other only partial recovery of the joint space. In the 6 hips with persistent pin penetration and chondrolysis, removal of the pins resulted in improvement in pain in all 6 and range of movement in 4 (67%)(Fig. 14a & b).

At final follow-up, there were 2 excellent, 4 good, 3 fair and 5 poor results (Table IX). Of the 3 patients with a fair result, 2 work as domestics and the third is a shop assistant who walks long distances without pain. Of the 5 hips with a poor result, 3 were pain free and had a jog of movement and were not ankylosed. The other two were in one patient who had minimal pain but who underwent lateral hip replacements for stiffness 23 years after he presented with SUFE.



Fig. 13a

A-P radiograph of a 14 year old female with a moderate slip of the left hip showing maximum joint space narrowing at 1 year. She had joint space narrowing at presentation. A primary intertrochanteric osteotomy had been performed.



Fig. 13b.

Follow-up at 7 years of the patient in Fig. 13a with recovery of her joint space to 4mm and she had a good clinical result.



Fig. 14a.

A-P pelvis radiograph of a 10 year old girl with a moderate slip of the left hip showing chondrolysis due to persistent pin penetration in the anterior superior quadrant with maximum joint space narrowing at 1 year.



Fig. 14b.

Six year follow-up of the patient in Fig. 14a. Her joint space had recovered to 3mm and she had a good clinical result after her pins had been removed at 2 years.

Table IX. Results of hips with chondrolysis

	Result			
	Excellent	Good	Fair	Poor
Chondrolysis at Presentation	1	2	2	3
Chondrolysis following Pin Penetration	1	2	1	2
Total (14)	2	4	3	5

DISCUSSION

Aetiology

Our 2 patients with detectable abnormalities of endocrine function illustrate the association with SUFE. Both of these patients had bilateral slips which were present simultaneously. Though the one patient was in the normal age range for SUFE (9-16 years), the other was 19 years 10 months old substantiating the proposal that an endocrine pathology should be entertained when SUFE occurs out of the normal age range. Patients with bilateral slips occurring simultaneously should be under suspicion.

The history of trauma in 21 (38%) of 55 hips suggests that it certainly has a role in the aetiology. Of the 8 acute slips, there was a history of trauma in 6 (75%) and trauma was present in 3 (50%) of the 6 acute on chronic slips. Twelve (29%) of the 41 chronic slips had a history of trauma. Trauma is more likely an aetiological factor in the acute and acute-on-chronic slips. However, patients often try and relate an episode of trauma to explain their symptoms though this trauma may in fact be insignificant and unrelated.

Alexander's theory regarding the greater incidence of involvement of the left hip in SUFE is interesting and credible. Our series was in keeping with this trend with 33 slips (60%) being left sided. This was presuming that the majority of our patients were right handed.

Incidence

There was no increase in incidence of onset in the summer months as compared to Loder (1990) who found an increased incidence of onset in the summer months in his series..

The equal incidence in boys and girls in this series is not in keeping with other reported series in which it is commoner in boys. In this series, 44% of the patients had weights above the 90th percentile for age and this is in keeping with the literature.

Radiological Diagnosis

The CT scan was found to give the best visualisation of the slip. The frog lateral requires the patient to flex and abduct the hip to 45° , this is a difficult position for these patients to attain as they are limited by pain. The head of the femur is very difficult to see with a Smith-Petersen (true) lateral. If a CT scan is not available, we have found that the acetabular oblique view (Menelaus 1986) provides a reproducible and easily obtainable lateral (Fig. 15). To obtain this view, the patient rolls his pelvis until the lateral aspects of his knee and ankle lie flat on the table, the radiograph beam is then directed perpendicular to the table above the hip.



Fig. 15.

The acetabular oblique view or roll over lateral as described by Menelaus.

Treatment

In our series the risk of avascular necrosis (45%) with osteotomy was too high to warrant this form of treatment (Fig. 16a & b).



Fig. 16a

Early post operative radiograph following an intracapsular osteotomy in a moderate slip..



Fig. 16b.

Follow-up radiograph at 5 years of the patient in Fig. 16a showing avascular necrosis.

Although Dunn and Angel (1978), Fish (1984) and Broughton, Todd, Dunn and Angel (1988) reported low rates of AVN following osteotomy, pinning in situ is much safer in our hands. In analysing Tables I & II in which the relationship between the different modalities of treatment, the severity of slip and the complications are shown, it can be seen that there were 13 cases of moderate slips that were pinned in situ and 2 (15%) of these developed chondrolysis with no cases of AVN. A comparable number (10) of moderate slips underwent osteotomies of which 4 (40%) developed AVN. Of the 5 severe slips, 2 were pinned in situ, 1 had an MUA followed by pinning, 1 had an osteotomy and the 5th had no treatment. Only the case which had undergone an osteotomy developed a complication ie: AVN.

Pinning in situ (40 hips) resulted in chondrolysis due to persistent pin penetration in 6 (15%) and AVN in 1 (2,5%) hip. These seven hips were pinned with multiple pins and in the hip with AVN, the pins were sited in the superior quadrant of the head which has been implicated as a cause of AVN (Brodetti 1960; Stambough et al 1986). With modern imaging techniques and the use of a single cannulated screw, these complications can almost be eliminated (Aronson and Carlson 1992; Ward et al 1992) (Fig.17a & b).



Fig. 17a.

A-P radiograph showing a case of pinning in situ with a single cannulated screw.



Fig. 17b.

Lateral radiograph of patient in Fig. 17a.

The overall results reveal that at final follow-up, there were 70% excellent, 15% good, 2,5% fair and 12,5% poor results in the hips pinned in situ as compared with 18% excellent, 9% good, 18% fair and 55% poor of the hips that had had osteotomies (Table III).

The proponents of intracapsular osteotomies feel that the normal relationship of the head to the neck must be restored so as to prevent osteoarthritis. However Orderberg, Hansson and Sandstrom (1984) have in a 20 to 40 year (average 37 years) follow-up of 49 patients with SUFE for which no treatment had been instituted, found that only 2 developed significant osteoarthritis to warrant total hip replacements. Similarly a long term follow-up (average 49 years) of 155 hips by Carney and Weinstein (1991) showed a more severe deterioration in the Iowa hip scores in those hips in which an osteotomy had been done as compared with those pinned in situ.

Fish reported one case of AVN out of 42 hips undergoing intracapsular osteotomies, he however had 1 case of osteoarthritis despite the realignment of the head. Dunn and Angel (1978) separate the slips into chronic slips with the growth plate open, chronic slips with the growth plate closed and acute on chronic slips. The numbers of each and incidences of AVN in Dunn's series are seen in Table X.

Table X. Rates of avascular necrosis in Dunn's series

Type	Hips	Avascular necrosis
Chronic slip with growth plate open	(41)	1 (2,5%)
Chronic slip with growth plate closed	(7)	3 (42%)
Acute on chronic slip	(25)	9 (36%)
Total	(73)	13 (18%)

The overall incidence of AVN in their series was 18%. They feel that the chronic cases with an open growth plate are the best candidates for osteotomy. It does appear that it is not always a simple matter to determine whether the growth plate is open or not and in 6 of their 7 cases with a closed growth plate this was only realised at operation. The high rate of AVN in the acute-on-chronic slips (36%) was attributed to the acuteness of the slip and not the operation. There was also one case of osteoarthritis in this series which was attributed to improper replacement of the head. The overall incidence of AVN in the follow-on series of 115 cases by Broughton, Todd, Dunn and Angel (1988) was 12%. Out of 70 cases with chronic slips and an open growth plate, 3 (4,2%) developed AVN. There were 3 cases of osteoarthritis. The series by Clarke and Wilkinson (1990) had an AVN rate of 16%.

These surgeons perform intracapsular osteotomies on moderate and severe slips. Moderate slips have been shown to have good results with pinning in situ. It is possible

that the intra-capsular osteotomy is technically easier with lesser degrees of slip and thus accompanied by lower rates of AVN.

Broughton, Todd, Dunn and Angel (1984) have expressed the fear that with technical difficulty in pinning severe slips, the posterior aspect of the neck is liable to be penetrated and can lead to compromise of the remaining blood supply. This would appear to be a theoretical risk only, as evidenced by our results (page 26; Fig. 7a & b). With improved pinning techniques and if necessary the use of the anterolateral approach as described by Crider et al (1988), posterior neck penetration can be avoided.

Two of the 3 hips in which manipulation resulted in reduction developed AVN. We feel that manipulation should be relegated to the history books.

Bone graft epiphyseodesis has been reported to have a low complication rate by some authors and a high rate by others. We have no experience with this technique but are not happy with the fact that the patients require to be immobilised in a hip spica post operatively as this has been implicated as a cause of chondrolysis. The hip is exposed through an anterolateral approach so as to apply the bone graft. Through this same approach a pin could be inserted in preference and thus eliminate the necessity for a hip spica.

Prophylactic pinning

In our series there were bilateral slips in 11 cases with 7 of these occurring simultaneously and 4 (9%) occurring at a later date. Most series have a similar incidence of slips occurring on the opposite side at a later date. With the incidence of around 10%, it means that if hips are prophylactically pinned, 9 out of 10 hips would have been prophylactically pinned unnecessarily. We therefore feel that hips should not be pinned prophylactically but that the parents and patients must be warned about the possibility of a slip on the opposite side and to attend as soon as there are symptoms.

Chondrolysis

Chondrolysis at presentation

Although Bishop et al (1978), Kennedy and Weiner (1990) and Spero et al (1992) did not find a higher incidence of chondrolysis in black patients, all our patients with chondrolysis at presentation were either black or coloured females with an incidence of 44% and 33% respectively. Similarly Wilson, Jacobs and Schecter (1965), Tillema and Golding (1971) and Heppenstall et al (1974) reported a higher incidence in blacks since it was first noted by Orfino, Innis and Lowrey in 1960 (range 28% to 50%). In our study the incidence of chondrolysis at presentation (ie: before treatment) was 40% in blacks, 15% in coloureds and 0% in whites. The high incidence of chondrolysis at presentation in black and coloured females suggests a genetic predisposition.

Pin penetration

Our findings concur with those of Zions, Simonian and Harvey (1991) that transient intra-operative pin penetration does not lead to chondrolysis. However a direct relationship was found between persistent pin penetration and chondrolysis. The risk of chondrolysis with persistent pin penetration is higher if the pin penetrates in the weight bearing area of the joint (ie: anterior superior quadrant). This suggests that the mechanism is a mechanical one rather than an autoimmune process as suggested by several authors (Mankin, Sledge and Rothschild 1975; Eisenstein and Rothschild 1976; Morrissy, Calderon and Gerdes 1981). One would expect chondrolysis to occur in all cases of pin penetration if the pathogenesis was solely an autoimmune one. The four patients in this series with persistent pin penetration in the non-weight bearing area of the joint did not develop pain or chondrolysis. Factors that have been implicated in chondrolysis include cast immobilization (Lowe 1961), heavy traction (Lowe 1961), Southwick osteotomy (Frymoyer 1974), all of which have the common denominator of immobilisation. Pin penetration in the weight bearing area of the joint may lead to more discomfort and a reluctance of the patient to move the hip. This decreased range in motion with resultant lack of production of synovial fluid and cartilage nutrition would support the original theory of Waldenstrom (1930) and Cruess (1963). This may explain

why the patients with persistent pin penetration in the weight bearing area of the joint improved after removal of the pins. Similarly, the greater degree of slip (moderate or severe) seen in the hips with chondrolysis at presentation (without pin penetration) may result in a greater restriction of movement; this being an additional factor to genetic predisposition in the aetiology of chondrolysis in these hips.

Natural history

Sixty-four percent (9 of 14; ie: those with a fair, good or excellent result) of our patients had a favourable functional result. Except for Lowe (1970) who reported a favourable functional outcome in all 6 of his patients, most authors report a poor outcome (ankylosis) ranging from 68% (Hartmann and Gates 1972) to 72% (Maurer and Larsen 1970) and 89% (Tillema and Golding 1971). In idiopathic chondrolysis the outcome has been reported as 33% to 67% poor (Jones 1971; Duncan, Nasca and Schrantz 1979; Sparks and Dall 1982; Bleck 1983). Jones and Sparks and Dall reviewed a similar population group at the same hospital in a similar period with idiopathic chondrolysis and reported a relentless deterioration leading to ankylosis in 12 of 18 patients. Therefore, in a similar environment, chondrolysis in SUFE has a more favourable outcome as compared to idiopathic chondrolysis (64% vs 33%). Pain is not a major problem and improvement can occur up to 3 years after maximal involvement and we suggest an expectant attitude is adopted for this period.

CONCLUSIONS

1. CT scan provides the best visualisation of the slip. If this is not available, the acetabular oblique view provides an easily obtainable reproducible lateral.
2. Pinning in situ is the safest management. Pin penetration of the head can be minimised with the use of good quality image intensification and the use of a single cannulated screw. The superior aspect of the head must be avoided to minimise the risk of AVN.
3. Intra-capsular and primary extra-capsular osteotomies are associated with a high incidence of AVN and should not be undertaken.
4. Manipulation is associated with AVN and should be avoided.
5. Black and coloured females have a high risk of developing chondrolysis at presentation.
6. Transient intra-operative pin penetration does not lead to chondrolysis.
7. Persistent pin penetration has a direct relationship with chondrolysis and the risk is higher if the pin penetrates the weight-bearing area (anterior superior quadrant) of the joint.
8. The outcome of chondrolysis is favourable in 64% of cases.

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