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ORIGINAL STUDY

Surgical treatment for developmental dysplasia of the hip- a single surgeon series of 47 hips with a 7 year mean follow up

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The treatment of developmental dysplasia of the hip (DDH) in children remains controversial. We describe the clinical and radiological outcomes of 47 hips in 43 children treated with open surgery by one surgeon between 2004 and 2008 for DDH.

The mean age at operation was 25 months (5 to 113) with a mean follow up of 89 months (22 to 169).

At the latest follow up 40 of the 45 hips where Severin grades were recordable (89%) were graded as excellent or good, Severin class I or II. Clinically significant AVN (grade II to III according to the Kalamchi and MacEwen classification) was seen in 6 (13%) of the hips.

We found a pelvic osteotomy to be a risk factor for AVN (p 0.02) and age at operation to be a risk factor for poor morphology at final follow up (p 0.03).

Over 18 months old a pelvic osteotomy should be performed in selective cases depending on intra-operative stability, but we will now consider doing this as a staged procedure and delaying the osteotomy for a period of time after open reduction to reduce the risk of AVN.

INTRODUCTION

DDH has a wide spectrum and presentation of abnormalities, varying from frank dislocation to mild dysplasia.

In 1991 it was suggested the term DDH should replace CDH, (congenital dislocation of the hip) as it encapsulated the concept of instability and imperfect formation without specifying when the displacement or dislocation occurred *(5)*.

The estimated incidence in the UK is 1 in 400 children *(2)*, however there is wide variation as the etiology of DDH is multifactorial with genetics, gender, environment and mechanical factors all predisposing the hip joint to displacement. In the native North Americans instability is up to 1 in 5, but the condition is practically absent in the black African population.

In the UK the screening programme includes patients with first degree family history, breech at 36 weeks or thereafter and abnormal clinical examination.

There is no consensus on treatment of frank dislocations presenting in differing age groups, with various techniques of closed reductions, open reductions, (via anterior or medial approaches) femoral shortening procedures and pelvic osteotomies being described *(4)*.

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The consequences of an unstable reduction are instability and dislocation, undue tension within the hip joint can cause AVN and reduced congruency, leading to early onset arthritis in adulthood.

We audited the techniques and outcomes from our centre by one surgeon (NK) performing open surgery between 2004 and 2008 on children with DDH in an attempt to suggest an algorithm that produces the best outcomes in terms of congruency, AVN and reoperation rates.

PATIENTS AND METHODS

When a patient presents under 3 months old we use a Pavlik harness. If a patient fails a harness or presents between 3 and 9 months old we perform an arthrogram and attempt a closed reduction If this is unsuccessful we proceed to open surgery.

If patients present over 12 months old or have failed closed reduction we perform open surgery by way of an anterior approach. We only consider a medial approach if inferior structures, in particular the psoas tendon and transverse acetabular ligament are tight on a previous arthrogram. If the limbus and inferior structures are obstructive we proceed to an anterior open reduction.

We follow Catterall's principles of operative intervention in DDH *(11)*, aiming for a stable, concentric, tension free reduction in a neutral weight bearing position. If the hip is stable in the 20-20-20 position of flexion, abduction, internal rotation we perform an anterior open reduction only. If the hip cannot be reduced or only reduced under tension we perform a femoral shortening osteotomy. At the same time a derotation and varus osteotomy is performed using the compression hip screw system (Smith and Nephew CHS). In children over the age of 18 months a Salter's pelvic osteotomy is considered if the hip remains unstable, or if thought that there is insufficient remodeling potential. In selected cases, with a large volume we perform a Pemberton pelvic osteotomy.

We do not routinely perform an arthrogram prior to open surgery. If the child is over 12 months, has had an arthrogram suggesting blocks to reduction or a failed closed reduction we proceed to open reduction plus consideration of pelvic and or femoral osteotomies. The anterior open reduction is performed as described by Smith Peterson *(9)*, with an associated iliopsoas tenotomy. Femoral osteotomies are performed using a separate direct lateral incision and length reduced by measuring intra-operatively. After an initial transverse osteotomy, the bone ends are overlapped until the joint is tension free at which point the femur is marked and shortened then secured using the CHS hip screw system. The neck shaft angle is measured and varised to 110 deg. Anteversion is measured and reduced to 20-30 degrees.

The patient is placed in a bilateral hip spica post operatively with the 20-20-20 position, abducted and internally rotated. The spica is retained for 12 weeks after soft tissue surgery alone and for 6 weeks for bony surgery, at which stage the patient returns to hospital for removal of spica and inpatient physiotherapy. The patient is discharged home once they are able to achieve full knee flexion to prevent femoral fractures. Metalwork is removed several months later.

Patients who had undergone an open reduction of the hip were identified from the surgeon's logbook between the periods of 2004 to 2008.

Patients were excluded if they had teratological dislocations, neuromuscular disorders, previous surgery elsewhere or the operation was performed by a different surgeon.

All radiographs were assessed and measured by two of the authors (JM and NK), and statistically analysed for inter-observer reliability. The last radiograph prior to operation was identified and the acetabular index (AI) measured along with Tonnis grading of the dislocation, presence or absence of ossific nucleus and pre-operative AI for those patients that required a second operation. Post operatively the centre edge angle (CEA) in those patients over 5 years old (AI if under 5), Kalamchi and MacEwen grade of AVN and Severin classification of congruency were recorded from the final available follow up radiograph. Serial radiographs were observed to further differentiate the AVN grade. Any clinical complications were recorded from the clinic note of examination findings.

In 6 patients no pre-operative radiographs were available so measurements were taken from a pre-operative arthrogram instead.

Statistical analysis

The inter-observer reliability in measuring the AI and CEA from radiographs was assessed using the Intraclass Correlation Coefficient (ICC(A,1)). Univariable Poisson regression was used to analyse all continuous predictors (age, acetabular index, Tonnis grade and CE angle) of AVN, post-op and persistent dysplasia, or the need for reoperations. Fisher's exact test was used for the univariable analysis of all categorical predictors (gender, prior closed reduction, prior Pavlik or Rosen, etcetera). All univariable predictors with a p-value below 0.15 were considered for inclusion in a multivariable regression, for which we used a penalized logistic regression method. All analyses were performed using R version 3.2.1 (R Foundation for Statistical Computing, Vienna, Austria, 2015) and the package logistf. P-values below 0.05 were assumed to denote statistical significance.

RESULTS

47 hips in 43 children met our inclusion criteria, 40 girls and 3 boys. 39 unilateral and 4 bilateral, all of which were girls. Of the unilateral, 24 were left and 15 were right. The mean age at operation was 25 months (5 to 113) with a mean follow up of 89 months (22 to 169).

46 hips had an anterior open reduction, 1 had a medial approach performed. 16 patients had an anterior open reduction only, 5 had an anterior open reduction plus Salter's osteotomy, 7 had an anterior open reduction plus femoral osteotomy and 18 had a combined femoral and pelvic osteotomy.

7 hips required a second operation for dislocation or subluxation. 1 patient had a Pemberton osteotomy in an older age group as a revision procedure.

The ossific nucleus (ON) was present in 34 hips pre-operatively, absent in 9 and not recorded in 6 as in these patients the measurements were taken from

Table I. — Description of operations and post operative outcomes versus age

Operation type and age at operation (months)	Number	AVN grade II – III (% of hips)	Severin Grade III-IV (% of hips)	Re-operations (% of Hips)	Mean age at first operation (months)
Overall	47	6 (13)	5 (11)	7 (15)	25
Under 12	13	0	0	1 (14)	10
12-48	29	5 (17)	3 (10)	6 (21)	25
>48	5	1 (20)	2 (40)	0	68

Table II. — Description of operations and post operative outcomes versus operation type

Operation type	Number	AVN grade II – III (% of hips)	Severin Grade III-IV (% of hips)	Re-operations (% of hips)	Mean age at first operation (months)
Medial open	1	1	0	1 (100)	5
Anterior open only	16	0	0	3 (19)	14
Ant open and Salters	5	3 (60)	2 (40)	1 (20)	35
Ant open and femur shortening	7	0	0	1 (14)	19
Ant open, femur and Salter's	18	2 (11)	3 (17)	1 (6)	41
Reoperations	7	1 (14)	1 (14)	0 requiring 3rd operation	22

Table III. — Severin classification at final follow up

Severin Class	I	II	III	IV	V	VI	VII	Unrecorded (too young)
Number of hips (%)	20 (43)	20 (43)	4 (9)	1 (2)	0	0	0	2 (2)

Table IV. — Avascular necrosis at final follow up (Kalamchi and MacEwen)

AVN group	None	I	II	III	IV
Number of hips (%)	36 (76)	5 (11)	4 (9)	2 (4)	0

Table V. — Further operations performed

First operation	Second operation	Indication	Number of hips
Medial open	Salter's	Dysplasia	1
Anterior open	Salter's	Dysplasia x 2 Subluxation x1	3
Anterior open, femoral shortening and Salter's	Repeat open reduction	Dislocation	1
Anterior open and Salter's	Femoral shortening and Pemberton	Dislocation and AVN	1
Anterior open and femoral shortening	Salter's	Dysplasia	1

Table VI. — Univariable risk factors for AVN (grade 0/1 versus 2/3)

Factor	**Odds Ratio or Risk Ratio**	**p-value**
gender (male)	1.0 (0.07 to 15)	1.00
age at operation (years)	1.3 (0.8 to 2.2)	0.24
prior closed reduction	1.0 (0.7 to 1.5)	1.00
prior Pavlik or Rosen	0.9 (0.7 to 1.1)	0.58
ossific nucleus	1.1 (0.9 to 1.4)	0.57
Tonnis grade	1.0 (0.2 to 2.8)	0.93
pre-op acetabular index	0.9 (0.7 to 1.1)	0.29
primary pelvic osteotomy	1.3 (1.01 to 1.6)	0.02
primary femoral osteotomy	0.9 (0.8 to 1.2)	0.65

Table VII. — Multivariable risk factors for AVN

Factor	**Odds Ratio**	**p-value**
Model		0.20
age at operation (years)	1.0 (0.5 to 1.6)	0.97
primary pelvic osteotomy	16 (1.2 to 2253)	0.03

Table VIII. — Univariable risk factors for dysplasia (severin grade 3 or more)

Factor	**Odds Ratio or Risk Ratio**	**p-value**
gender (male)	0.3 (0.04 to 1.8)	0.30
age at operation (years)	3.5 (1.6 to 14)	0.02
prior closed reduction	1.0 (0.7 to 1.5)	1.00
prior Pavlik or Rosen	0.9 (0.7 to 1.1)	0.57
ossific nucleus	1.1 (0.9 to 1.4)	0.56
Tonnis grade	1.1 (0.3 to 3.4)	0.87
pre-op acetabular index	1.0 (0.8 to 1.2)	0.69
primary pelvic osteotomy	1.3 (1.02 to 1.6)	0.02
primary femoral osteotomy	1.0 (0.8 to 1.3)	1.00

Table IX. — Multivariable risk factors for poor Severin grade (III/IV)

Factor	Odds Ratio	p-value
Model		0.07
age at operation (years)	1.9 (1.1 to 7.2)	0.03
primary pelvic osteotomy	3.4 (0.1 to 554)	0.51

Table X. — Univariable risk factors for need for re-operation

Factor	Odds Ratio or Risk Ratio	p-value
age at operation (years)	0.9 (0.4 to 1.4)	0.68
prior closed reduction	1.3 (0.6 to 2.9)	0.41
prior Pavlik or Rosen	0.98 (0.7 to 1.4)	1.00
Ossific nucleus	0.9 (0.6 to 1.4)	0.61
Tonnis grade	1.0 (0.3 to 2.5)	1.00
pre-op acetabular index	1.3 (1.1 to 1.7)	0.01
primary pelvic osteotomy	0.9 (0.7 to 1.1)	0.42
primary femoral osteotomy	0.8 (0.7 to 1.1)	0.23
postop CEA	1.0 (0.9 to 1.1)	0.57

a pre-operative arthrogram rather than a radiograph. 9 patients had failed treatment prior to open surgery, 1 patient had a pavlik harness then attempted closed reduction, 2 patients had closed reductions, 5 had pavlik harness and 1 had a von rosen harness.

At the latest follow up 40 of the hips were graded as excellent or good, Severin class I or II. 5 were grade III or IV and 2 children were too young to record Severin grades. AVN grade 0 or I in 41/47 (87%) of hips, grade II to III according to the Kalamchi and MacEwen classification) was seen in 6/47, (13%) of the hips. The 4 bilateral girls all had AVN grade 0 or I and Severin class I or II.

The inter-observer reliability of measuring the AI and CEA from radiographs was 0.85 for the AI and 0.93 for the CEA.

DISCUSSION

Overall we found our practice to provide a safe, low risk outcome for open surgical treatment of DDH with an overall AVN rate of 13% (excluding grade I) and Severin good or excellent outcomes in 89% of patients, as illustrated in figure 1.

This compares favourably with previous reports in the literature ranging from 13-23 % AVN rates for anterior open reductions and up to 45% when using a medial approach [6]. Joint congruency according to Severin classification of 75 - 84% good or excellent in those operated on under 7 years old and as low as 58% in those older than 7 *(3)*.

All patients under the age of 12 months had excellent outcomes due to the remodeling potential in this age group.

Poorer AVN outcomes did not necessarily correlate with morphology based on the Severin Grading.

We found older age at operation to be a risk factor for poorer outcomes in terms of morphology (p=0.02), in keeping with previous studies [6], but not, in terms of AVN, as illustrated in figure 2.

We found a risk factor for AVN to be a pelvic osteotomy (p 0.02), older age at operation was a risk factor for dysplasia (p 0.03), and AI was found to be a risk factor for reoperation for dysplasia or subluxation (p 0.01).

Given that we tend to perform more pelvic osteotomies with older children, the problem is differentiating the two factors. Hence we performed more applied statistics. Multivariable risk analysis suggests that a pelvic osteotomy and not age is the risk factor for AVN, whereas age and not pelvic osteotomy is the risk factor for dysplasia. Previous studies have conflicting evidence on risks of performing staged open reductions then Salter or concomitant open reduction and Salter *(3,6)*. Given these results we will perform further studies on the effect of pelvic osteotomies and may consider performing staged Salter's osteotomies in future to reduce the

risk of AVN. The pelvic osteotomy is performed for instability, however instability does not cause AVN, as the native dislocated hip does not develop AVN. Hence the AVN is iatrogenic due to surgical dissection and alteration in forces around the hip joint.

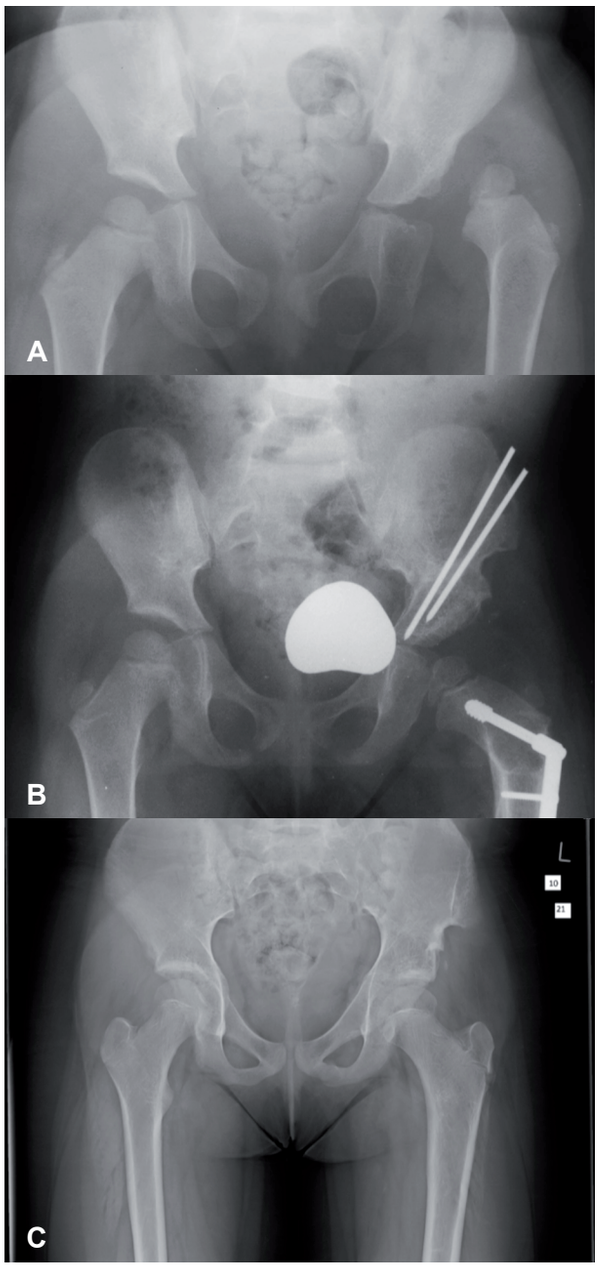

Fig. 1. — Patient 1. pre operatively tonnis 2, acetabular index 40 degrees(a). Operated on at 2 years old Salters and femoral osteotomy (b) and at age 11 had a good outcome with no AVN and Severin grade I(c).

There was no statistical significance in outcome relative to ON being present or whether the patient had failed harness or closed reduction. Likewise the Tonnis grade of dislocation had no bearing on post operative outcomes. Other studies have proved inconclusive as to whether the presence of the ON is protective against AVN *(8)*. Aydin reported poorer outcomes in terms of AVN with higher dislocations *(1)*. Gender was not a risk factor. A large pre-operative AI was a risk factor for reoperations for dysplasia and subluxation. (p0.01),

With regard to the medial approach our result reflects the literature of higher rates of AVN and complications, although the procedure was only performed once, the patient required reoperation despite the age at reduction being only 5 months. In general, we find that with a failed closed reduction the limbus is seen to be obstructive on arthrogram and therefore we perform an anterior open reduction.

We used the Pemberton osteotomy on one occasion in a patient who presented at 7 years old as a revision procedure, following previous open reduction and Salter, the outcome was moderate dysplasia, Severin grade 3 but no AVN. Szepzi also found poorer outcomes when performing Pemberton osteotomies in patients older than 7 years [10].

The Pemberton osteotomy is thought to provide a more powerful correction as it is performed closer to the origin of deformity and hinges around the triradiate cartilage whereas the Salter osteotomy hinges on the symphysis pubis *(7)*. In his original paper Salter suggested that a pelvic osteotomy in those older than 6 was contraindicated as a congruent reduction could not be achieved. Pemberton did not give specific age criteria although all the patients in his original study were under 4 years old. Subsequently studies have shown fair results when performing Pemberton osteotomies in patients older than 6 years old *(10)*.

We performed femoral shortening in conjunction with the Salter's osteotomy in 18 patients with good results despite a relatively old mean age at operation of 41 months. Conversely, although only small numbers, the 5 patients who had open reduction and Salter's osteotomy only had high rates of both AVN and dysplasia. As a result of this finding we will

in future have a lower threshold for performing a femoral shortening osteotomy in conjunction with a pelvic osteotomy to reduce the risk of a poor outcome.

Four of the patients with a femoral osteotomy and one with an open reduction and Salter developed a leg length discrepancy these were all less than 20mm. Otherwise there were no clinical complications at final follow up and all patients had a good pain free range of movement of their hip joint.

A weakness of our study are that it is a retrospective audit and not a prospective study. Also, numbers were relatively small, hence statistical significance was only achievable for some factors.

Given our findings, a randomized trial of open and Salter versus staged open and Salter's osteotomies would now be of interest.

The mean follow up was 89 months and hence could only provide indications of medium term not long term outcomes in this cohort of patients. Zadeh et al suggest that rates of AVN and dysplasia can significantly increase during the adolescent growth spurt and outcomes reported prior to this will significantly underestimate poor radiological outcomes *(11)*.

CONCLUSION

This study has allowed us consider a new algorithm to use when treating DDH to provide good medium term outcomes. We proceed to open surgery in patients over 12 months old or those with failed closed reduction, and employ a femoral shortening varus and derotation osteotomy if there is tension. Over 18 months old a pelvic osteotomy should be performed in selective cases depending on intra-operative stability, but we will now consider doing this as a staged procedure and delaying the osteotomy for a period of time after open reduction to reduce the risk of AVN. An anterior open reduction and salter osteotomy alone appears to provide a poorer outcome. We would therefore consider a femoral shortening osteotomy in this scenario.

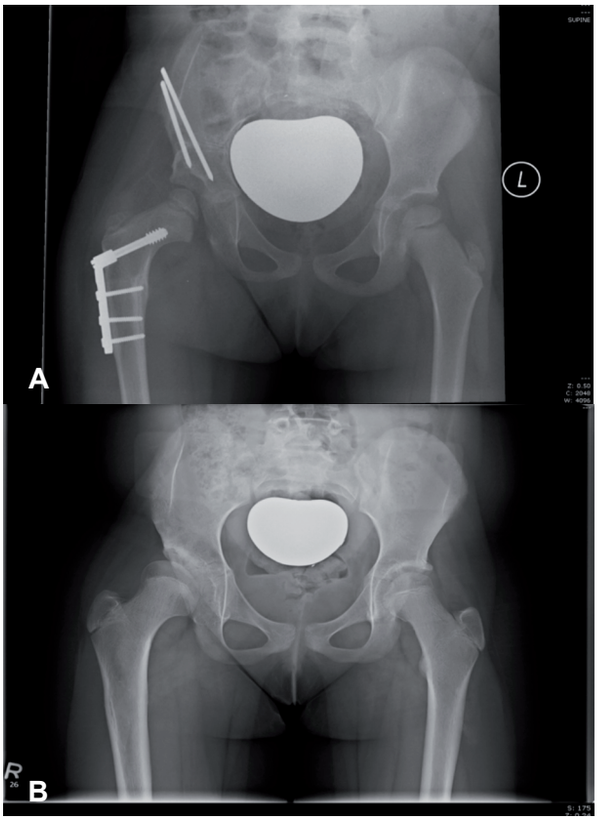

Fig. 2. — Patient 2. Unfortunately no pre operative radiographs, however operated on at 4 years old with open reduction, Salters and femoral osteotomy(a), at 11 years old had no AVN, but Severin grade III (b).

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