The success of management with the Pavlik harness for developmental dysplasia of the hip using a United Kingdom screening programme and ultrasound-guided supervision


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We present the results of treatment of developmental dysplasia of the hip in infancy with the Pavlik harness using a United Kingdom screening programme with ultrasound-guided supervision. Initially, 128 consecutive hips in 77 patients were reviewed over a 40-month period; 123 of these were finally included in the study. The mean age of the patients at the start of treatment was five weeks (1 to 12). All hips were examined clinically and monitored with ultrasound scanning. Failure of treatment was defined as an inability to maintain reduction with the harness. All hips diagnosed with dysplasia or subluxation but not dislocation were managed successfully in the harness. There were 43 dislocated hips, of which 39 were reducible, but six failed treatment in the harness. There were four dislocated but irreducible hips which all failed treatment in the harness. One hip appeared to be successfully treated in the harness but showed persistent radiological dysplasia at 12 and 24 months. Grade 1 avascular necrosis was identified radiologically in three patients at 12 months.

The use of a Pavlik harness is an accepted treatment for the management of instability in developmental dysplasia of the hip (DDH), as it allows rapid remodelling of the acetabulum in the presence of a reduced femoral head. It has been shown to be highly successful in screening programmes, with a low rate of avascular necrosis (AVN). However, a recent publication from The Netherlands reported a success rate of only 20% in Graf type IV hips, and a rate of AVN of 16% at one year. The principal difference between practice in the United Kingdom and The Netherlands is the time of initiation of treatment. In The Netherlands the current national screening programme identifies affected babies at between three and five months of age, with a mean age at the start of treatment of four months. The current United Kingdom-based screening programme identifies affected babies at between three and five months of age, with a mean age at the start of treatment of four months. The current United Kingdom-based screening programme recommends screening for at-risk babies at six weeks.

We present our results of the use of the Pavlik harness in the management of DDH using a United Kingdom screening programme and ultrasound-guided supervision.

Patients and Methods

The study was carried out at a tertiary referral paediatric orthopaedic unit between February 2004 and June 2007 (40 months). Patients who were diagnosed with DDH through our screening programme were enrolled. Patients with teratological causes of hip dysplasia were excluded, as were tertiary referral cases, as these were generally patients who presented later with a potentially different natural history.

There were three routes of patient identification. Every child born at our institution undergoes a mandatory clinical examination of the hips, including the tests described by Barlow of hip dislocation with a posterior force in adduction and flexion, and by Ortolani in which the hip is relocated with an anterior force in abduction and flexion. Any baby with an abnormal examination was referred for ultrasound screening. A baby with a frank dislocation was assessed by a clinical specialist physiotherapist, put immediately into a Pavlik harness, and then referred to the next available ultrasound clinic, within two weeks. Any child born with a normal clinical examination but with risk factors for DDH including a positive family history, breech presentation at delivery, a lower limb deformity such as congenital talipes equinovarus, scoliosis or severe oligohydramnios was referred for screening. Any patient with an abnormal hip examination by their general practitioner at six weeks was referred to the next available combined ultrasound clinic.
The combined ultrasound clinic is run fortnightly with a consultant paediatric orthopaedic surgeon and team, a consultant paediatric musculoskeletal radiologist and a clinical specialist physiotherapist. All babies undergo an ultrasound and clinical examination at each visit. The ultrasound measures the congruency of reduction of the hip, the development of the acetabulum using the Graf angle of < 60°. Our indication for management with a Pavlik harness is the presence of instability or frank dislocation on dynamic ultrasound scanning. Four groups of patients are therefore identified: dysplasia without instability, a subluxable hip, a dislocated hip which is clinically reducible, and a dislocated hip which is not reducible. During the period of this study it was our practice to use a trial of the Pavlik harness in all unstable hips.

The Pavlik harness was applied by the specialist physiotherapist in the position of maximum stability, as defined by the ultrasound scan. This is with the anterior straps holding the hips in 90° to 100° of flexion and the posterior straps tightened to limit adduction to between 3 cm and 5 cm between the knees. Each baby is then seen at one to two week intervals to check the harness, which is changed to a larger size if required. Each baby has a repeat ultrasound two weeks after application of the harness to ensure adequate reduction, and then four- to six-weekly to assess acetabular development. The harness is removed when the Graf angle reaches > 60° and the hip is stable to dynamic ultrasound examination. Failure is defined as the inability of the harness to achieve or maintain concentric reduction, or failure of acetabular development despite concentric reduction.

After removal of the harness each baby was followed up clinically and radiologically at 12 months and for a minimum of two years. The radiographs were reviewed independently by two observers (MJW, WGA). AVN was assessed using the scoring system described by the Commission for Study of the Hip (Table I) and acetabular development using the acetabular index.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Radiologic findings</th>
<th>Prognosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Slightest degree of changes, femoral head ossification centre with slightly blurred margins, slightly granular and irregular in structure</td>
<td>Generally regresses over time</td>
</tr>
<tr>
<td>2</td>
<td>More blurred margins of the ossification centre with irregular structure, more granular than for grade 1. Also cyst formation or punched out partial defects</td>
<td>Changes usually regress, possible flattening of the head</td>
</tr>
<tr>
<td>3</td>
<td>Whole femoral head ossification centre disintegrated or only visible as individual fragments or a flat strip. Very small head nucleus, possibly completely broken up or only visible after many months</td>
<td>Frequent deformation of the femoral neck initially, which regresses at a later date</td>
</tr>
<tr>
<td>4</td>
<td>Additional involvement of the epiphyseal plate. Irregularities also apparent on the margins of the epiphyseal plate at the femoral neck</td>
<td>Serious consequences for growth</td>
</tr>
</tbody>
</table>

## Results

Initially, 128 hips in 77 patients were included in the study. There were 73 left hips and 55 right with bilateral disease in 51 patients. In 12 hips identified at birth an initial ultrasound assessment was not undertaken. The remaining hips were identified at between four and 12 weeks of age in the combined ultrasound screening clinic, and a Pavlik harness was applied at a mean of five weeks (1 to 12).

Four hips were initially treated successfully with a Pavlik harness, but treatment was abandoned due to failure of the Pavlik harness to maintain a concentric reduction of the contralateral hip and they were therefore excluded. One hip with a reducible dislocation appeared to have successful treatment but showed persistent acetabular immaturity on subsequent radiological follow-up, and was also excluded from the analysis. There were 64 subluxatable hips in the presence of dysplasia (mean Graf α angle = 52°, 43° to 59°), and 43 dislocatable hips (mean Graf α angle = 45°, 34° to 52°). In 16 patients with bilateral disease, the milder of the two hips showed evidence of dysplasia (mean Graf α angle = 54°, 52° to 59°) but no instability on the dynamic ultrasound scan. Although, in our practice this type of hip is routinely treated by serial observation and ultrasound scan, in view of the significant contralateral dysplasia they were managed with a Pavlik harness and therefore included in this study.

Following the exclusion of five of the 128 hips initially entered in the study, 111 of 123 hips (90%) were managed successfully with a Pavlik harness. There were 12 failures in nine patients (10%) owing to inability of the harness to achieve or maintain concentric reduction of the hip. The mean initial Graf α angle in the successful group was 52° (34° to 59°) and 44° (38° to 52°) in the group that failed. All 12 failures occurred in the group of 43 dislocated hips, eight of which were clinically reducible (mean Graf α angle = 46°, 39° to 52°) and four initially clinically irreducible (mean Graf α angle = 42°, 30° to 45°). All of these latter four failed treatment with the harness. In three we were unable to achieve concentric reduction, and one became reducible after two weeks in the harness, but the reduction could not be maintained. Of the 12 hips that failed treatment with a
The Pavlik harness, 11 were treated with an adductor tenotomy followed by closed reduction and one required open reduction by the medial approach. All were then managed in a hip spica for three months (Table II).

The ultrasound scans of all the dislocated hips (n = 43) were reviewed retrospectively and formally graded by a consultant paediatric radiologist (RH) using the Graf scoring system.6 There were 29 Graf III and 14 Graf IV hips. Of the 39 hips defined as reducible, 27 were Graf III and 12 Graf IV. Of the irreducible dislocations two were Graf III and two Graf IV. Treatment with the harness was successful in 23 but failed in six, a success rate of 79%. Treatment with the harness was successful in eight Graf IV hips and failed in six, a success rate of 57%.

The predictive value of Graf grade and ultrasound scan reducibility was then assessed. The positive predictive value (i.e. the chance of successful treatment with the Pavlik harness) of both reducibility on ultrasound prior to treatment and a Graf III classification was 0.79. The negative predictive value (i.e. likelihood of failure) of irreducibility on ultrasound was 1 (sensitivity 1, specificity 0.66) compared to Graf IV classification of 0.43 (sensitivity 0.74, specificity 0.5).

At radiological review, three hips (2% overall, 7% of dislocated hips) were identified on the 12-month radiograph as having potential AVN (Table II). All three were classified as grade I by both reviewers. Treatment with the Pavlik harness had been successful in two of the hips with potential AVN. Both patients had bilateral disease, and in both the worst hip was affected. Both had been dislocated but reducible (one Graf III, one Graf IV) on ultrasound scan examination. The third hip with potential AVN was an irreducible dislocation (Graf IV). This hip failed treatment with the harness and required an adductor tenotomy and management in a hip spica. All three hips are asymptomatic at present and are being managed conservatively.

Acetabular maturation was assessed radiologically using the acetabular index (AI). All hips that were successfully treated with the harness are maturing satisfactorily with the AI in the normal distribution, as defined by Tonnis and Brunken,10 of at 12 months < 22°, and 24 months < 19°, except one. This hip appeared to have been successfully treated with the harness but showed persistent acetabular immaturity on radiological follow-up at 12 months with an AI of 27°. The patient underwent an examination under anaesthesia and hip arthrography at 24 months of age, which demonstrated a concentrically reduced hip with no instability. The AI is improving (25°) and she continues to be managed conservatively. None of the nine patients (12 hips) who failed management in the harness and required adductor tenotomy or open reduction have required further surgical treatment. Acetabular maturation in this group is delayed compared to normal, with a mean AI of 22° (19° to 27°) at 24 months, although this continues to improve on serial radiographs.

**Discussion**

The use of a selective hip screening programme in infancy has been shown to be an acceptable and cost-effective method of treating DDH.11-13 The main principle of management is to maintain concentric reduction of the hip during the period of early acetabular development. Many devices have been used to hold the hips in a flexed and abducted position. The Pavlik harness is the most common form of splintage and is in widespread use throughout Europe and the United States. We believe that this study demonstrates that treatment with the harness can be successful and has few complications when applied early in the natural history of the disease. Our results are in keeping with those of other series using a similar protocol.2,14,15 However, other devices, such as the von Rosen splint, have also been shown to be successful.16,17 It has been suggested that the more rigid splintage offered by the von Rosen splint may be more successful than the Pavlik harness in the management of severe DDH, but so far no formal randomised controlled trial has been conducted.

In this study there were a relatively high number of mildly affected hips, in particular the group with ultrasound dysplasia without instability. All of these were in infants with bilateral hip dysplasia and involved the milder affected hip. They were therefore included in the study. The management of dysplasia without instability is variable and its benefit questionable.18 All of these hips in our study were successfully managed with a Pavlik harness, but we accept that they are a group which is likely to have done well despite treatment. Our current practice is to manage dysplastic hips without instability by observation and serial ultrasound to ensure satisfactory development.

**Table II. Summary of outcome**

<table>
<thead>
<tr>
<th>Dysplasia without instability (range)</th>
<th>Number</th>
<th>Mean α angle</th>
<th>Mean age at start of treatment (wks)</th>
<th>Mean duration of treatment (wks)</th>
<th>Treatment success (%)</th>
<th>Avascular necrosis</th>
<th>Persistent acetabular dysplasia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subluxatable (range)</td>
<td>64</td>
<td>52 (43 to 59)</td>
<td>6 (1 to 12)</td>
<td>11 (6 to 16)</td>
<td>64 (100)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Dislocated but reducible</td>
<td>39</td>
<td>46 (34 to 53)</td>
<td>3 (1 to 12)</td>
<td>12 (6 to 16)</td>
<td>31 (79)</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Dislocated and irreducible</td>
<td>4</td>
<td>42 (38 to 45)</td>
<td>2 (1 to 2)</td>
<td>2 (abandoned)</td>
<td>0 (0)</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>123</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In this study the success rate for treatment of subluxatable hips with the Pavlik harness was 100%. All 12 failures (10%) occurred in patients with dislocation of the hip. These were divided into two groups: those that were clinically reducible on ultrasound scan prior to management, and those that were irreducible. We do not routinely use the Graf grading system for our patients at hip ultrasound scan. This study has shown that the relatively simple demonstration of reducibility on the ultrasound scan has at least the same positive predictive value as a Graf III classification. Our success rate in this group would be higher than demonstrated, as we did not retrospectively review and grade the subluxable hips group using the Graf scoring system within which there might have been a number of Graf III hips. The diagnosis of irreducibility was a better predictor of failure than a Graf IV classification. The 100% failure rate in hips that present initially as irreducible is similar to the findings of Lerman et al.\textsuperscript{19} We therefore no longer attempt treatment with a Pavlik harness in the irreducible group, and instead proceed directly to closed reduction under anaesthesia.

There was a trend in this study for failure of treatment with the Pavlik harness to be associated with increasing instability and a decreasing Graf \( \alpha \) angle. The degree of dysplasia as measured by the Graf \( \alpha \) angle in the failure group was also seen in patients whose treatment was successful. The degree of dysplasia did not, therefore, appear to be an independent predictor of failure.

The reported statistical significance of the association between the timing of diagnosis and start of treatment and the success of management with the Pavlik harness is variable.\textsuperscript{19,20} However, there is a difference between this study, where the mean age at the start of treatment was five weeks (1 to 12) and those where the mean age at the start of treatment was four months. The difference was most apparent in the most severely affected Graf IV hips. Our success rate (57%) in this group was lower than in milder disease, but contrasts with the 20% reported by van der Sluijs et al.\textsuperscript{3} The AVN rate of 16% at one year observed in that series\textsuperscript{3} is also higher than in ours and many other studies.\textsuperscript{2,4,14,15,21} This more severely affected group of patients would appear to benefit from earlier diagnosis and treatment, which we believe can improve the initial outcome and lead to a potential reduction in longer term complications.

We continue to recommend treatment with the Pavlik harness for infants with DDH in conjunction with an early screening programme. Parents may be reassured that the outcome in the presence of a subluxated hip is almost universally good. The dislocated but reducible hip remains a greater challenge. When diagnosed early, treatment with the Pavlik harness still has a 79% success rate and a low rate of AVN. However, we no longer recommend treatment with a Pavlik harness for the irreducible hip, as this was unsuccessful in this series and may delay more appropriate treatment.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References