



## ■ CHILDREN'S ORTHOPAEDICS

# Should closed reduction of the dislocated hip be attempted after failed Pavlik harness treatment in developmental dysplasia of the hip?

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### Aims

To determine the likelihood of achieving a successful closed reduction (CR) of a dislocated hip in developmental dysplasia of the hip (DDH) after failed Pavlik harness treatment. We report the rate of avascular necrosis (AVN) and the need for further surgical procedures.

### Methods

Data was obtained from the Northern Ireland DDH database. All children who underwent an attempted closed reduction between 2011 and 2016 were identified. Children with a dislocated hip that failed Pavlik harness treatment were included in the study. Successful closed reduction was defined as a hip that reduced in theatre and remained reduced. Most recent imaging was assessed for the presence of AVN using the Kalamchi and MacEwen classification.

### Results

There were 644 dislocated hips in 543 patients initially treated in Pavlik harness. In all, 67 hips failed Pavlik harness treatment and proceeded to arthrogram (CR) under general anaesthetic at an average age of 180 days. The number of hips that were deemed reduced in theatre was 46 of the 67 (69%). A total of 11 hips re-dislocated and underwent open reduction, giving a true successful CR rate of 52%. For the total cohort of 67 hips that went to theatre for arthrogram and attempted CR, five (7%) developed clinically significant AVN at an average follow-up of four years and one month, while none of the 35 hips whose reduction was truly successful developed clinically significant AVN.

### Conclusion

The likelihood of a successful closed reduction of a dislocated hip in the Northern Ireland population, which has failed Pavlik harness treatment, is 52% with a clinically significant AVN rate of 7%. As such, we continue to advocate closed reduction under general anaesthetic for the hip that has failed Pavlik harness.

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### Introduction

Closed reduction is a well-recognized treatment for the dislocated hip in developmental dysplasia of the hip (DDH). Performed under general anaesthesia, it is often combined with an arthrogram, with or without the addition of an adductor tenotomy, then a period of immobilisation in a hip spica. Success can be defined as a stable concentric reduction or obviating the need for further surgery,<sup>1</sup> but avascular necrosis (AVN) is a concerning

complication.<sup>2,3</sup> Success rates are quoted as between 57%<sup>4</sup> and 94%.<sup>1</sup> There is a paucity of evidence regarding the success rate of closed reduction following failed Pavlik harness treatment, and in available literature, success rates may be as low as 20%.<sup>5</sup> There may be an argument to proceed directly to open reduction.

Defining success as a stable concentric reduction at the time of closed reduction with no subsequent re-dislocation, this study

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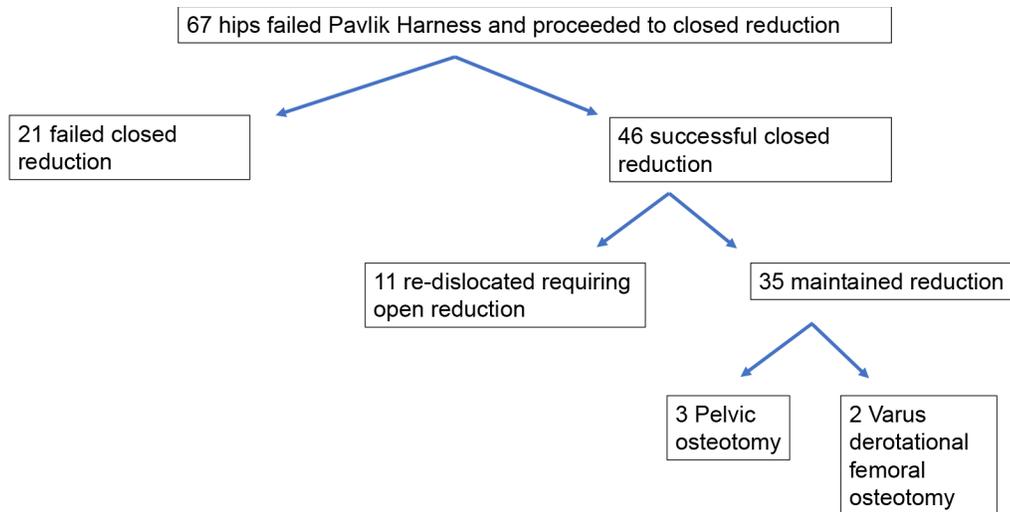


Fig. 1

Flow chart demonstrating outcome following attempted closed reduction.

aims to determine the success of closed reduction in children in Northern Ireland who have failed Pavlik harness treatment while documenting the incidence of avascular necrosis and need for further surgery (femoral or pelvic).

### Methods

In Northern Ireland, the pathway to Pavlik harness treatment is initiated by a referral to the DDH clinic on the basis of clinical instability or a history of risk factors. Infants referred with instability are examined by an experienced DDH nurse within one to two weeks of referral. Diagnosis of dislocation is made on ultrasound scan (USS) using the Graf method. If the hip is reducible, a Pavlik harness is applied and patient scanned weekly. The Pavlik harness is abandoned at week three if the hip is not reduced.

All closed reductions are performed under general anaesthesia with an arthrogram undertaken in all cases. An adductor tenotomy is performed at individual surgeon's discretion determined by degree of adduction contracture and hip stability. Children whose reductions are deemed successful are placed in a hip spica incorporating both legs, at 100° flexion and 45° abduction. A CT scan is performed at day one postoperatively to confirm reduction. The spica is maintained for three months at which point it is removed and the child placed into ring splints for a further six weeks. A change of spica is performed only if required.

The ethical approval for this study was granted by the Standards, Quality, and Audit department of the Belfast Health and Social Care Trust.

The Northern Ireland DDH database was interrogated, and all patients presenting with a dislocated hip treated in Pavlik harness between January 2011 and December 2016 were identified. A total of 644 dislocated hips in 543 patients met the inclusion criteria (467 females and

76 males). In all, 577 hips reduced successfully in Pavlik, leaving 67 hips in 54 patients (46 females and eight males) proceeding to closed reduction.

Of the patients who failed Pavlik harness treatment, and subsequently underwent an attempted closed reduction, the following was recorded: sex, age at Pavlik application, age at closed reduction, if an adductor tenotomy was performed or not, outcome of attempted closed reduction, and whether any later surgical procedures were performed. The presence or absence of AVN was determined by the senior author on the most recent follow-up radiograph and graded using the Kalamchi and MacEwen classification.<sup>6</sup>

### Results

A total of 67 consecutive hips in 54 patients (46 females and eight males) proceeded to closed reduction following failed Pavlik harness treatment with one of five consultants (including AC, ER). There were 28 right hips and 39 left hips, and 13 patients had bilateral dislocations; these hips were considered independent events in total data analysis. The median age at the time of Pavlik application was 64 days (2 to 170) and at closed reduction was 181 days (118 to 362). Hips were followed for a median of 4.1 years (1.6 to 7.4). The mean average age of children at time of most recent follow-up for AVN was over four years (2.1 to 7.7).

In all, 46 hips (69%) were deemed to have reduced in theatre and were placed in a hip spica; eleven (24%) subsequently re-dislocated (Figure 1). Three hips were dislocated on the postoperative CT scan, one dislocated within one month, five by six months, and a further two by ten months (Table I). The median time to re-dislocation was 163 days (interquartile range 186 to 187). The true successful closed reduction rate was therefore 52%.

**Table I.** Time to redislocation following closed reduction.

Hip	Number of days from closed reduction to re-dislocation
1	58
2	187
3	292
4	274
5	1
6	1
7	172
8	1
9	21
10	168
11	163

All hips that re-dislocated subsequently underwent open reduction at a median of 231 days (154 to 516) from initial surgery. The arthrograms of the eleven hips that re-dislocated were reviewed. Five demonstrated a congruent reduction in theatre while the remaining six had an incongruent reduction with a limbus or constricted capsule blocking reduction.

There was no significant difference in the sex, age at presentation, or age at closed reduction between the successful closed reduction group (35 hips) and those who failed closed reduction (32 hips) (Table II). There was a statistically significant difference for time spent in Pavlik harness, the failed group spending a shorter length of time in harness (difference of seven days between median averages). There was also a statistically significant difference between the Graf classification of the hips at presentation. There was a higher ratio of Graf 4 hips in those that failed closed reduction. In all, 24 hips underwent adductor tenotomy (nine of the 11 hips that re-dislocated, and 25 of the 35 successfully reduced hips).

Considering the bilateral cases independently, 13 children of the 54 had bilateral dislocations (three had bilateral successful closed reductions, four had a unilateral successful closed reduction, and six had bilateral failed closed reductions). Thus, the successful closed reduction rate for a bilateral hip was 38% (ten of twenty-six hips).

In relation to the need for further surgery, two successfully reduced hips (in the same child) appeared subluxed on a follow-up radiograph. This was determined to be the result of excessive femoral anteversion on a diagnostic arthrogram. They underwent femoral de-rotation osteotomies at 16 months after closed reduction and progressed to normal acetabular development. A further three hips required a pelvic osteotomy at a mean average of four years (2.7 to 6) from their closed reduction giving an overall secondary surgery rate of 14%.

In all, eight of the 35 hips (23%) that reduced and remained reduced developed grade I AVN. No hip had grade II, III, or IV AVN. A total of six of the 11 hips (55%) re-dislocated and subsequently proceeded to open

**Table II.** Comparison of hips that underwent successful and failed closed reduction.

Variable	Successful closed reduction	Failed closed reduction	p-value*
Hips, n	35	32	
Sex, males, n	7	4	0.5131
Median age at presentation, days (IQR)	69 (49 to 108)	56 (26 to 74)	0.0854
Median age at application Pavlik harness, days (IQR)	72 (50 to 110)	57 (26 to 76)	0.0784
Median time in Pavlik harness, days (IQR)	21 (11 to 35)	14 (10 to 19)	0.0316
Graf Classification at initial ultrasound, type III/type IV, n	20/13	10/22	0.0253
Median age at closed reduction, days (IQR)	188 (149 to 205)	174 (147 to 198)	0.4295

\*Fisher's exact  $\chi^2$  test for categorical variables and Mann-Whitney U test for continuous variables.  
IQR, interquartile range.

**Table III.** Comparison of avascular necrosis in selected groups.

Variable	Hips, n	Kalamchi grade of AVN, n			
		I	II	III	IV
Total cohort	67	21	1	3	1
Successful closed reduction	35	8	0	0	0
Failed closed reduction, total	32	13	1	3	1
Failed closed reduction and procedure abandoned	21	7	1	1	1
Re-dislocated	11	6	0	2	0

reduction developed grade I AVN, and two (18%) grade III. Of the remaining 21 hips whose procedure was abandoned and proceeded to open reduction, seven (33%) had grade 1 AVN, one (5%) had grade 2, one (5%) had grade 3, and one (5%) had grade 4.

In the total cohort of 67 hips which had failed Pavlik and proceeded to closed reduction, 26 (39%) developed radiological evidence of AVN (grade I in 21 hips (81%), grade II in one hip (4%), grade III in three (12%), and grade IV in one hip (4%)) (Table III).

The rate of clinically significant AVN (grade II and above) was 7% for the total cohort, 0% in the successfully reduced hips, 8% in the re-dislocated hips, and 14% in the hips that primarily failed closed reduction.

## Discussion

The success rate of closed reduction is variably reported in the literature. There is a paucity of literature specifically considering CR after failed Pavlik. Iqbal et al<sup>5</sup> reported a 20% success rate after failed Pavlik harness treatment in 102 hips over a 13-year period, although this was only published as an abstract. They suggested the low success rate was the result of an inability to address intrinsic and

extrinsic obstructing factors responsible for failure of the Pavlik. Our successful closed reduction rate is higher at 52% but considerably lower than the 80% reported by Galek-Aldridge et al,<sup>7</sup> although their cohort was small (15 patients over a six-year period) and the follow-up period short at one year. Senaran et al<sup>8</sup> also report a high success rate of 94% in 35 hips, and notably all their children underwent CR within three months of age, whereas ours had a median age of 181 days (118 to 362). Murray et al,<sup>1</sup> whose mean age at closed reduction was six months, quote a success rate of 69% in 26 children, although this study defines success as a stable reduction achieved at the time of CR in theatre. Additionally, as part of a larger cohort, Sankar et al<sup>3</sup> report two failed closed reductions in 29 children giving an initial success rate of 93%. However, it is uncertain how many in this group subsequently re-dislocated. The number of children with bilateral dislocations in our study may in part explain the average success rate. There were 13 children with bilateral dislocations, only three of whom had successful bilateral CRs. Tennant et al<sup>9</sup> conclude that bilateral dislocations are more likely to fail.

If studies are considered that include children undergoing CR with or without prior Pavlik re-dislocation, rates vary. Li et al<sup>10</sup> reported a re-dislocation rate of 23.5%, which is similar to ours of 24%, although their study is specific to children undergoing CR older than 24 months; DeRosa and Feller<sup>11</sup> report ten persistently unstable hips of 60 (16%) that had a CR, Tennant et al<sup>9</sup> 15% at 12 months, Sankar et al<sup>3</sup> 9%, Murray et al<sup>1</sup> 6%, and Senaran et al<sup>8</sup> 0%.

In our cohort of hips, the only significant differences identified prior to attempted closed reduction was Graf classification and time spent in Pavlik harness. Overall, the harness was abandoned earlier in the hips that went on to fail closed reduction, and this group had a higher ratio of Graf IV hips. Graf IV classification on initial USS has previously been evidenced as a predictor of failed closed reduction.<sup>12</sup>

On review of the arthrograms of the hips that re-dislocated in our study, five demonstrated a congruent hip, while six had either an inverted limbus or obstructing ligamentum teres. Of the 35 hips in the successful closed reduction group, 19 arthrograms were available for review. Two of these demonstrated an inverted limbus. Zhou et al<sup>13</sup> suggest that 80% of hips become concentric over time, that has not been our experience.

Success is sometimes also reported as a need for secondary surgery, defined in this study as subsequent femoral or pelvic procedures. Our rate of 14% compares favourably with the CR literature, in which rates are quoted between 5%<sup>11</sup> and 66%.<sup>14</sup> The low rate can be attributed to the early age at closed reduction, facilitating acetabular development.

AVN is a recognized complication of CR, with reported rates of between 2.6% and 60%.<sup>3,15</sup> Determination of AVN and literature comparison is challenging due to various treatment methods and AVN classification systems.<sup>16</sup> Bradley et al<sup>16</sup> performed a systematic review and determined the benchmark for clinically significant AVN to be 10% after five years follow-up in children treated before two years. Our clinically significant AVN rate of 7% (calculated by intention to treat) meets this benchmark.

It is important to note that in our series the clinically significant AVN rate for a hip that primarily failed CR and proceeded to open reduction was 15% whereas for the successful CR group was 0%. The overall AVN rate followed a similar trend (successful CR 23% vs open reduction 35%).

Interestingly, the hips that re-dislocated and proceeded to open reduction had a lower rate of AVN than those that initially failed CR. Hao-Che Tang et al<sup>17</sup> also noted this phenomenon and postulated that the CR could reduce soft tissue tension so reducing the AVN rate after open reduction.

This study has limitations. One is the absence of assessment for outcome of our patients at skeletal maturity. Proximal femoral growth disturbance, a possible sequela of AVN, may present late and cause morbidity.<sup>18</sup> The assessor for AVN was not blinded, and this may have introduced bias. Another limitation is that although the five consultants used a similar technique for closed reduction, variability in judgement regarding acceptable closed reduction on arthrogram images may exist. Despite these, this study represents the Northern Ireland experience with closed reduction and it is a large cohort of failed Pavlik harness hips.

In conclusion, despite a moderate success rate we continue to advocate closed reduction as a first line treatment for children who have failed Pavlik harness. A successful CR has a lower AVN rate than open reduction, and exhibits a satisfactory further surgery rate. However, we would advocate that only hips with a normal arthrogram combined with clinical stability proceed to hip spica.



### Take home message

- Closed reduction is a reasonable first line treatment for children who have failed Pavlik harness.
- A successful closed reduction has a lower avascular necrosis rate than open reduction and exhibits a satisfactory further surgery rate.
- Only hips with a normal arthrogram combined with clinical stability should proceed to hip spica.

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- A. Cosgrove: Collected the data, Edited the manuscript.
- E. Robinson: Collected the data, Performed the literature search, Wrote and edited the manuscript.

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