Treatment of Graf's Ultrasound Class III and IV Hips Using Pavlik's Method

Eli Peled MD, Viktor Bialik MD, Alexander Katzman MD,
Mark Eidelman MD, Doron Norman MD

Published online: 21 February 2008
© The Association of Bone and Joint Surgeons 2008

Abstract When Pavlik introduced his method of treating congenital dislocation of the hip, he emphasized reducing the rate of osteonecrosis. Graf's method of sonographic evaluation afforded earlier accurate diagnosis and subsequent treatment of developmental dysplasia of the hip. To ascertain whether treatment duration, gender, age at diagnosis, clinical stability, and/or treatment onset correlate with the risk of osteonecrosis in Graf Type III or IV hips, we clinically and sonographically screened 18,067 neonates (36,134 hips) for developmental dysplasia of the hip over a 4-year period; 151 had Graf Type III or IV hips, and 78 of these were treated by us and had known outcomes. Of these 78 hips, 65 (0.18%) had Graf Type III and 13 (0.036%) had Graf Type IV hips. Sixteen of the 65 Type III hips (25%) reduced spontaneously. Using Pavlik's method, reduction was achieved in 46 of 65 (88.5%) Type

III hips and eight of 13 Type IV hips. None of the hips treated exclusively by Pavlik's method developed osteonecrosis. Thus, the method achieves one of Pavlik's original goals of decreasing osteonecrosis incidence to close to zero.

Level of Evidence: Level II, prognostic study. See the Guidelines for Authors for a complete description of levels of evidence.

Introduction

Developmental dysplasia of the hip (DDH), formerly known as congenital dislocation of the hip, includes hip disorders that can be unstable clinically with acetabular misdevelopment with or without femoral head decentering [4]. The long-term morbidity of DDH is unclear, but it is associated with complications such as chronic pain and early osteoarthritis, gait abnormalities, and leg length discrepancy [11, 22]. Prolonged hip subluxation and dislocation may predispose to osteoarthritis in the adult, but there is no clear association between acetabular dysplasia without clinical instability and osteoarthritis [22]. It is well-known that prompt recognition and appropriate treatment reduce the risk of late morbidity of the hip [9]. Therefore, routine clinical screening for DDH in neonates and infants, originally instituted by Ortolani [13], Barlow [2], and Von Rosen [21], is commonly used today, enhanced by the more recent sonographic methods introduced mainly by Graf [7]. Graf's method identifies the exact anatomic structure of the hip and serves as a basis for treatment of DDH. It is now accepted that ultrasound is the most sensitive method for detecting hip disorders during the first weeks of life and until approximately 1 year of age, thus allowing assessment of hip development during

Each author certifies that he has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

Each author certifies that his institution has waived or does not require approval for the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.

E. Peled, D. Norman
Department of Orthopedic Surgery B, Rambam Health Care
Campus, Haifa, Israel

V. Bialik (✉), A. Katzman, M. Eidelman
Pediatric Orthopedics Unit, Rambam Health Care Campus, PO
Box 9602, Haifa 31096, Israel
e-mail: bialikv@hotmail.com

E. Peled, V. Bialik, A. Katzman, M. Eidelman, D. Norman
Bruce Rappaport Faculty of Medicine, Technion-Israel Institute
of Technology, Haifa, Israel

and after treatment. However, screening the neonatal hip using sonography combined with clinical examination may lead to overdiagnosis and overtreatment when not used properly [3].

Pavlik developed a functional method for treating DDH that is in wide use today [15]. His method emphasized a new conceptual approach that was both functional and provided a solution for the high rate of osteonecrosis after incorrect treatment of DDH in his time [14]. He used stirrups, which he defined as a tool to achieve the child's active movement of the dislocated or dysplastic hip, directing without force the femoral head into the acetabulum. Pavlik's method is successful in most children, especially those whose treatment is started before 6 months of age. According to MacEwen and Millet [9], the key to successful treatment of DDH is early initiation of treatment; early screening followed by correct early treatment results in hip reduction or healing. Pavlik's method, especially if used early, is effective and safe, even for more severe cases of DDH, reducing the incidence of osteonecrosis (ON) to nearly zero [19].

We describe our experience in the assessment of the relationships between gender, sonographic abnormality, age at diagnosis, and age at start of treatment with the rate of ON and healing and duration of treatment using Pavlik's method for Type III and IV hips according to Graf's classification. We focus on the question of whether this method results in a low rate of ON in infants with severe hip sonographic abnormality, ie, Graf's Type III and IV hips. We further asked whether gender, side of the DDH, or stability influenced timing and duration of treatment and whether any of these factors influenced the likelihood of developing ON.

Materials and Methods

From January 1, 1997, until December 31, 2000, we clinically and sonographically examined 18,067 neonates (36,134 hips) for disorders or diseases within the first 48 hours of life (Table 1). All patients were examined clinically by experienced neonatologists from our institute

with a pediatric orthopaedic surgeon (VB) performing the clinical examination followed by ultrasonography [21]. We included only babies who were born in our hospital and then diagnosed and treated by us. We excluded those babies who were first diagnosed with sonographic DDH during the first 48 hours of life but whom we did not follow. The clinical examination by the neonatologists was performed as described by Ortolani [13] and Barlow [2], and the sonographic examination was performed according to Graf's method using a 7.5-MHz transducer [8, 21]. The clinical examination by the pediatric orthopaedic surgeon was performed only when the sonographic investigation revealed hip abnormality. The hips included in the study belonged to all the neonates with sonographic hip abnormality rated Graf Type III and IV who were born and treated in our hospital until reaching normal. After the diagnosis was established, we postponed the onset of treatment according to the development of the hip but usually began between 4 and 6 weeks of age. In the case of spontaneous continuous improvement, the babies were thus spared from treatment. During the investigated periods, we diagnosed 151 hips with Graf Type III and IV DDH, 78 of which were treated by us (Table 1) and form the basis of the report. These 78 hips were found in 66 newborns (54 girls, 12 boys) (Table 2). Most of the treated hips were Type III in girls on the left side and were clinically unstable (Table 2). Sixty-five hips were Type III and 13 were Type IV. Twelve newborns had bilateral DDH; one girl had Type IV bilateral DDH, six newborns (three boys and three girls) had Type III DDH on one side and a Type IV contralateral hip, and five had bilateral Type III DDH. Three weeks later, 16 of the 78 Type III joints (21%) in 15

Table 2. Sonographic hip distribution

Hip	Female/Male	Right	Left	Stable	Unstable*
Type III	53/12	20	45	24	41
Type IV	10/3	4	9	4	9
Total	63/15	24	54	28	50

* Ortolani [13] and Barlow [2] positive.

Table 1. Incidence of sonographic pathology distribution per year

Year	Number of newborns (hips)	Type IIa/c (%)*	Type D (%)*	Type III/IV*	Affected hips* (incidence %)
1997	4640 (9280)	137/143 (1.48/1.54)	48 (0.52)	30/11 (0.32/0.12)	369 (3.98)
1998	4723 (9446)	145/134 (1.54/1.42)	47 (0.44)	21/7 (0.22/0.07)	354 (3.75)
1999	4411 (8822)	91/107 (1.03/1.21)	62 (0.70)	36/5 (0.41/0.06)	301 (3.41)
2000	4293 (8586)	100/116 (1.16/1.36)	51 (0.59)	37/4 (0.37/0.05)	308 (3.59)
Mean	18,067 (36,134)	1.30%/1.38%	0.44%	0.33%/0.08%	3.68%

* Number per year (incidence in percentages).

newborns (12 girls, including one with bilateral DDH, and four boys) had sonographically achieved Type I hips without any treatment. No patient was lost to followup. The minimum followup was 3 weeks (mean, 16.8 ± 14.1 weeks; range, 3–60 weeks).

All patients were treated exclusively according to Pavlik's method for 1.5 to 42 weeks (mean, 14.1 weeks).

We determined the presence or absence of ON as described by Tönnis [18] using anteroposterior radiographs of the pelvis.

We determined the likelihood of achieving a Graf Type I hip at followup. We then determined the risk of ON as related to gender, age at diagnosis, and treatment duration. We used the Mann-Whitney test to determine differences in risk as related to the three factors.

Results

None of these Graf Type III or IV hips demonstrated ON.

Type III DDH responded to Pavlik's method of treatment, reaching Type I in 46 of 48 (95.8%) hips. Two clinically unstable Type III hips in female patients underwent arthrography followed by closed reduction and spica casting under general anesthesia, the first at the age of 20 weeks and the second at the age of 42 weeks. The first of these two hips achieved successful reduction by closed reduction at 20 weeks followed by 6 weeks of casting. The second hip was not reduced after 42 weeks of Pavlik's treatment but achieved successful closed reduction and spica casting for 14 weeks.

Treatment duration was longer ($p = 0.16$) in boys, but we found no differences between the genders concerning age at start of treatment and its duration when comparing treatment with Pavlik's method and spontaneous reduction (Table 3). The time of treatment onset correlated ($r = 0.49$) with treatment duration with Pavlik's method in boys, but we observed no correlation in girls and spontaneously healed boys.

We observed no differences between the right and left sides in the treated group or in the spontaneously reduced joints concerning treatment duration and age of onset (Table 3). We did not find any differences ($p > 0.05$) in outcome between treatment and duration and between sides of the abnormality. Because no ON was found, the assessed parameters did not affect or cause ON.

Clinically unstable hips reached sonographic Type I spontaneously faster ($p < 0.05$) without any treatment than clinically stable joints (Table 3). On the other hand, stable joints needed a shorter treatment time ($p < 0.05$) than unstable joints. A correlation coefficient ($r = 0.41$) was found between age of onset of stable joint treatment and duration.

Table 3. Comparison of Pavlik's method and spontaneous reduction to gender, side, and stability*

Variable	Female/Male		Right/Left		Stable/Unstable	
	Pavlik's method	Spontaneous	Pavlik's method	Spontaneous	Pavlik's method	Spontaneous
Treatment type						
Number of hips	40/8	13/4	15/33	5/12	17/31	7/10
Treatment onset [†] (range)	$5.1 \pm 3.2/3.9 \pm 3.2$ (1.5–13)/(2–9)	No treatment needed	$4.9 \pm 2.1/5 \pm 3.6$ (2.5–9)/(1.5–13)	No treatment needed	$5.1 \pm 3/4.9 \pm 3.3$ (1.5–11)/(1.5–13)	No treatment needed
Treatment duration [†] (range)	$15.2 \pm 11/16.1 \pm 17.7$ (3–56)/(7–56)	$8.33 \pm 2.3/9 \pm 1$ (5–10)/(8–10)	$14.4 \pm 9.1/14.8 \pm 13.1$ (3–30)/(3–56)	$9.7 \pm 0.6/8.1 \pm 2$ (9–10)/(5–10)	12.9 ± 8.5 (3–30)/(3–56)	$9.6 \pm 0.9/7.3 \pm 2.1$ (8–10)/(5–9)
Reduced joints	38/8	13/4	15/31	5/12	17/29	7/10
p value	Female > 0.05	Female > 0.05	Right > 0.05	Right > 0.05	Stable > 0.05	Unstable < 0.05

* Rate of osteonecrosis = 0; [†]time in weeks.

Table 4. Type IV developmental dysplasia of the hip distribution and details

Variable	Harness reduction	Failed harness reduction
Number of joints	8	5
Treatment onset (weeks)*	6.4 ± 3.1 (2.5–15)	8.1 ± 11.7 (1.5–29)
Treatment duration (weeks)*	13.9 ± 7.2 (8–29)	32.7 ± 11.5 (26–46)

* Mean ± standard deviation (range).

Pavlik's method of treatment reached sonographic Type I and clinically stable joints in eight of 13 hips with Type IV DDH joints. Five were treated by closed reduction after arthrography under general anesthesia followed by plaster spica casting. Three of these did not respond and underwent open reduction. Type IV DDH hips were found in 10 girls and three boys (four on the right side and nine on the left); four joints were stable and nine were unstable. Treatment onset age in the joints reduced by Pavlik's method was younger ($p > 0.05$) than hips that did not respond to this method of treatment. Treatment duration for reduction of Type IV hips was similar to Type III. No further statistical evaluations were performed because of the small numbers of joints. Pavlik's method of treatment achieved hip reduction in 71 of 78 (91%) joints in this cohort, and no ON was demonstrated (Tables 3, 4).

Discussion

Pavlik's method of treating DDH was intended in part to reduce the rate of osteonecrosis. Graf's method of sonographic evaluation afforded earlier accurate diagnosis and assessment of severity of DDH. However, the literature does not state of how Graf Types III and IV hips respond to treatment using Pavlik's method and whether these hips have a reduced risk of ON. We therefore asked whether there were any relationships between sonographic abnormality, age at diagnosis, and age at start of treatment with the rate of ON and healing and duration of treatment using Pavlik's method for these hips. We questioned whether this method results in a low rate of ON in infants with severe hip sonographic abnormality, ie, Graf Type III and IV hips. We further explore the relationships of the likelihood of achieving a normal hip and gender, side of the DDH, stability, timing of treatment outcome, and its duration.

The major limitation of this study is it is a retrospective study with some missing data. We did not have data, for example, on all of the 151 hips we screened and found Graf Type III and IV hips, and rather only the 78 we treated. The numbers (especially for Type IV hips) were limited and therefore we could perform limited statistical analyses.

Our main aim was to assess ON using Pavlik's method among severe DDH Type III and IV hips. Sonographic examination of the newborn hip is a highly sensitive method of detecting abnormalities; it is sometimes considered too sensitive, especially for neonates, because it can lead to overdiagnosis [3]. On the other hand, early diagnosis and treatment are generally accepted as the keys for a successful outcome [6, 9, 16].

It is important when assessing the success rates of treating DDH using Pavlik's method to ascertain ON rates. Mostert et al. [12] treated 41 dislocated hips with Pavlik's method (29 Type III and 12 Type IV). The treatment was successful in relocating 97% Type III and 50% Type IV joints. Ucar et al. [19] treated 22 Type IIc DDH or more severe hips by Pavlik's method and reported a 95.4% success rate and two cases of ON. Atalar et al. [1] treated 31 Type IIc or more severe hips, of which 18 (58%) were reduced successfully and were related to Graf type and age at treatment onset. However, there was no relationship to gender and the side of the affected hip, similar to our findings, but for smaller cohorts. Age at treatment onset correlated with treatment duration only in male infants, but not with side of the affected hip. No ON was detected in this cohort. Approximately 10 years ago, Malkawi [10] reported a 100% success rate with 0% ON when he used Pavlik's method and sonographically followed 699 hips in 547 infants. The high success rate might have been a result of early treatment onset; most of the joints were treated at approximately 6 weeks of age, which might affect the reduction rate. Using Pavlik's method, patients up to 6 months of age have a higher success rate, as described also by Vitale and Skaggs [20]. Our group found unstable hips needed a shorter treatment period [5]. The incidence of Type III and IV hips in our cohort was 0.41%, similar to that described in our other publications. Toma et al. [17] reported their results of sonographic screening for DDH incidence as 4.7%, of which 3.36% were Type IIa; their screening was performed on children younger than 4 months of age.

Pavlik's method for treating DDH is the first and usual choice of treatment for DDH, especially for children younger than 3 months of age, mainly because of the close to zero rates of ON, its efficiency, and its simplicity. The method is based on a simple concept that the activity of the babies reduces the hip [14]. In our experience, some Type III joints can be reduced spontaneously. None of the Type IV hips reduced spontaneously and all underwent treatment, but the group was too small for further evaluation. The treatment period in male children was a little longer than in female children. Clinically stable joints needed a shorter treatment time compared with unstable joints. No ON was found in the hips treated in this cohort. The side of the hip and its stability did not influence treatment. Starting

treatment early in severe cases might yield a high rate of success, as seen in this cohort. Our data suggest Pavlik's method is a safe treatment option, avoiding ON even for severe DDH Graf Type III and IV hips.

Acknowledgments We thank Mrs. Myrna Perlmutter for her help in the preparation of this manuscript. We also are very grateful to the medical staff of the Neonatal Unit who performed all the routine clinical examinations.

References

- Atalar H, Sayli U, Yavuz OY, Uras I, Dogruel H. Indicators of successful use of the Pavlik harness in infants with developmental dysplasia of the hip. *Int Orthop*. 2007;31:145–150.
- Barlow TG. Early diagnosis and treatment of congenital dislocation of the hip. *Proc R Soc Med*. 1963;56:804–806.
- Bialik V, Bialik GM, Blazer S, Sujov P, Wiener F, Berant M. Developmental dysplasia of the hip: a new approach to incidence. *Pediatrics*. 1999;103:93–99.
- Committee on Quality Improvement, American Academy of Pediatrics. Clinical practice guidelines: early detection of developmental dysplasia of the hip. *Pediatrics*. 2000;105:896–905.
- Eidelman M, Katzman A, Freiman S, Peled E, Bialik V. Treatment of true developmental dysplasia of the hip using Pavlik's method. *J Pediatr Orthop B*. 2003;12:253–258.
- Felus J, Kowalczyk B. Clinically silent developmental hip dysplasia—significance of the hip ultrasonographic examination [in Polish]. *Chir Narzadow Ruchu Ortop Pol*. 2005;70:397–400.
- Graf R. *Guide to Sonography of the Infant Hip*. Stuttgart, Germany: Thieme Medical; 1987:1–114.
- Graf R, Tschauer C, Klapsch W. Progress in prevention of late developmental dislocation of the hip by sonographic newborn hip screening: results of a comparative follow-up study. *J Pediatr Orthop*. 1988;8:12–16.
- MacEwen GD, Millet C. Congenital dislocation of the hip. *Pediatr Rev*. 1990;11:249–252.
- Malkawi H. Sonographic monitoring of the treatment of developmental distribution of the hip by the Pavlik harness. *J Pediatr Orthop B*. 1998;7:144–149.
- Moony JF, Emans JB. Developmental dislocation of the hip: a clinical overview. *Pediatr Rev*. 1995;16:299–303.
- Mostert AK, Tulp NJ, Castelein RM. Results of Pavlik harness treatment for neonatal hip dislocation as related to Graf's sonographic classification. *J Pediatr Orthop*. 2000;20:306–310.
- Ortolani M. Congenital hip dysplasia in the light of early and very early diagnosis. *Clin Orthop Relat Res*. 1976;119:6–10.
- Pavlik A. Stirrups as an aid in the treatment of congenital dysplasias of the hip in children. *J Pediatr Orthop*. 1989;9:157–159.
- Pavlik A. The functional method of treatment using a harness with stirrups as a primary method of conservative therapy for infants with congenital dislocation of the hip: 1957. *Clin Orthop Relat Res*. 1992;281:4–10.
- Smergel E, Losik SB, Rosenberg HK. Sonography of hip dysplasia. *Ultrasound Q*. 2004;20:201–216.
- Toma P, Valle M, Rossi U, Brunenghi GM. Paediatric hip—ultrasound screening for developmental dysplasia of the hip: a review. *Eur J Ultrasound*. 2001;14:45–55.
- Tönnis D. An evaluation of conservative and operative methods in the treatment of congenital hip dislocation. *Clin Orthop Relat Res*. 1976;119:76–88.
- Ucar DH, Isiklar ZU, Kandemir U, Tumer Y. Treatment of developmental dysplasia of the hip with Pavlik harness: prospective study in Graf type IIc or more severe hips. *J Pediatr Orthop B*. 2004;13:70–74.
- Vitale MG, Skaggs DL. Developmental dysplasia of the hip from six months to four years of age. *J Am Acad Orthop Surg*. 2001;9:401–411.
- Von Rosen S. Diagnosis and treatment of congenital dislocation of the hip joint in the new-born. *J Bone Joint Surg Br*. 1962;44:284–291.
- Weinstein SL. Developmental hip dysplasia, dislocation. In: Morrissy RT, Weinstein SL, eds. *Lovell and Winter's Pediatric Orthopaedics*. 4th ed. Philadelphia, PA: Lippincott-Raven; 1996:903–943.