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Dynamic ultrasonography in developmental dysplasia of the hip treated with Pavlik harness

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= **Abstract** =

To evaluate the usefulness of dynamic ultrasonography in documenting treatment efficacy and expecting prognosis in developmental dysplasia of the hip (DDH), 49 DDH hips in 32 patients, who had serial dynamic ultrasonographic examinations by Harcke's method during Pavlik harness treatment, were studied as for the progression of ultrasound findings. Graf's alpha and beta angle were measured in coronal flexion view of dynamic ultrasonography. Among 49 hips, on follow-up radiographs, 44 hips showed normal hip development and 5 hips showed dysplasia. In 44 normal hips, 43 hips had alpha angle of more than 50 degrees and stability on dynamic sonogram at the time of weaning of harness. In contrast, all five hips with residual dysplasia exhibited instability on dynamic stress with comparable alpha angle to that of normal hips. This finding suggests that when the hip matures beyond "delayed ossification"(alpha angle more than 50 degrees) with stability on dynamic sonogram, normal hip development can be expected. But if the hip is continuously unstable, regardless of alpha angle, there can be a possibility of residual dysplasia.

Key Words : DDH-Residual dysplasia-Dynamic ultrasonography-Pavlik harness

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INTRODUCTION

There ar two basic philosophies of hip ultrasound. Graf's static and Harcke's dynamic ultrasonography. Graf's method emphasizes the development of acetabular morphology, measuring the bony roof(alpha) angle and cartilage roof(beta) angle. In contrast, Harcke's dynamic method places greater emphasis on the position and the stability of the hip joint[1,2,8]. In the treatment of DDH, there are three phases, reduction, stabilization and residual dysplasia phase. This study is retrospective analysis of patients with developmental dysplasia of the hip(DDH) treated with Pavlik harness and monitored using dynamic ultrasound. The purpose of this study is not to evaluate hip reduction by harness, but to find out the progression of ultrasound findings after reduction phase, mainly focused on the stabilization and residual dysplasia phase.

MATERIALS AND METHODS

Our protocol of dynamic sonography was similar to that of Harcke's ; transverse neutral view, transverse flexion view with abduction and adduction stress, coronal flexion view and coronal flexion posterior view with push and pull stress[1]. In contrast, only coronal neutral view is taken in Graf's static sonography, and alpha and beta angle are measured in this view. Originally, in dynamic sonogram, emphasizing the stability, Harcke did not make any angle or distance measurement. However, authors tried to measure the Graf's alpha and beta angle in coronal flexion view of dynamic sonogram and thereby could classify the hip according to the Graf's criteria(Dr. Harcke totally agreed to this approach in personnal communication). In addition, dynamic stability of the hip joint was assessed according to Harcke's method in every sonogram and again grouped the hip into normal(stable), lax on stress, subluxated, dislocatable or dislocated hip according to Harcke's criteria(Table 1). Pre-Pavlik sonogram was taken every week until the hip was reduced and stabilized. Otherwise sonogram was performed every 3 week interval and at the time of weaning of harness. Finally, most recent follow-up radiograph of each patient was analysed blindly from the previous ultrasonographic findings and classified into two groups, hips showing normal development(normal group) and showing residual dysplasia(dysplastic group). Two criteria were used for this grouping, acetabular index and superolateral acetabular rim defect which was clearly described by Tonnis. The hip was defined as "residual dysplasia" when acetabular index was abnormally high beyond two standard deviation or when there was a demonstrable superolateral acetabular rim defect on the follwo-up radiographs. The author reviewed 175 DDH patients who were treated with pavlik harness and followed up with serial dynamic ultrasound examinations during the harness application, for the last two years(from June 1990 to August 1992) at the Children's Hospital, San Diego. Inclusion criteria of this study were : prop-

Table 1. Classification of hip by dynamic ultrasonographic findings(Harcke, 1989)

Hip type / View	Normal (Stable)	Lax on stress	Subluxated	Dislocated or dislocatable
Trn-Neut	N	N	Abn	Abn
Trn-Flex	N	N(A)*	A(N)*	Abn
Crn-Flex	N	N	Abn	Abn
Crn-Flex-Post	N	N(A)**	Abn	Abn

Four cardinal views of dynamic ultrasonography
Trn-Neut : Transverse neutal view
Trn-Flex : Transverse flexion view
Crn Flex : Coronal flexion view
Crn-Flex-Post : Coronal flexion posterior view
N : Normal
Abn : Abnorml
N(A)* : Normal, but become abnormal with abduction maneuver
A(N)* : Abnormal, but become normal with abduction maneuver
N(A)** : Normal, but become abnormal with push maneuver

er fitting of the harness and good compliance ; minimum of two ultrasound examinations done at the begining and at the time of weaning of harness ; successful reduction with Pavlik harness ; hips graded as Type 2C with laxity on stress, all Type 2D, 3A, 3B, and Type 4 hips by Graf's angle measurement, and any subluxated, dislocatable or dislocated hips by Harcke's classification ; radiographic follow-up after the weaning of harness.

A total of 49 hips in 32 patients met these criteria(bilateral involvement in 17 patients, right hip in 4 patients, left hip in 11 patients). There were 4 boys and 28 girls. As for the age distribution, 21 patients(66%) were less than 1 month, 9 patients(28%) were 1-3 months, and 2 patients(6%) were more than 3 months of age at the beginning of Pavlik treatment. Ultrasound machine was Ultramark 4, 25mHz(from Ultrasound system, Adv. Tech. Lab.). The average duration of full time Pavlik application was 3.6 months, ranging from 2.5 to 7 months. The final follow-up radiographs (pelvis AP) were taken after the weaning of harness at average 12.3 months of age.

RESULTS

1. Progression of ultrasound findings

At the begining of Pavlik harness treatment, Graf hip types were as follows ; 16 hips(33%) were Type 2C, 7 hips(14%) Type 2D, 7 hips(14%) Type 3A, 14 hips(29%) Type 3B, and 5 Hips(10%) Type 4. As for dynamic findings, in 16 Type 2C hips, 15 hips were lax on stress and 1 hip was subluxated. In 7 Type 2D hips, 5 hips were lax and 2 hips were subluxated. In 7 Type 3A hips. 1 hip was lax and 6 hips subluxated. In 14 Type 3B hips, 1 hip was lax, 1 hip was subluxated and 12 hips were dilslocated. In 5 Type 4 hips, all hips were dislocated.

At the time of weaning of harness, 9 hips(19%) were Graf Type 1(normal hip development) and all these hips were stable on dynamic stress. Two hips(6%) were Type 2A(-)(All stable), 37 hips(73%) were Type 2B(31hips stable, 6 hips lax on stress), and 1 hip was Type 2C(stable)(Table 2).

Table 2. Ultrasonographic findings of 49 DDH hips treated with Palvik harness

Stage of hip Development(Graf)	Graf hip type	Start of Treatment		End of Treatment		Follow-up X-ray	
		Graf hip type	Harcke hip type	Graf hip type	Harcke hip type	Normal group	Residual dysplasia group
Normal Maturity	1			9	9-stable	9	
Physiologic immaturity	2A(+)						
Delayed ossification (before 3 months)	2A(-)			2	2-stable	2	
Delayed ossification (after 3 months)	2B			37	31-stable 6-Lax	32	5
Severe dysplasia	2C	16	15-Lax 1-Sublux.	1	1-stable	1	
Decentering hip	2D	7	5-Lax 2-Sublux.				
Dislocation	3A	7	1-Lax 6-Sublux.				
	3B	14	1-Lax 1-Sublux. 12-Disloc.				
	4	5	5-Disloc.				
Total No. of Hips		49	49	49	49	44	5

Lax : Lax on stress Sublux. : Subluxated Disloc. : Dislocated or Dislocatable

2. Follow-up radiographic findings after wean-ing.

After the weaning of the Pavlik harness, among 49 hips, 44 hips(90%) showed normal hip development(normal group) on follow-up radiographs, and 5 hips showed residual dysplasia. In all five dysplastic hips, harness treatment was started before the age of 8 weeks, and initial sonographic findings were 2C lax, 2C subluxated, 2D subluxated, and two 3B subluxated hips, respectively.

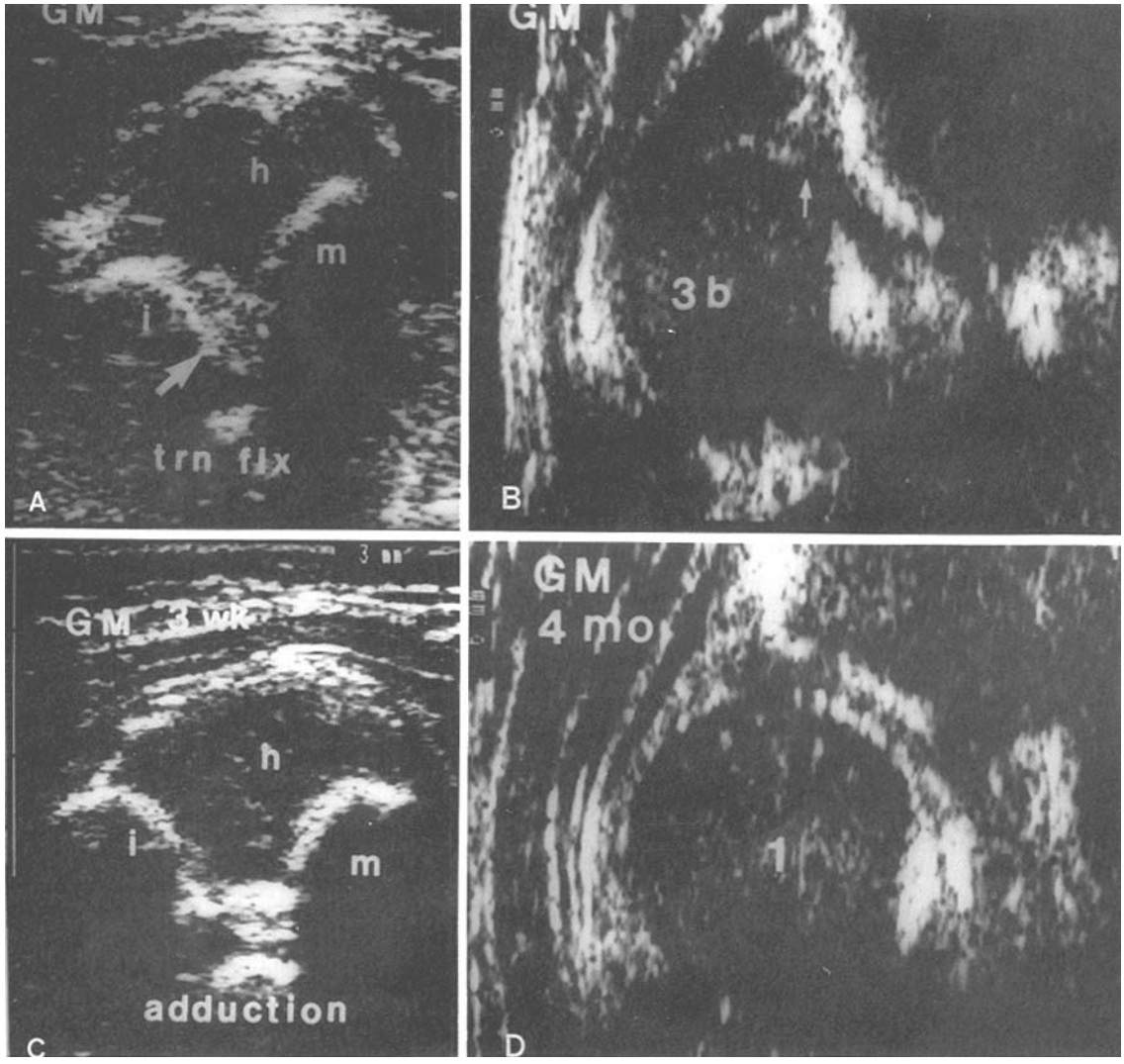

Fig. 1. Case showing successful treatment with Pavlik harness followed up by dynamic ultrasonogram.

A. Transverse flexion view of 6 weeks old female shows the dislocation of the femoral head with the echoes(arrow) between femoral head and acetabulum.

B. Coronal flexion view shows displacement of the femoral head. Bony roof contour of this hip is poor and cartilagenous roof is displaced and echogenic(arrow). Graf's angle was measured and was Type 3B.

C. After 3weeks of Pavlik harness application, the hip became stable even with adduction stress on transverse flexion view.

D. Four months after the application of Pavlik harness, on coronal flexion view, the bony roof contour is good and cartilagenous roof became narrow and covers the head wall(h ; femoral head, i ; ischium, m ; metaphysis of proximal femur)

3. Comparison of weaning sonographic findings between normal and dysplastic group.

Hip types of normal group at the time of weaning were ; 9 hips were Type 1, 34 hips were Type 2A(-) or 2B(delayed hip development), and 1 hip was Type 2C. In dysplastic group, all five hips were Type 2B. Therefore, in normal group, 43 out of 44 hips(98%) had an alpha angle of more than 50 degrees, and in dysplastic group, all five hips likewise had alpha angle of more than 50 degrees, which meant no significant difference between two groups in terms of an alpha angle or bony acetabular development.

Dynamic sonographic findings of 44 hips of normal group at the time of weaning of harness were ; 43 hips were stable and 1 hip was lax on stress(Fig. 1). In contrast, in dysplastic group all five hips showed laxity on stress.

Therefore, as for the stability of the hip after Pavlik treatment, in normal group 98% were stable hip compared with dysplastic group in which all five hips were unstable even with prolonged Pavlik harness treatment.

DISCUSSION

After the application of the Pavlik harness, concentric reduction and stability should be clearly demonstrated because, by persistent instability, it frequently fails to assure normal development of the hip presumed to be reduced. The usefulness of roentgenogram for these assessment is debatable and clinical examination has been emphasized to supplement the pitfalls of roentgenograms[3].

However, there is still a chance of so-called surreptitious reduction, that is, fixed posterior dislocation[9]. Computed tomography can be used to confirm the reduction, with its drawbacks of radiation and need for general anesthesia in infants. In this regards, ultrasonography is the most accurate and easiest means in evaluating the concentricity and stability, and therefore is an ideal means of assessing efficacy of reduction and stabilization phase[5,8]. There are several reports of residual dysplasia in long term follow-up after the completion of Pavlik treatment[3,7]. In this study, we tried to find out which parameter was most likely to contribute to this dysplastic development after Pavlik treatment by analysing the dynamic ultrasonographic findings sequentially.

Graf first used the ultrasound in-depth to detect the hip dysplasia in infant by the morphological assessment of the acetabular development. For this, he proposed to measure the alpha and beta angle using clearly defined three landmarks in coronal neutral view, those are ; superior bony rim, lower iliac margin, and labrum(Static sonography)[8]. In contrast, Harcke emphasized theimportance of the stability of the hip joint and the relationship between the acetabulum and the femoral head in the normal development of maturing hip[1,2].

At the time of ultrasound, the position and the stability of the femoral head are assessed with the stress applied and a minimum of four previously mentioned images are usually recorded. By these findings, each hip is classified into four categories as shown in Table 2(Dynamic sonography). Each method has its own critics and advocates. The critics of Graf's morphological techniques are its questionable accuracy of measurements and reproducibility while that of dynamic method is that it is more prone to subjectivity by the examiner.

Authors used the coronal flexion view with three clear landmarks, instead of coronal neutral view of Graf, to measure the alpha and beta angle because hip flexion does not make any difference in the acetabular bony and cartilaginous morphology.

In this study, we included hips with sonographic findings equal or worse than Type 2C with laxity on stress, that is, any Type 2D, 3A, 3B, and Type 4 hips by Graf typing and any subluxated dislocat-

able or dislocated hips by Harcke criteria, which we thought the proper sonographic indications of Pavlik application. With the Pavlik treatment, there was a marked improvement in the ultrasound findings in our study. The pathological significance of these improvement is that 23 hips with severe dysplasia or subluxation and 26 dislocated hips before Pavlik treatment improved to 9 normal hips, 39 delayed ossification hips and 1 dysplastic hip after completion of Pavlik treatment.

Duration of Pavlik harness treatment is usually 3 to 4 weeks after the stability is achieved[4] and ultrasonography can be a most satisfactory method assessing stability during harness treatment. In our series all the reduced hips became stabilized during Pavlik treatment except 6 hips among which 5 hips were dysplastic on follow-up radiographs.

The difference of weaning sonographic findings between normal and dysplastic group was not so remarkable by Graf's acetabular angle measurement, which is an index of bony acetabular development, because almost all the hips matured beyond delayed ossification range with the alpha angle more than 50 degrees in both groups. As for the beta angle, though Malkawi thought the beta angle is more accurate reflection of the hip pathology in the newborn[6], it seemed to be consistently decreased with the alpha angle improvement to provide secure cartilage roof coverage and was not so much different between two groups like alpha angle in our study. The most marked difference between two groups was dynamic assessment. In the dysplastic group, all five hips were unstable on stress even with prolonged Pavlik application.

CONCLUSION

Authors proposed to use the dynamic ultrasonography in order to effectively monitor the Pavlik harness treatment of DDH, and found that when the acetabulum matures beyond the certain range of ossification(in this study, delayed ossification with alpha angle more than 50 degrees by the measurement in coronal flexion view), then persistent sonographic instability on dynamic stress seemed to be the most important parameter in expecting residual dysplasia after the weaning of Pavlik harness.

REFERENCE

1) **Harcke HT and Grissom LE :** Performing dynamic sonography of the infant hip. *Am J Radiology*, 155 : 837-844, 1990.
2) **Harcke HT and Kurmar SJ :** Current concepts review ; The role of ultrasound in the diagnosis and management of congenital dislocation and dysplasia of the hip. *J Bone Joint Surg*, 73-A : 622-628, 1991.
3) **Harris IE, Dickens RD and Menelaus MB :** Use of the Pavlik harness for hip displacements. *Clin Orthop*, 281 : 29-33, 1992.
4) **Herring JA :** Conservative treatment of congenital dislocation of th hip in the newborn and infant. *Clin Orthop*, 281 : 41-47, 1992.
5) **Jones GT, Schoenecker PL and Luciano SD :** Developmental hip dysplasia potentiated by inappropriate use of the Pavlik harness. *J Ped Orthop*, 12 : 722-726, 1992.
6) **Malkawi H., Asir B., Tadros F and Khasawneh Z :** Sonographic image of the newborn with positive Ortolanti's sign. *Clin Orthop*, 279 : 138-142, 1992.
7) **Tucci JJ, Kumar SJ, Guille JT and Rubbo ER :** Late acetabular dysplasia following early successful Pavlik harness treatment of congenital dislocation of the hip. *J Ped Orthop*, 11 : 502-505, 1991.
8) **Tonnis D :** Contenital dysplasia and dislocation of the hip. pp. 172-229. Springer-Verlag, Berlin-Heidelberg, 1987.
9) **Viere RG, Birch JG, Herring JA, Roach JW and Johnston CE :** Use of the Pavlik harness in congenital dislocation of the hip. *J Bone Joint Surg*, 72-A : 238-244, 1990.

= 국문 초록 =

고관절 이형성증에서 Dynamic ultrasonography를 이용한 Pavlik보장구치료의 추시

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고관절 이형성증의 진단과 치료에 있어 유용하게 사용되고 있는 초음파 검사는 비구개의 발달을 중요시하여 초음파 상의 비구개의 alpha각과 beta각을 측정하여 비구개의 상태를 평가하는 Graf의 방법(static ultrasonography)과 고관절의 안정성을 더욱 중요시하여 여러가지 stress를 가하면서 대퇴골두와 비구의 상호 위치 관계를 통하여 고관절의 안정성을 알아보는 Harcke의 방법(Dynamic ultrasonography)의 두 가지가 있다.

저자들은 Pavlik보장구로 치료하면서 Dynamic ultrasonogram으로 추시가 가능하였던 32명의 고관절 이형성증 환자의 49 고관절을 Pavlik보장구 치료가 끝난 후의 방사선 소견에 따라 정상군과 이형성군의 두군으로 나누고 각군의 초음파 소견의 비교를 통하여 초음파 소견의 어느 요소가 Pavlik보장구 치료가 끝난 후에도 이형성증이 좋아지지 않고 계속되는 것과 관계가 있는지를 알아보았다. Dynamic sonogram의 coronal flexion ivew에서 Graf의 비구의 각도를 측정하였으며 이때 측정한 alpha각이 50도 이상이고 Dynamic sonogram에서 고관절의 안정성이 있으면 고관절의 정상정인 발육을 기대할 수 있으며, 고관절의 안정성이 없으면 alpha각의 호전 여부와 관계없이 이형성증의 가능성이 있으므로 주의를 기울여야 한다.