15. JAFFE, H. L.: Metabolic, Degenerative, and Inflammatory Diseases of Bones and Joints, pp. 240-271. Philadelphia, Lea and Febiger, 1972.
16. KASABACH, H. H., and DYKE, C. G.: Osteoporosis Circumscripta of the Skull as a Form of Osteitis Deformans. Am. J. Roentgenol., **28:** 192-203, 1932.
17. KASABACH, H. H., and GUTMAN, A. B.: Osteoporosis Circumscripta of the Skull and Paget's Disease. Fifteen New Cases and a Review of the Literature. Am. J. Roentgenol., **37:** 577-602, 1937.
18. MCKENNA, R. J.; SCHWINN, C. P.; SOONG, K. Y.; and HIGINBOTHAM, N. L.: Osteogenic Sarcoma Arising in Paget's Disease. Cancer, **17:** 42-66, 1964.
19. MILLER, A. S.; CUTTINO, C. L.; ELZAY, R. P.; LEVY, W. M.; and HARWICK, R. D.: Giant Cell Tumor of the Jaws Associated with Paget Disease of Bone. Report of Two Cases and Review of the Literature. Arch. Otolaryngol., **100:** 233-236, 1974.
20. MURRAY, R. O., and JACOBSON, H. G.: The Radiology of Skeletal Disorders: Exercises in Diagnosis. Edinburgh and London, Churchill Livingstone, 1971.
21. PAGET, JAMES: On a Form of Chronic Inflammation of Bones (Osteitis Deformans). Med.-Chir. Trans., **60:** 37-63, 1877.
22. PORRETTA, C. A.; DAHLIN, D. C.; and JANES, J. M.: Sarcoma in Paget's Disease of Bone. J. Bone and Joint Surg., **39-A:** 1314-1329, Dec. 1957.
23. PRICE, C. H. G., and GOLDIE, W.: Paget's Sarcoma of Bone. A Study of Eighty Cases from the Bristol and the Leeds Bone Tumour Registries. J. Bone and Joint Surg., **51-B:** 205-224, May 1969.
24. REIFENSTEIN, E. C., JR., and ALBRIGHT, FULLER: Paget's Disease: Its Pathologic Physiology and the Importance of This in the Complications Arising from Fracture and Immobilization. New England J. Med., **231:** 343-355, 1944.
25. SCHATZKI, S. C., and DUDLEY, H. R.: Bone Sarcoma Complicating Paget's Disease. A Report of 3 Cases with Long Survival. Cancer, **14:** 517-523, 1961.
26. SCULLY, R. E., and MCNEELY, B. U.: Case Records of the Massachusetts General Hospital, Case 16-1975. New England J. Med., **292:** 908-913, 1975.
27. SCURR, J. A.: Myeloma Occurring in Paget's Disease. Proc. Roy. Soc. Med., **65:** 725, 1972.
28. SEAMAN, W. B.: The Roentgen Appearance of Early Paget's Disease. Am. J. Roentgenol., **66:** 587-594, 1951.

Congenital Dislocation of the Hip

USE OF THE PAVLIK HARNESS IN THE CHILD DURING THE FIRST SIX MONTHS OF LIFE

BY PAUL L. RAMSEY, M.D.*, STEPHEN LASSER, M.D.†, AND G. DEAN MACEWEN, M.D.‡, WILMINGTON, DELAWARE

From the Alfred I. duPont Institute, Wilmington

ABSTRACT: **From 1968 to 1972, twenty-three infants under six months old with twenty-seven dislocated hips were treated with a Pavlik harness. All the dislocations except three were successfully reduced. Only one child required hospitalization. All the patients were followed for more than two years. All but three of the hips were clinically and roentgenographically normal at follow-up, and none had avascular necrosis. In infants, the Pavlik harness successfully utilizes the principle of reduction in flexion, avoiding forced abduction.**

A congenital dislocation of the hip that persists beyond the newborn period rapidly shows signs of secondary changes in the soft tissues and bone which can lead to a protracted and difficult course of treatment. There is then an increased risk of incomplete reduction, poor development of the acetabulum or femoral head, and avascular necrosis. Persistent dislocation of the hip can be attributed to failure of detection, failure to administer treatment, or failure of the treatment method. Since detection and treatment in the newborn nursery can greatly reduce these problems, we began a routine nursery examination of all newborn babies. All newborns with dislocated hips detected at the nursery evaluation and all infants under six months old who had the abnormality and were referred to our clinic from outside the community were treated with the Pavlik harness [10].

* 1431 North Madison Avenue, Anderson, Indiana 46012.
† Hospital for Joint Diseases, 1919 Madison Avenue, New York, N.Y. 10035.
‡ Alfred I. duPont Institute, P.O. Box 269, Wilmington, Delaware 19899.

Material

All the infants in this study were under six months old. All had frank dislocation of one or both hips, and none had been treated prior to evaluation at the Alfred I. duPont Institute. The study period was from 1968 to 1972. The diagnosis was established by clinical and roentgenographic criteria consistent with a dislocated hip. Clinically a dislocation was established by a positive Ortolani sign [8] which was usually present in those under eight to twelve weeks old. In the older infants, the sign tended to disappear but limited abduction or a foreshortened thigh segment were evidence for a dislocation, which then had to be confirmed roentgenographically. Roentgenograms of newborns were of little diagnostic benefit, but in the infants a few months old the typical signs of lateral and cephalic displacement of the proximal end of the femur with an interrupted Shenton's line and false acetabulum were apparent. A hip in which the femoral head was seated in the acetabulum but could be completely displaced was designated as dislocatable, and one in which the femoral head could be partially displaced, subluxatable. We

FIG. 1-A

FIG. 1-B

Fig. 1-A: Anterior view of the Pavlik harness with straps properly adjusted to flex hips more than 90 degrees but allow for further flexion. Note the spontaneous abduction of the hips.

Fig. 1-B: Posterior view demonstrating slack in the posterior straps to avoid forced abduction.

excluded both these categories of hips as well as those with teratologic dislocations secondary to arthrogryposis, myelodysplasia, or other neuromuscular abnormalities.

There were twenty-three patients with twenty-seven dislocations. Nineteen of the infants were girls and four were boys. The left hip was dislocated in fourteen patients and the right hip, in five. Four patients had bilateral dislocation. Seven infants had been delivered by breech presentation. At the time of treatment, eleven patients (with thirteen involved hips) were under one month old; six (with seven involved hips), one to three months old; and six (with seven involved hips), three to six months old.

Method

All infants were treated with the Pavlik harness (Figs. 1-A and 1-B). This device consists of an adjustable circumferential abdominal band with posterior crossed shoulder straps and leg stirrups. It is composed of canvas webbing, felt, Velcro fasteners, and metal buckles.

The Pavlik harness utilizes the principle of flexion with free abduction to achieve reduction. Prior to its application, a roentgenogram was made with flexion of the hip of more than 90 degrees. When the roentgenogram showed the proximal end of the femur or the femoral head directed towards the triradiate cartilage, we considered it possible to achieve reduction. Failure to achieve redirection towards or below the triradiate cartilage in flexion was a contraindication to use of the harness because the chances of continued dislocation were good. The error of inadequate flexion is shown in Figures 2-B and 2-C. After the child was first placed in the harness, roentgenograms were made routinely to ensure correctness of position.

The harness was applied with the hips at 90 degrees of flexion or more (Figs. 2-A, 2-B, and 2-C), but always short of full forced flexion (Figs. 1-A and 1-B). It was essential that the posterior harness strap not be tight, but that the hips be allowed to fall freely into abduction by only the weight of the legs. To guard against forced abduction, the straps were lax enough for the knees to come within three to five centimeters of the midline.

FIG. 2-A

Ten-week-old infant with bilateral congenital dislocation (L. P.).

FIG. 2-B

Inadequate flexion allows persistent dislocation of the left hip.

FIG. 2-C

During the same clinic visit, increased flexion permits reduction. Normal hips were evident when the infant was twenty-eight months old.

At first, the infant wore the harness full time and was evaluated after two days. Then evaluations were made at weekly intervals. When the hip became clinically stable, the harness was removed for two hours a day. Gradually the infant was allowed out of the harness two to four hours

TABLE I

Patient	Sex	Side	Breech	Start of Treat. (Weeks)	End of Treat. (Mos.)	Age at Follow-up (Mos.)	Acetabular Index (Degrees) R	Acetabular Index (Degrees) L	C.-E. Angle (Degrees) R	C.-E. Angle (Degrees) L
K. M.	F	L		6	Failed					
L. P.	F	Bilat.		10	11	28	22	22	20	20
T. O.	F	L		10	7	40	15	20	25	23
A. N.	F	R	+	10	Failed					
H. G.	F	R		12	9	34	23	18	20	20
N. T.	F	L	+	12	9	52	12	11	26	26
A. M.	M	L		13	6	45	16	15	18	20
J. W.*	F	L	+	14	12	73	18	18	21	23
M. N.	F	Bilat.		14	9	43	17	15	20	20
A. T.	F	L		16	15	33	20	20	17	22
S. B.†	F	R		16	10	45	20	20	15	15
E. L.	F	R		24	9	35	14	15	25	30

* Traction for two weeks, then Pavlik harness.
† Pavlik harness, then abduction brace for another twelve months.

more every two weeks if a neutral anteroposterior roentgenogram was consistent with reduction, if the acetabular index was stable or improving, and, if present, the femoral head showed evidence of growth. The length of time in the harness was quite variable, depending on the severity of the abnormality of soft tissue and bone in the individual patient. The secondary deformities generally were mild in the newborns. Therefore, once clinical stability was achieved, they were usually weaned out of the harness in four to six weeks. In older infants the soft-tissue contractures normally stretched out in a few days but secondary roentgenographic changes might take several months to show improvement.

Results

All patients were followed for more than twenty-four months, with an average follow-up of forty months (range, twenty-four to seventy-three months). The patients were evaluated clinically with regard to range of motion and stability of the hip, shortening of the limb, and abnormalities of gait. Roentgenographic analysis at follow-up included measurement of acetabular indices and center-edge angles. The ossification centers of the femoral heads were assessed with regard to the time of appearance, the rate of growth, the presence of fragmentation, and the final configuration of the nuclei.

Of twenty-seven hips treated, twenty-four achieved stable reduction with the Pavlik harness. Eleven patients were three weeks old or younger when treatment was started. All but three of their involved hips were reduced and stable by three weeks. Two of those three hips required five and six weeks to achieve stability; one failed to reduce. Excepting the failure, all these hips were roentgenographically and clinically normal after three to five months of treatment. The results for the remaining twelve patients are tabulated in Table I. In one fourteen-week-old infant (J. W.), initial failure seemed to be evident, but after two weeks of traction reduction was achieved with the Pavlik harness. Thereafter the treatment was successful according to the regimen outlined.

The Pavlik harness failed in three patients. One was a week old when treatment was begun and the others (K. M. and A. N.) were six and ten weeks old, respectively. Two of the failures were clearly the result of inadequate flexion in the harness; the cause of the other failure is unknown. When failure became obvious, all three patients were treated with traction followed by subcutaneous adductor tenotomy and closed reduction with plaster-cast immobilization. Subsequently, one patient had mild vascular changes and required a varus derotation osteotomy. The other two achieved excellent clinical results although one (A.N.) retained a smaller than normal femoral head.

There was no significant difference in results with respect to side, sex, or presentation. The duration of treatment varied according to the age at which treatment was begun (Table II). At follow-up, all twenty-four patients with successful reductions had a full range of motion, no shortening, a normal gait, and a negative Trendelenberg sign. Analyses of the acetabular index and center-edge angle at follow-up revealed no significant differences in unilateral cases between the two sides (Table I).

Comparison of the development of the ossification centers in the femoral heads in normal hips with this development in the dislocated hips showed no significant difference in the sizes of the ossification centers at follow-up and no instances of fragmentation, metaphyseal widening, coxa magna, or coxa plana. However, there was delayed ossification of the femoral heads in one patient with bilateral dislocation. Both femoral heads appeared when

TABLE II

Age at Onset of Treatment (Mos.)	No. of Patients	Av. Length of Treatment (Mos.)	No. of Failures	Av. Length of Follow-up (Mos.)
Under 1	11	3.6	1	38.2
1 to 3	6	7.0	2	38.5
3 to 6	6	9.3	0	45.6

this patient was fifteen months old and thereafter increased in size without fragmentation. When the patient was fifty-four months old, the hips were roentgenographically and clinically normal.

Discussion

The importance of early detection of congenital dislocation of the hip by routine examination of the newborn is well accepted [1,2,6,9]. The apparatus discussed here was developed by Pavlik, who treated 632 dislocations and a similar number of dysplastic and subluxatable hips. Other reports of the use of the Pavlik harness are available [3-5,11,12].

In young infants, especially after the neonatal period, the concept of positioning the thighs to allow spontaneous reduction is encouraged in contrast to the more prevalent concept of maintaining a fixed reduction. We used the Pavlik harness to keep the hips in positions of flexion which usually exceeded 90 degrees. The normal degree of valgus of the femoral head and neck requires this degree of hip flexion to promote spontaneous reduction of a dislocation, because if the hip is at less than 90 degrees of flexion the femoral head is directed towards the superior part of the acetabulum rather than towards the triradiate cartilage. Likewise the femoral head is more adequately contained anteriorly in the acetabulum when the hip is flexed more than 90 degrees. In the frog-leg position the femoral head tends to be uncovered anteriorly [13]. It is very important to realize that inadequate flexion is the most common reason for failure of reduction. Most of the centering of the femoral head is gained by flexion, with abduction a secondary adjustment to align the axis of the acetabulum and femoral head for maximum containment. The Pavlik harness encourages optimum and individualized abduction without force by allowing the leg to fall freely into abduction. Therefore, to allow the harness to safely and adequately reduce the dislocated hip, it is important that the range through which abduction is allowed be within an arc that we have termed the safe zone (Figs. 3-A and 3-B). This safe zone is defined as the arc between the angle of abduction that can be comfortably attained and the angle which allows redislocation. When the contracture of soft tissue limits abduction markedly, the safe zone is narrow. Then there is greater risk of too little adduction (redislocation) and too much abduction (possible avascular necrosis). The Pavlik harness is the only apparatus readily available which promotes spontaneous reduction by positioning the hip in flexion with essentially free abduction. It thus provides a maximum opportunity to attain reduction with minimum risk of avascular necrosis.

At present, we have two criteria that must be met for continued use of the Pavlik harness. First, the femoral head must be directed towards the triradiate cartilage. We accept lateral displacement as long as this first criterion is met. Second, after two to three weeks, the clinical examination must prove to the examiner that the femoral head is in the acetabulum. If a frank dislocation continues but the hip can be reduced easily, then occasionally an adductor tenotomy, traction, or both may be helpful in gaining stability. If, however, the dislocation persists, use of the harness should be discontinued.

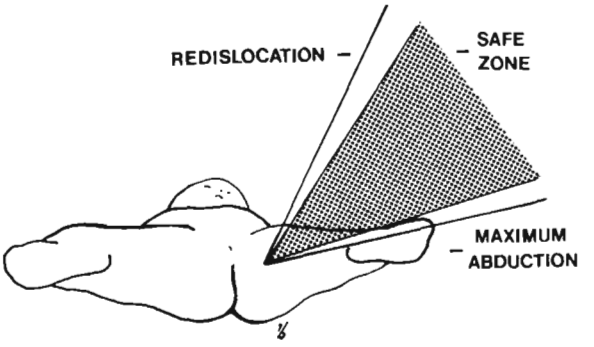

FIG. 3-A

The so-called safe zone is the arc of the shaded area. The harness does not permit adduction to such a point that a dislocation is likely, and the angle of comfortable abduction marks the other limit of the zone.

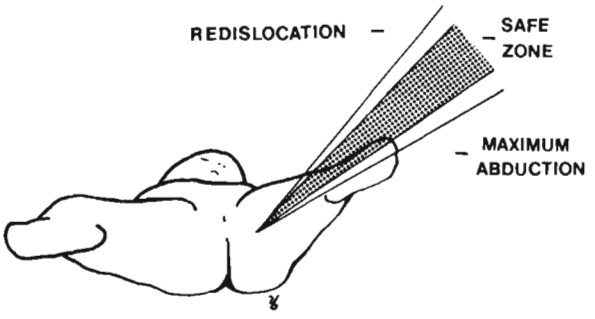

FIG. 3-B

The safe zone narrows as the contracture becomes more severe. The angle where redislocation can occur is closer to the angle of possible comfortable abduction.

Certain principles must be kept in mind when using the Pavlik harness. (1) No force should be used when attempting reduction. (2) The adequacy of the flexion-abduction must be confirmed roentgenographically at the time of application of the harness. (3) The hips should be maintained at 90 degrees of flexion or more, but forced flexion is not to be used and the final position must permit further spontaneous flexion of the hips. A complication of forced flexion was demonstrated by a patient not in the present study who had a transient palsy of the femoral nerve. The palsy was possibly caused by entrapment of the femoral nerve under the inguinal ligament. (4) To avoid forced abduction, the posterior straps must not be tight and should allow the knee to be adducted within three to five centimeters of the midline (Fig. 4). (5) The stability of the hip should be frequently assessed in the harness during the early stages of treatment, when the femoral head may move in and out of the acetabulum. It is possible that the femoral head may not progress to a stable reduction.

The Pavlik harness is a very attractive device to use because of its simplicity of design and application. In addition, there are several theoretical advantages that cannot be obtained with other devices. First, reduction is promoted with the hip in an attitude of flexion, the

physiological position of the neonate. Second, the maneuvers employed to attain reduction are gentle and require no anesthesia in the majority of infants. The adductors, if tight at first, usually will stretch gradually and spontaneously without force (Fig. 5). Third, active motion is maintained within the desired limits but extension is not allowed, nor is adduction past the midline. Both extension and adduction may predispose to continued instability or

FIG. 4

Proper adjustment of the Pavlik harness allows the knees to come within three to five centimeters of the midline.

even dislocation. Fourth, the active knee flexion and extension cause the hamstrings to tighten and tend to keep the hip reduced. Fifth, the risk of avascular necrosis is minimized because there is no forced abduction of the hip[7]. Sixth, the great majority of patients under six months old can be successfully treated entirely on an outpatient basis. The Pavlik harness is readily accepted by parents and patients and does not affect the normal routines of nursing and diapering. Also, clinical and roentgenographic evaluation with the child in the harness is easily accomplished.

In this series, all twenty-four hips that were successfully reduced had normal acetabular indices and center-edge angles on follow-up, and the sizes of the femoral heads were normal (Table I). This information suggests that hips reduced before the patients are six

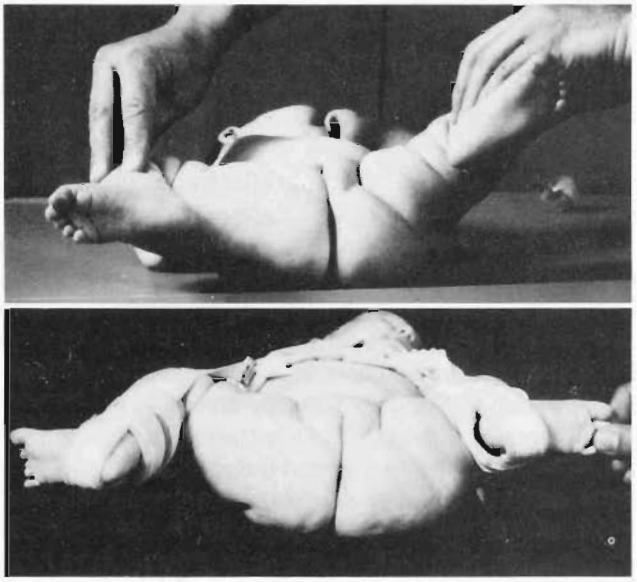

FIG. 5

A four-month-old infant had a dislocated left hip and tight contracted adductors. After two weeks in a Pavlik harness, the adductors gradually stretched to allow full abduction.

months old have an excellent chance of returning to normal. The duration of treatment required to achieve clinical stability was related to the age at which treatment was begun (Table II). The age was also related to the total length of treatment required. A good estimate is that treatment will last an interval approximately two times the age of the infant when the Pavlik harness is first applied. This correlation supports our contention that early diagnosis and treatment are important.

References

1. ANDRÉN, L., and VON ROSEN, S.: The Diagnosis of Dislocation of the Hip in Newborns and the Primary Results of Immediate Treatment. Acta Radiol., **49:** 89-95, 1958.
2. COLEMAN, S. S.: Diagnosis of Congenital Dysplasia of the Hip in the Newborn Infant. J. Am. Med. Assn., **162:** 548-554, 1956.
3. COLEMAN, S. S., and MACEWEN, G. D.: Congenital Dislocation of the Hip in Infancy. *In* Instructional Course Lectures, The American Academy of Orthopaedic Surgeons. Vol. 21, pp. 155-166. St. Louis, C. V. Mosby, 1972.
4. ERLACHER, P. J.: Early Treatment of Dysplasia of the Hip. J. Internat. Coll. Surg., **38:** 348-354, 1962.
5. FRIED, AMNON, and SEELENFREUND, M.: The Treatment of Congenital Dislocation of the Hip by the Pavlik Strap Brace. Bull. Hosp. Joint Dis., **30:** 153-163, 1969.
6. HIRSCH, CARL, and SCHELLER, SVEN: Result of Treatment from Birth of Unstable Hips. A 5-Year Follow-up. Acta Orthop. Scandinavica, Supplementum 130, pp. 25-29, 1970
7. OGDEN, J. A.: Treatment Positions for Congenital Dysplasia of the Hip. J. Pediat., **86:** 732-734, 1975.
8. ORTOLANI, M.: Un segno poco noto e sua importanza per la diagnosi precoce di prelussazione congenita dell'anca. Pediatria, **45:** 129-136, 1937.
9. PALMÉN, KURT: Preluxation of the Hip Joint. Diagnosis and Treatment in the Newborn and The Diagnosis of Congenital Dislocation of the Hip Joint in Sweden during the Years 1948-1960. Acta Paediat., Supplement 129, 1961.
10. PAVLIK, ARNOLD: Die funktionelle Behandlungsmethode mittels Riembenbügel als Prinzip der konservativen Therapie bei angeborenen Hüftgelenksverrenkungen der Säuglinge. Zeitschr. f. Orthop., **89:** 341-352, 1957.
11. REITER, R.: Erfahrungen mit dem Riemenzügel nach Pavlik. Zeitschr. f. Orthop., **95:** 220-232, 1961.
12. SAKAGUCHI, R.: The Treatment of Congenital Dislocation of the Hip. Am. Digest Foreign Orthop. Lit., third quarter: 9-11, 1971.
13. SIFFERT, R. S.; EHRLICH, M. G.; and KATZ, J. F.: Management of Congenital Dislocation of the Hip. Clin. Orthop., **86:** 28-33, 1972.