Congenital Dislocation of the Hip
Observations on the Early Diagnosis and Results of Treatment With an Abduction Brace in Infants Two to Nine Months of Age in Greece

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In Greece, despite efforts toward early diagnosis of congenital dislocation of the hip (CDH) during the last 20 years, treatment of 75% of infants so diagnosed has not been begun until they are 2 to 9 months of age, with an average treatment onset age of 4.6 months. Five hundred eighty-seven infants (947 hips) two to nine months of age with typical CDH or subluxation were treated with a specially designed abduction brace. This brace, which has been in use for more than 22 years, proved simple and reliable. The follow-up period ranged from two to 20 years (average, 4.5 years). Excellent results were found in 862 hips (91.0%), good results in 44 hips (4.5%), fair results in 32 hips (3.5%), and poor results in nine hips (1.0%). Changes due to ischemic necrosis were noted in 6.8% of the hips, with severe changes present in 3.0%. The most recent results have improved as a result of greater attention to very gentle and gradual abduction of the hips before the application of the brace and the avoidance of extreme abduction positioning in the brace.

Congenital dislocation of the hip (CDH) is a common abnormality in Greece. The condition was known to Hippocrates (460-370 B.C.), who distinguished it from the acquired varieties of hip dislocation.

Efforts toward early diagnosis, prophylaxis, and treatment in Greece started in 1960.6-26 Orthopedic surgeons, pediatricians, and general practitioners were alerted to the advantages of diagnosing the condition early, and the public was made aware of the consequences of the traditional practice of swaddling babies. Pediatricians and general practitioners have been informed of the importance of neonatal screening for CDH and the necessity for examination of the hips of all infants at the time of routine pediatric follow-up examinations. Infants showing clinical signs of CDH have been referred to orthopedic surgeons for evaluation and treatment. Although considerable progress has been made in the early diagnosis of the condition during the last two decades, it has nevertheless been observed that, in 75% of children, treatment was started between two and nine months of age.38

In most reports on the treatment of CDH in infants younger than one year of age, the criteria for diagnosis were seldom strictly defined, whereas a standard form of management was applied to a wide spectrum of conditions.4 In fact, several published studies included results of conservative treatment of various types of hip abnormalities, often without roentgenologic diagnosis,2,7,28 and some studies contained limited numbers of patients.14,29,30,36

This report examines 587 cases selected from a large number of children diagnosed as having CDH. Strict clinical and roentgenologic criteria were used for diagnosis. Treatment was similar in all infants and evaluation of anatomic results was based on a standard method. Finally, there was a minimum follow-up period of two years.
This article has three main goals: (1) to present the authors’ observations on the early diagnosis of CDH, (2) to describe the method of treatment with a specially designed abduction brace, and (3) to analyze the results in 587 infants two to nine months of age with typical CDH (947 hips).

Only a small number of children younger than one year of age with CDH were treated before 1960. Of 550 children with CDH treated from 1955 to 1958, only 28 (5%) younger than one year of age and only 20 (3.5%) younger than six months of age were found. The age at onset of treatment in 960 children with CDH seen from 1966 to 1975 at one of the authors’ institutions and in private practice was compared with the ages of 836 children seen from 1976 to 1984. It was found that the number of children younger than one month of age seen during the second decade doubled (from 5% to 10%), and the number of children older than nine months of age decreased (from 26% to 15%). Nevertheless, 75% of children commenced treatment between two and nine months of age.

MATERIALS AND METHODS

In a review of the authors’ records, 82 neonates ten to 30 days of age with CDH treated by various means of hip abduction positioning, such as diapers, homemade pillows, H-shaped splints, and camp splints, were found. These patients were not included in the current analysis because the method of treatment varied and the follow-up time was short in most cases. Five hundred eighty-seven infants two to nine months of age with 947 dislocated hips and having complete records and roentgenograms were selected for analysis. All cases had typical clinical and roentgenographic signs of CDH. An Ortolani’s click was the most common clinical sign. Since this sign tended to disappear in infants older than three to four months of age, other signs, in particular limitation of abduction, pointed to the diagnosis of CDH. This was confirmed in all cases by roentgenograms. Apart from the lateral and upward displacement of the upper end of the femur and the appearance and size of the ossific nucleus, the degree of acetabular dysplasia was evaluated by measuring the acetabular angle. An acetabular angle of more than 30° when the infant was older than three months of age and more than 40° when the infant was younger than this age was considered abnormal and was thus evaluated in association with other roentgenologic and clinical signs.

All cases with the clinical diagnosis of dislocatable, subluxable, or unstable hips were excluded from this study. Moreover, cases of teratologic and neuromuscular dislocation were omitted.

The study population comprised 90 male and 497 female infants. In 360 cases, dislocation was bilateral. It was unilateral in 227 cases; the left hip was affected in 160 cases and the right hip in 67 cases. Typical dislocation was found in 807 hips and typical subluxation in 140. The age of the infants at the onset of treatment is shown in Table 1. The mean age was 4.6 months. In all 587 infants, a specially designed brace was used. This brace has been in use since 1965 and has been coined the P. A. Kyriakou Children’s Hospital brace (Fig. 1). The brace was made of leather or plastic and sized for each infant. It consists of two rings for the thighs and one for the waist. These rings are reinforced by metal one-half ring plates. The thigh rings are connected with two short Z-shaped metal parts to two curved posterior metal bars, which are fixed to the posterior surface of the waist ring. The desired degree of flexion and abduction of the hips can be easily arranged by bending the metal parts. In older children, who crawl a great deal, an anterior metal bar is often added to strengthen the device (Fig. 2). This brace resembles the Browne splint in appearance but differs from it in concept. Browne emphasized that, with his splint, complete abduction of the thighs in flexion was sought. With the child prone, a pad of sponge rubber placed over the sacrum acts as a fulcrum, enabling the child’s knee to be pulled backward and levering the head of the femur into the acetabulum. In contrast to this dynamic form of reduction of the dislocation, the brace used in the present study was designed not to produce but to maintain reduction of the dislocation obtained before its application. Therefore, a prerequisite for the application of the brace was that the dislocated hips be easily reducible. It was
noted that in most hips, reduction of dislocation was obtained at 35° to 45° of abduction. Stability was achieved after a few degrees of abduction beyond the point of reduction, usually at 45° to 60°. Extreme positions of abduction, even if gradually obtained, were found unnecessary and are probably harmful. In a few infants, the dislocation was easily reducible without forced abduction. In these cases only, the brace was applied immediately. In the majority of cases, however, particularly in older children, gradual abduction was obtained over a period of four to 12 days by using diapers, cloths or, more often, an H-shaped aluminum abduction splint. Finally, in infants with more severe limitation of abduction, skin traction and gradual abduction were used before the brace was applied, often followed by abductor tenotomy. Stability of reduction was checked clinically and roentgenologically after the brace was applied. The metal parts, if placed correctly, do not impede x-rays.

If complete reduction of the femoral head is not certain, further investigation is required. In some cases, computed tomographic scanning may be helpful in clarifying the exact position of the femoral head in relation to the acetabulum. If there is doubt, it is preferable to refrain from applying the brace and, instead, admit the infant to the hospital for assessment. No attempt should be made to apply the splint in an irreducible dislocation.

After the brace had been worn continuously for three to four months, it was removed by the orthopedic surgeon, and the hips were examined both clinically and roentgenographically. If they were found to be stable and roentgenograms demonstrated concentric reduction of the femoral

FIG. 1A AND 1B. The brace used in the treatment of CDH in infants three to nine months of age seen (A) in isolation and (B) while in use. The desired degree of flexion and abduction can be arranged by bending the metal parts. The posterior metal bars are curved so that contact with the skin is avoided.

FIG. 2. In older infants, who crawl a great deal, an anterior metal bar is used to strengthen the appliance.
head and improvement of the acetabular dysplasia, the infants were allowed out of the brace for two-hour periods daily with periods lengthened every three weeks. In infants three to four months of age, the brace was thus removed for progressively longer periods of time over the next two to three months. For infants older than four months of age, the application of the brace was prolonged by adding approximately one month of brace wear for every month of age over four months. Roentgenograms were taken every three months until removal of the brace was completed and at longer intervals during the follow-up period.

RESULTS

A simplified version of Severin's method was used to classify the roentgenographic results. In Type I, the hip was normal and the angle between the center of the femoral head and the lateral end of the acetabulum (CE angle) was within normal limits. The result was considered excellent. In Type II, there was either slight deformity of the femoral head or slight shortening of the neck. However, the CE angle was within normal limits, and the result was considered good. In Type III, there was dysplasia of the acetabulum but no subluxation, the CE angle was below normal, and the result was considered fair. In Type IV, there was subluxation, and the CE angle was close to zero. In Type V, there was more severe subluxation, and in Type VI, there was redislocation. All hips of Types IV, V, and VI were considered poor results. Follow-up time ranged from two to 20 years (average, 4.5 years). The anatomic results in 947 hips are shown in Table 2. Results of treatment of 180 hips treated from 1982 to 1985 are shown in Table 3.

COMPLICATIONS

The brace was generally well accepted by both the infants and the parents, who were enlisted to participate actively in their child's treatment. They were instructed to closely supervise their baby and to watch and care for any pressure sores. Diapering and nursing presented no problems. Minor pressure sores appeared in five cases. These were treated by the infants' mothers after the rings of the brace had been slightly adjusted. The use of the brace was never discontinued because of pressure sores or intolerance. There were 12 failures of reduction seen two to three months after the brace was applied. In six infants with bilateral CDH, one of the hips was easily reducible and stable in the safe position, but the opposite hip was unreducible. In these cases, the brace was applied and the reducible hips were treated in the usual manner. The unreducible hips were kept in 20° of abduction in the brace until the end of treatment and then were treated by open reduction when the patient was approximately one year of age.

Ischemic necrosis of the proximal femoral epiphysis was the most serious complication. It was evaluated according to the classifications of Salter et al., Kalamchi and MacEwen, and Thomas and Ogden. There were 38 hips with Type I changes according to the criteria of Kalamchi and MacEwen

| TABLE 2. Roentgenographic Results of Treatment in 947 Hips |
|----------------|--------|-----|
| Result         | n      | %   |
| Excellent      | 862    | 91.0|
| Good           | 44     | 4.5 |
| Fair           | 32     | 3.5 |
| Poor           | 9      | 1.0 |
| Total          | 947    | 100.0|

| TABLE 3. Roentgenographic Results of Treatment in 180 Hips With Congenital Dislocation of the Hip Treated From 1982 to 1985 |
|----------------|--------|-----|
| Result         | n      | %   |
| Excellent      | 166    | 92.2|
| Good           | 8      | 4.5 |
| Fair           | 6      | 3.3 |
| Poor           | 0      | 0   |
| Total          | 180    | 100.0|
and Thomas and Ogden. In ten hips, Type II changes and in eight, Type IV changes were noted, according to the criteria of Thomas and Odgen. All nine cases with poor results had severe Type III changes associated with acetabular dysplasia and subluxation. The overall incidence of ischemic necrosis was 6.9%, but it was severe enough to cause substantial deformity of the upper end of the femur in 3.0% of cases. Limitation of external rotation associated with increased internal rotation of the hips due to femoral anteversion was common. It tended to improve with time, but in a considerable proportion of children, limitation of external rotation persisted until or near completion of growth. In 25 hips, internal rotation was considerably increased and interfered with cosmetic appearance and the children’s activities. Roentgenograms showed increased anteversion but no subluxation. These hips were treated by subtrochanteric osteotomy with excellent results. Finally, in 40 hips, Types I, II, and IV changes due to ischemic necrosis were seen, according to the criteria of Thomas and Odgen. These changes were associated with increased anteversion and often with slight acetabular dysplasia. The hips so classified were treated by subtrochanteric osteotomy.

**DISCUSSION**

The introduction of neonatal examination for CDH has resulted in the diagnosis of large numbers of abnormal hips, and early treatment yielded results far superior to those obtained previously. This led to rather optimistic statements that the problems associated with CDH would be eliminated. Nevertheless, after more than 30 years, it is being realized that, even in well-planned neonatal screenings, a considerable number of dislocated hips escape diagnosis (0.07 to two per 1000). It has also been suggested that 25% to 50% of dislocatable hips go unnoticed during neonatal examinations. Although inefficient early detection may be responsible for these missed cases, there is some evidence to support the existence of delayed or developmental dislocation. It has been noted that full dislocation has developed later on in hips found to be normal in repeated examinations during the first weeks of life.

There is only one report of a very low incidence of missed CDH cases (0.07 per 1000 live births) and excellent results by applying the Von Rosen splint on all neonates with clicking hips within 48 hours after birth. It is inevitable that, with the above treatment policy, a large number of hips will be treated that would have ordinarily spontaneously become normal in the course of the following weeks. In the series reported here, 75% of the children were two to nine months of age at the onset of treatment. The main reason for this was that pediatricians delayed diagnosis for several months in order to obtain roentgenologic confirmation of the dislocation. Also, a considerable number of infants had been treated initially by double diapers or cloths in order to obtain abduction of the hips. This was usually done very inefficiently and for short periods of time. A number of infants, therefore, particularly those with less severe hip abnormalities, were not referred to an orthopedic surgeon. A small number of parents ignored the requests for follow-up observation because they did not believe there was anything wrong with their infants. In addition, swaddling was practiced in some instances. Finally, a small number of infants had been repeatedly examined by well-qualified pediatricians and orthopedic surgeons during the first months of life. These infants were not found to present signs of CDH but appeared later with typical dislocation. It is likely that Ortolani’s sign was not elicited in many of these cases because joint laxity was not prominent and, most likely, was not the only or the main etiologic factor. However, in those hips, acetabular dysplasia was probably responsible for the manifestation of the dislocation. Acetabular dysplasia was common in the cases reported here. In one survey
carried out at the present authors' institution, it was found that among 151 sets of parents of CDH children, acetabular dysplasia was present in one parent in 71 instances (47%).

All 587 infants in this series were treated in the same manner with a specially designed abduction brace. This was applied if the hips were easily reducible and stable within the so-called safe zone of abduction. This, according to Ramsey et al., is an arc between the angle of abduction comfortably attained and the angle at which the hip redislocates. The importance of gradual abduction, gentle reduction, and avoidance of extreme positions of immobilization of the hips in treating CDH has been stressed by many authors. In the present authors' cases, abduction was very gently and gradually increased to the appropriate degree before the brace was applied. This brace has been in use for 22 years and was found to be simple and reliable.

Results of treatment in 947 hips were satisfactory (Table 2). Later results in 180 hips appear slightly superior. There were no poor results in this group (Table 3). This was attributed to the considerable care taken to obtain gradual abduction of the hips and to avoid extreme abduction positioning. It must be admitted that, in the early years, there was some impatience in obtaining rapid hip abduction and applying the brace due to lack of staff and hospital beds. Also, the position of hip abduction in the brace was greater than necessary for stability. It was eventually realized that no more than 40° to 60° of abduction was required. It is difficult to compare the present results with those of other series because the methods of treatment, the types of hip abnormalities, and the ages of the patients vary. However, Elsworth and Walker reported the results of treatment of 104 children with a modified Browne splint. In 78 unstable but reducible hips, the splint was applied within a few days of birth for four to six weeks. In a second group of 49 hips, the splint was applied after gradual abduction of the hips with traction, abductor tenotomy, and occasionally after application of a plaster cast.

They recorded 12 hips with avascular necrosis (9%), which was severe in only four hips (3%). Reduction failed in six hips. Pool et al. treated 173 infants younger than three months of age (238 hips) having a clinical diagnosis of CDH, and 31 infants older than three months of age (33 hips), with a modified Browne splint. They found a 2.5% incidence rate of avascular necrosis in the group of infants treated with the splint alone, in contrast to a 60.6% incidence rate in the group of infants older than three months of age treated with tenotomy and plaster followed by application of the splint. The incidence rate of significant disturbance of the proximal end of the femur, however, was 0.7%. Failure of reduction was noted in 1.4% of the hips. Bradley et al. reported a 2% incidence rate of avascular necrosis in 104 unstable hips treated during the first nine months with the Von Rosen splint, a 13% incidence rate in 40 hips treated with the Pavlik harness, and a 20% incidence rate in 15 patients treated with the Pavlik harness followed by plaster casting. In 6.9% of the hips, operative treatment was necessary. In reviewing other methods of treatment, it appears that the Pavlik harness is becoming popular. With this device, reduction of the dislocation is obtained by flexion of the hips more than 95° while the legs fall free to abduction.

Pavlik reported 84% very good and 16% poor results after using his harness in 632 hip dislocations and 632 subluxations and dysplastic hips. Ramsey et al. treated 23 dislocated hips with the same method, and reported excellent results in 87% of their cases. Suzuki reported 85.5% very good results in 109 hips, emphasizing the difficulties and complications of the method. Similar difficulties were reported by Mubarak et al. in 110 infants treated by the same method. Ueno et al. reported 81% very good results in 114 hips, and Erlacher reported 85% ex-
cellent results in 550 children with CDH. Tönnis\textsuperscript{10} reported a 93.7\% successful reduction rate with the Pavlik harness, and a 9.9\% rate of ischemic necrosis. Iwasaki\textsuperscript{16} reported a 28\% incidence rate of avascular change in the hips of children who were maintained in a Pavlik harness in the supine position in the hospital and 5.8\% incidence rate in patients treated at home in a more varied posture. Finally, in a multicenter study of the European Pediatric Orthopaedic Society,\textsuperscript{12} the Pavlik harness was used on 3611 hips in 2636 infants with CDH younger than 11 months of age. Failure of reduction was noted in 8\% and avascular necrosis in more than 2\% of cases.

It appears that the results of the series reported here compare favorably with those of the aforementioned series. It is important to note that mild changes due to ischemic necrosis may not be detectable in the early stages of this disease. Even if they are detected, it is difficult to foresee the final outcome in many cases despite the criteria suggested in excellent articles in the literature.\textsuperscript{18,32,39} The present authors therefore believe that at least 1.5 years, or better, two years, are required to assess the results of treatment in hips showing no evidence of ischemic necrosis. If such changes are present, the children should be followed until growth is complete. In conclusion, treatment of CDH in infants two to nine months of age is not always simple, because adaptive changes in the joint render closed reduction in many cases difficult. Such cases need thorough assessment. If reduction is not easily obtained and is not stable, repeated attempts at closed reduction should be abandoned, and immobilization in extreme positions of abduction should be avoided. These hips need thorough investigation. It is preferable to leave unreducible hips untreated to be dealt with by open reduction at approximately one year of age. The present authors believe that results of treatment of CDH may be improved by continual education and training of medical staff in neonatal units, of pediatricians, and of general practitioners in order to minimize the number of missed CDH cases. All suspect hips should be referred to orthopedic surgeons for evaluation, treatment, and follow-up study. No matter what method of treatment is used, results will be better if factors known to affect the prognosis are strictly observed. Such factors include gentle and gradual abduction of the hips, premanipulative traction, abductor tenotomy, and avoidance of forced abduction and immobilization in extreme positions.

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