The correction of leg-length discrepancy after treatment in developmental dysplasia of the hip by using a percutaneous epiphysiodesis

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The aims of this study were to determine factors that cause a leg-length discrepancy (LLD) to the extent that correction is indicated after treatment in developmental dysplasia of the hip and determine whether the LLD may be treated with a percutaneous epiphysiodesis. Twelve children were included in this study. The factors which caused LLD were avascular necrosis, femoral shortening and varus at reduction, and septic arthritis. Percutaneous epiphysiodesis of the contralateral limb reduced the mean predicted LLD from 3.8 to 1.2 cm at maturity. We concluded that LLD (>2.5 cm) might result from complications of developmental dysplasia of the hip and these patients can be treated with a percutaneous epiphysiodesis. ***J Pediatr Orthop B*** **17:43–46 © 2008 Wolters Kluwer Health | Lippincott Williams & Wilkins.**

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Introduction

Developmental dysplasia of the hip (DDH) is a complex problem. If detected early an anatomically normal hip may be obtained with conservative treatment such as the Pavlik harness, traction, or casting. In older children, however, operative reduction is required to restore the normal anatomic relationship of the hip joint [1–5]. The outcome of treatment whether conservative or surgical is variable and complications after treatment include the following: avascular necrosis (AVN) [6–8], a femoral shortening with proximal femoral varus osteotomy exceeding 3 cm [4,9], septic arthritis secondary to surgical treatment [10,11], and redislocation or resubluxation [10,11]. All of these complications may cause a limb-length discrepancy (LLD). AVN may arise as a complication of treatment and cause LLD of up to 5 cm [7]. Femoral shortening and varus osteotomy in the proximal femur to achieve concentric reduction in older children with DDH has been advocated; however, surgeons should consider that these procedures might lead to LLD in a patient with unilateral involvement if the femoral shortening exceeds 3 cm and if the neck-shaft angle is angulated to less than 110° [4,5,9,12–14]. Deformation of the femoral head and an earlier closure of the growth plate may result as sequelae of septic arthritis and has been shown to cause shortening of the affected extremity [6,11].

The aims of this study were to determine factors (AVN, femoral shortening and varus, and septic arthritis) that cause LLD after treatment in DDH and determine whether the LLD may be treated with a percutaneous epiphysiodesis.

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Materials and methods

From January of 1983 to December of 2003, 398 consecutive patients diagnosed with DDH were treated at the Alfred I. duPont Hospital for Children. Of this population, 12 children developed a LLD, which was anticipated to be 2.5 cm or more at maturity and constituted this study. Demographic data recorded from the charts include the involved extremity, earlier procedures, etiology of LLD, prediction of LLD, site of epiphysiodesis, and LLD at maturity.

AVN at the time of surgery was graded according to the Kalamchi and MacEwen classification [7]. The LLD was measured by orthorontgenograms. The Greulich and Pyle [2] atlas was used to determine skeletal age. Moseley's straight-line method [15] was used in predicting LLD at maturity, as well as to determine the timing of the epiphysiodesis (Table 1). The LLD in all cases was treated by a percutaneous epiphysiodesis as described by the senior author (J.R.B.) [16,17].

Ten girls and two boys were present with a mean skeletal age of 12 years (range, 10.6–13.8 years) at the epiphysiodesis. All patients were followed until skeletal maturity, a mean of 4.6 years (range, 2–9 years). The left hip was involved in 10 patients, the right in two patients. Eleven out of the 12 children had a history of failed closed reduction. LLD developed in two hips (cases 1 and 3) following a closed reduction. Nine children had multiple surgical procedures, which included an open reduction, proximal femoral osteotomies,

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Table 1 Patients' data

Case	DDH side	Sex	Previous operation [first; age (years)/ second; age]	Causing factor for LLD	Procedures for AVN (surgery; years)	Site of the procedure (side)	Skeletal age at operation	LLD at operation (cm)	Anticipated LLD (cm)	Age at follow-up	LLD at maturity (cm)	FU
1	L	F	No	AVN (IV)	A; 12	Distal femur and proximal tibia (R)	11.9	3.2	3.5	21	2	9
2	L	F	FVDO and FS; 2.5	Varus and femoral shortening	No	Distal femur (R)	12.5	3	3.5	20	0.5	7.5
3	L	F	No	AVN (IV)	TAO; 10	Distal femur (R)	10.6	4.5	5	16	2	5.4
4	L	F	OR; 1/FVDO; 1.7/FS + PIO; 3.4	Shortening and AVN (III)	TAO; 12	Distal femur (R)	12.2	1.8	3.2	17	0	4.8
5	L	F	OR; 1/OR + SIO; 1.8/OR + FVDO + FS + PIO; 4	Varus + AVN (IV)	TAO; 13	Distal femur and proximal tibia (R)	12.1	3.3	4.6	15	1.8	3
6	R	F	OR; 1/OR + SIO; 1.6	AVN (III)	A; 4	Distal femur (L)	11	2.2	3.4	15	1.5	4
7	L	F	OR + PIO; 4/FVDO; 4.8	AVN(II)	TE; 8	Distal femur (R)	11.2	2.5	3	16	0	5
8	L	M	OR; 1/FDO; 2.5	AVN (III)	No	Distalfemur (R)	11	3.3	4.6	15	0.8	4
9	L	F	SIO; 10	Septic arthritis	TAO; 10	Distal femur (R)	11.6	3	5.5	15	2	3.6
10	L	F	No history	AVN (IV)	TAO; 12	Distal femur (R)	12.2	2.6	3	14	1.4	2
11	L	F	OR; 1.2/FDO + FS; 3.5	AVN (III)	No	Distal femur (R)	12.6	2.5	3	17	1	4.6
12	R	M	OR; 1.6/OR + FVDO + FS; 2/TPO; 8	Femoral fracture + varus	No	Distal femur (L)	13.8	3.2	4	16	2	2.2

A, acetabuloplasty; AVN, avascular necrosis; F, female; FDO, femoral derotation osteotomy; FS, femoral shortening; FU: follow-up; LLD, leg-length discrepancy; M, male; OR, open reduction; PIO, Pemberton iliac osteotomy; SIO, Salter iliac osteotomy; TAO, trochanteric advancement osteotomy; TE, trochanteric epiphysiodesis; TPO, triple pelvic osteotomy.

pelvic osteotomies, or a combination of these (Table 1). One child (case 10) had inadequate information regarding initial treatment. Trochanteric advancement osteotomy in five hips (cases 3, 4, 5, 9 and 10) and trochanteric epiphysiodesis in one hip (case 7) was performed to restore the abductor mechanism. Shelf acetabuloplasty was performed in two hips (cases 1 and 6) to increase coverage of the femoral head.

Results

The factors which caused LLD in older children included the following: AVN, femoral shortening and varus, and septic arthritis. AVN was present in nine of the 12 children. In seven patients, AVN was the principal cause of the LLD (cases 1, 3, 6, 7, 8, 10 and 11). In two patients the shortening was secondary to a surgical procedure as well as AVN. A varus osteotomy of 94° and type IV AVN was seen in case 5. In case 4, a femoral shortening of 3 cm was found in combination with a type III AVN. In the other three cases shortening occurred without AVN. The shortening was due to a varus osteotomy with a neck-shaft angle of 92° in one case (case 2), a varus osteotomy with a neck-shaft angle of 98° in combination with a femoral shaft fracture was the cause of shortening in case 12. In one patient, septic arthritis developed after an open reduction, which led to the development of the LLD (case 9).

The mean predicted LLD was 3.8 cm (range, 3–5.5 cm) and the mean LLD at operation was 3.0 cm (range, 1.8–4.5 cm). Percutaneous epiphysiodesis of the contralateral limb reduced the mean predicted LLD from 3.8 to 1.2 cm (range, 0–2 cm) at maturity. Percutaneous epiphysiodesis was performed in the right distal femur in eight patients, right distal femur and proximal tibia in two patients, and left distal femur in two patients. Complete physeal arrest following epiphysiodesis was observed radiographically in all patients. One patient (case 5) who developed a postoperative knee effusion, which resolved spontaneously after 3 weeks was present. No infections, peroneal nerve palsy, residual angular deformity or partial growth arrest were noted.

Discussion

LLD is a complication, which may be seen after treatment of DDH. Numerous factors, which may cause the development of a shorter limb are found. The most common cause of LLD seen in our patient population was AVN of the femoral head. This may occur after treatment of DDH because of premature growth arrest at the proximal femur, which produces shortening of the femoral neck and decreased height of femoral head [5–7,18]. According to previous studies, AVN can generate LLD of up to 5 cm [7]. The most common cause of LLD found in our patient population was AVN. Seven of the 12 patients had AVN as the sole cause of the shortening, which averaged to 3.6 cm (range, 3–5 cm). Two other cases had AVN along with other factors, which may have contributed to the LLD.

Another factor which may result in LLD is femoral shortening with varus in the proximal femur particularly

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in the unilateral cases [4,13,14,19]. Schoenecker and Strecker [14] reported the largest LLD seen in a patient treated surgically. Grzegorzewski *et al.* [20] reported that LLD was most often seen after a varus osteotomy. In our study, shortening was seen after a femoral shortening and varus osteotomy in one case (case 2), the varus was to 92° and shortening was up to 4.2 cm. In the other three cases, varus osteotomy was associated with type IV AVN in one case (case 5), a femoral shortening and type III AVN in another (case 4), the third case was a varus osteotomy associated with a femoral shaft fracture (case 12). In these three cases, it may be difficult to ascertain whether the shortening was secondary to the surgical procedure or the other factors. In one case (case 2), however, surgery was clearly the cause of the LLD.

LLD may also be seen as sequelae to septic arthritis [6,11]. Choi *et al.* [10] classified the sequelae of septic arthritis into four grades according to severity of involvement and found that the more severely involved hips (grades III and IV) had a greater LLD. In our study, we had one case that developed a septic arthritis after an open reduction and was classified as type III-B. The LLD in this patient measured 3 cm at the time of surgery and was projected to be 5.5 cm at maturity.

Children who develop a LLD greater than 2.5 cm from the treatment of DDH meet the indications for treatment with contralateral epiphysiodesis or stapling [8,16,21–25]. An alternative treatment could be ipsilateral femoral lengthening; however, in our cases hip disease is a relative contraindication and lengthening has a high complication rate [19,26–30].

Epiphysiodesis is a well-accepted technique that can address LLD of less than 5 cm in children with sufficient anticipated growth in the contralateral shorter limb. Schoenecker and Strecker [14] found LLD (1–4 cm) in all children who had DDH treated with femoral shortening. They treated two out of these patients with epiphysiodesis and on follow-up both patients had less than 1 cm LLD. Porat *et al.* [8] used epiphysiodesis to eliminate LLD in children with DDH and AVN and they achieved equalization of limb length at maturity. Our goal in treating these children was to achieve a LLD of less than 2.5 cm at maturity. We achieved this goal in all cases using the percutaneous epiphysiodesis technique.

Percutaneous epiphysiodesis have been reported as a safe, reliable technique and reported complications, which are rare, include knee effusion, incomplete growth arrest, and angular deformity [16,23–25,31,32]. In our series, only one patient had knee effusion that resolved in 3 weeks and no patient had incomplete growth arrest. A problem with epiphysiodesis is the accurate timing of the surgical procedure [33]. Moseley's straight-line method [16] has commonly been used to predict growth. We were able to calculate the timing of the epiphysiodesis accurately by using Moseley's straight-line method.

In conclusion, this study showed that a LLD after treatment of DDH may result from an AVN, septic arthritis of the hip, or femoral shortening with or without a varus osteotomy of the proximal femur. Any of these factors alone or in combination may cause an LLD of 2.5 cm or more. The moderate LLD found in these patients can be treated, safely and reliably with a percutaneous epiphysiodesis.

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