

A GRAPHIC METHOD FOR TIMING THE CORRECTION OF LEG-LENGTH DISCREPANCY

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We have developed a clinical method for the graphic recording, analysis and planning of treatment of leg-length discrepancy during growth. Initially, the clinically determined discrepancy is plotted against the chronological age yearly, and then in late childhood at six-monthly intervals. CT and measurements of skeletal age are made in middle and late childhood to confirm the clinical findings.

In a prospective study in 20 children, we observed that only eight had a linear increase in discrepancy. The observed pattern of increase was therefore used to estimate the mature discrepancy. Epiphyseodesis reference slopes were used to determine the most appropriate time and type of epiphyseodesis. In all children, the leg-length discrepancy at maturity was within 1 cm of the predicted amount. Changes in discrepancy due to leg lengthening or correction of deformity were also plotted graphically.

We conclude that the clinical graphic method is simple to use, takes into account the varying patterns of discrepancy, and minimises radiation dosage.

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Percutaneous epiphyseodesis and leg lengthening by callus distraction have improved the results of treatment of leg-length discrepancy during growth (Paley 1988; Liotta, Ambrose and Eilert 1992). The estimated discrepancy at skeletal maturity and the timing of these procedures are determined by analysis of leg-length data using either the growth-remaining method (Anderson, Green and Messner 1963), the arithmetic method (White and Stubbins 1944; Menelaus 1966) or the straight-line graphic method (Moseley 1977).

The growth-remaining and the straight-line graphic methods require yearly radiological assessments of femoral and tibial lengths and of skeletal age, but the arithmetic method relies on yearly clinical measurements of leg-length discrepancy and chronological age with less frequent radiological measurements to confirm the clinical observations. It has the advantage of simplicity, reduced exposure to radiation and inclusion of the foot in the measurements (Westh and Menelaus 1981) but a major disadvantage is that it does not display the data or the likely outcomes of treatment in a graphic form.

The growth-remaining and straight-line graphic methods assume that the amount of growth inhibition is constant while the arithmetic method assumes that the annual increase in discrepancy is constant. These assumptions may be incorrect, however, as Shapiro (1982) observed five developmental patterns of leg-length discrepancy in 803 children who had been followed to skeletal maturity or until they had surgery. In type I the leg-length discrepancy increases at a constant rate. Type II is similar in early to middle childhood but the annual rate of increase diminishes thereafter. In type III the discrepancy first increases, then stabilises and remains unchanged. Type IV is similar to type III in early and middle childhood but then increases towards the end of growth. Finally, type V consists of an initial increase, stabilisation and then a decrease in discrepancy.

We report a clinical graphic method of displaying the main components of the arithmetic method of analysis of leg-length discrepancy. The arithmetic method has been further modified by taking into account the observed pattern of growth rather than assuming a constant annual increase in discrepancy. We have evaluated the clinical graphic method prospectively in 20 children whose leg-

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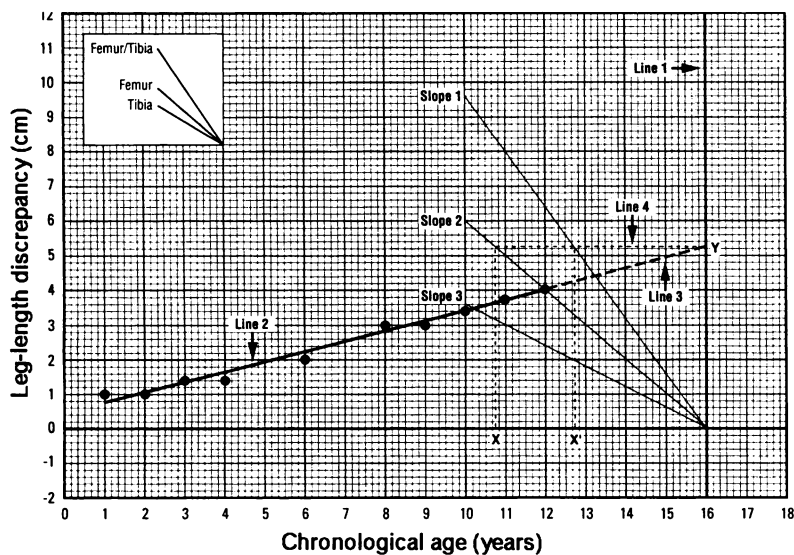


Fig. 1

Case 8. Clinical leg-length discrepancy graph for boys showing a type-I pattern of growth (Line 1, skeletal maturity line; Line 2, observed discrepancy line; Line 3, projected discrepancy line; Line 4, mature discrepancy line; Slope 1, femoral and tibial epiphyseodesis reference slope; Slope 2, femoral epiphyseodesis reference slope; Slope 3, tibial epiphyseodesis reference slope; Y, estimated mature discrepancy; X and X', chronological ages for femoral or femoral and tibial epiphyseodeses, respectively).

length discrepancy was suitable for correction by epiphyseodesis.

PATIENTS AND METHODS

The graph. The chronological age is plotted on the horizontal axis in years with two-monthly subdivisions and the leg-length discrepancy on the vertical axis in centimetres with 0.2 cm subdivisions (Fig. 1). The latter has been restricted to 12 cm for clarity; 16 cm is normally used. The heavy vertical line at 16 years on the boy's graph (Line 1, Fig. 1) and at 14 years on the girl's graph (see Fig. 3) are the skeletal maturity lines which are the average ages at which skeletal growth ceases (Menelaus 1966).

Superimposed on the graphs are epiphyseodesis reference slopes (Slopes 1 to 3, Fig. 1) which converge to the skeletal maturity lines at zero leg-length discrepancy. The slopes of these lines are based on the average annual growth of 0.6 cm from the proximal tibial growth plate and 1 cm from the distal femoral growth plate after the age of 8 years in girls and 10 years in boys (White and Stubbins 1944; Anderson et al 1963; Westh and Menelaus 1981).

Recording of data. When the child is first seen a full clinical and radiological assessment is made of the cause and severity of the leg-length discrepancy. This is measured clinically by the thickness of the block required under the short leg to achieve a level pelvis (Menelaus 1966). In infants, it is measured by tape measure. The skeletal age is derived from a wrist and hand radiograph (Greulich and Pyle 1959).

Children are reviewed annually, preferably close to their birthdays, and then six-monthly as they approach the age for epiphyseodesis. At this age, CT scans, including the heel heights, are performed to obtain confirmation of the clinical measurements and to determine the relative discrepancies of the limb segments (Carey, de Campo and Menelaus 1987). Skeletal age is again determined (Greulich

and Pyle 1959). The clinical discrepancy is plotted on the graph at each visit (Fig. 1).

Estimated mature discrepancy and timing of surgery.

The pattern of differential growth of the legs is determined from the graph (Shapiro 1982) and used to predict the pattern of further differential growth and the leg-length discrepancy at skeletal maturity (Fig. 1). The observed discrepancy line (Line 2, Fig. 1) is projected to the skeletal maturity line (Line 3, Fig. 1). The point of intersection (Y, Fig. 1) gives the estimated mature discrepancy. The mature discrepancy line (Line 4, Fig. 1) is drawn horizontally from point Y and may intersect one or more of the epiphyseodesis reference slopes. Vertical lines are dropped from these points of intersection to give the chronological ages for epiphyseodesis of the appropriate growth plates (X and X', Fig. 1).

Changes in discrepancy due to leg lengthening or the correction of deformities are also recorded on the graph. Overcorrection is plotted as a negative value.

Evaluation. We have used the clinical graphic method to determine prospectively the pattern of growth discrepancy, the estimated mature discrepancy and the timing and type of epiphyseodesis in ten girls and ten boys (Table I). There were two cases each of Perthes' disease, poliomyelitis, osteomyelitis and fracture, four of congenital dislocation of the hip, seven of hemihypertrophy or hypoplasia, and one case of tibial pseudarthrosis. All the children were followed to skeletal maturity. There were eight type-I, two type-II, five type-III and five type-IV patterns of growth discrepancy (Shapiro 1982).

RESULTS

In all children, the leg-length discrepancy at maturity was within 1 cm of the predicted amount (Table I). We performed epiphyseodesis of the proximal tibia in two children, the distal femur in 11 and of both sites in seven.

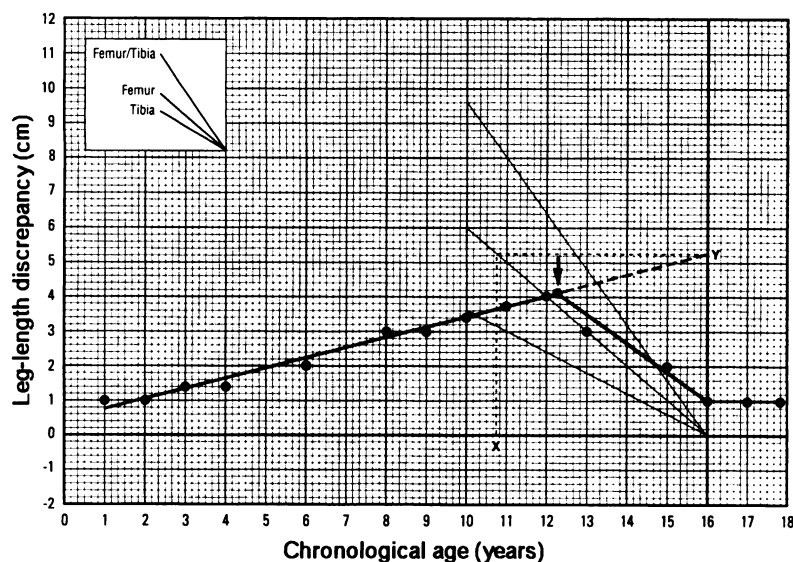


Fig. 2

Case 8. Clinical leg-length discrepancy graph showing the result of distal femoral epiphyseodesis at 12 years 3 months of age (arrow). The later than ideal time of epiphyseodesis had an expected mature discrepancy of 1.4 cm and an observed mature discrepancy of 1 cm (Y, estimated mature discrepancy of 5.2 cm; X = chronological age (10 years 9 months) for complete correction of the discrepancy by distal femoral epiphyseodesis).

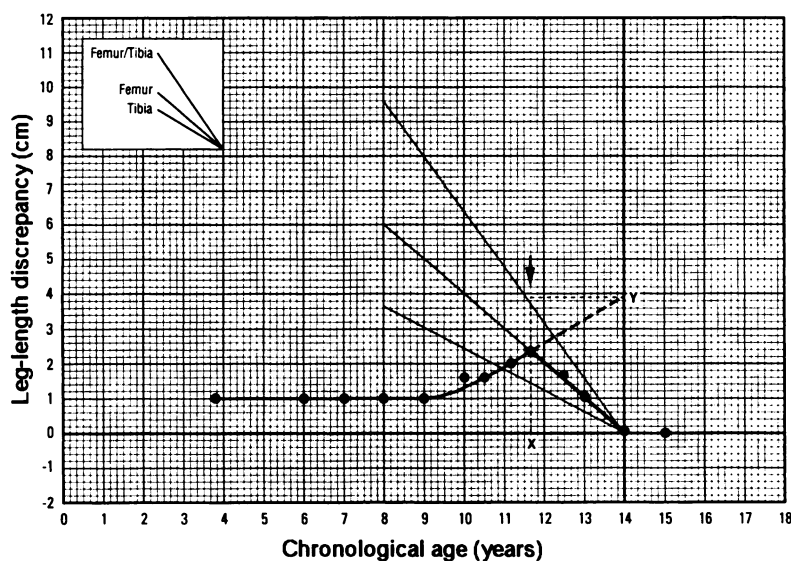


Fig. 3

Case 16. Clinical leg-length discrepancy graph showing a type-IV pattern of discrepancy. The tibial and femoral epiphyseodeses were undertaken at 11 years 8 months (arrow) with complete correction (Y, estimated mature discrepancy of 3.9 cm; X = chronological age (11 years 8 months) for complete correction of the discrepancy by tibial and femoral epiphyseodeses).

Illustrative case reports

Case 8. A one-year-old boy presented with right hemihypertrophy and a leg-length discrepancy of 1 cm (Fig. 2). He developed a type-I pattern of leg-length discrepancy (Shapiro 1982). His chronological and skeletal ages were not significantly different (Cundy et al 1988). At the chronological age of 12 years he had a 4 cm discrepancy which was confirmed by CT. The estimated mature discrepancy was 5.2 cm (Y, Fig. 2). The mature discrepancy line did not intersect the tibial epiphyseodesis reference slope so that tibial epiphyseodesis alone would not have corrected the discrepancy and would have resulted in a mature discrepancy of approximately 2.8 cm. This was determined from the vertical distance at age 12 years between the tibial epiphyseodesis reference slope and the mature discrepancy line (Fig. 2).

The mature discrepancy line intersected the femoral

epiphyseodesis reference slope at the chronological age of 10 years 9 months (X, Fig. 2). As a result, it was too late to achieve full correction of the discrepancy with a distal femoral epiphyseodesis. The mature discrepancy line, however, intersected the femoral and tibial epiphyseodesis reference slope at the age of 12 years 9 months. Epiphyseodesis of the femoral and tibial growth plates at this age would have been expected to correct the discrepancy but the parents wished only the distal femoral epiphyseodesis to be undertaken. This was done at 12 years 3 months with an expected mature discrepancy of 1.4 cm and an observed discrepancy of 1 cm (Fig. 2)

Case 16. A girl presented at 3 years 9 months with avascular necrosis of the proximal femoral epiphysis after treatment for congenital dislocation of the left hip. She had a constant leg-length discrepancy of 1 cm between 4 and 9 years of age (Fig. 3) but developed a type-IV pattern

Table I. Clinical details, treatment and outcome in 20 children

Case	Sex	Shapiro type	Disease	Age at fusion (y m)	Physes fused	Estimated mature discrepancy (cm)	Mature discrepancy (cm)*
1	F	I	Osteomyelitis of the femur	9 9	Distal femur	4.5	0
2	F	I	Pseudarthrosis of tibia	9	Proximal tibia	3.0	1.0
3	F	I	Hypoplasia of leg	10 6	Proximal tibia	2.0	-0.5
4	M	I	Congenital dislocation of hip	14 6	Distal femur	2.0	-0.5
5	M	I	Poliomyelitis	13	Distal femur	2.5	-0.5
6	M	I	Hypoplasia of leg	13	Distal femur and proximal tibia	4.5	0.5
7	M	I	Hemihypertrophy	14 3	Distal femur and proximal tibia	3.0	0
8	M	I	Hemihypertrophy	12 3	Distal femur	5.2	1.0
9	F	II	Perthes' disease	10 3	Distal femur	3.8	0
10	M	II	Perthes' disease	11 6	Distal femur	4.0	0
11	F	III	Congenital dislocation of hip	10 6	Distal femur	3.5	-0.5
12	M	III	Osteomyelitis of femur	13 9	Distal femur and proximal tibia	3.5	0.5
13	M	III	Poliomyelitis	14 3	Distal femur and proximal tibia	2.75	0.5
14	M	III	Fractured femur	13 6	Distal femur	2.5	-0.5
15	M	III	Fractured femur	13 6	Distal femur	3.0	-0.5
16	F	IV	Congenital dislocation of hip	11 8	Distal femur and proximal tibia	3.9	0
17	F	IV	Congenital dislocation of hip	12	Distal femur and proximal tibia	3.0	-1.0
18	F	IV	Hemihypertrophy	11 6	Distal femur	2.5	0
19	F	IV	Hemihypertrophy	11	Distal femur	2.8	-0.5
20	F	IV	Hemihypertrophy	9 11 3	Proximal tibia Distal femur	6.0 1.0	

* - values indicate overcorrection

(Shapiro 1982). At 11 years, her discrepancy was 2 cm and her estimated mature discrepancy was 3.9 cm (Y, Fig. 3). Her chronological and skeletal ages were not significantly different (Cundy et al 1988). The mature discrepancy line intersected the femoral and tibial epiphyseodesis reference slope at 11 years 8 months (X, Fig. 3). We performed epiphyseodesis of the femoral and tibial physes at this age and her leg lengths were equal at skeletal maturity.

DISCUSSION

By recording on a graph the clinically determined leg-length discrepancy against chronological age, patterns of change similar to those reported by Shapiro (1982) were seen. In his study, the radiologically determined discrepancy between the combined femoral and tibial lengths of each limb were also plotted against chronological age.

It is difficult to predict the developmental pattern of a leg-length discrepancy in early childhood since most causes

of discrepancy produce different patterns and most patterns can be produced by different causes (Shapiro 1982). They are best determined therefore in each child initially by yearly reviews beginning in early childhood, and then six-monthly from 9 years of age (Shapiro 1982).

From a review of our graphs and those of Shapiro (1982), we concluded that all the types of pattern can be identified by 11 years of age although some type-IV patterns may still resemble type-III patterns at this time.

At approximately 11 years of age, an observed discrepancy line and a projected discrepancy line are constructed to estimate the mature discrepancy. In only eight of the 20 children did the pattern follow type I with a linear increase in discrepancy. Our predictions of future growth and the mature discrepancy in children with types I to IV patterns were reasonably accurate since the observed mature discrepancies after epiphyseodesis were within 1 cm of the predicted values. Larger differences would have occurred had we used the standard arithmetic method which assumes

a type-I pattern of discrepancy for all children (Westh and Menelaus 1981).

We did not determine whether changes in growth inhibition were responsible for the different patterns of discrepancy (Anderson et al 1963; Moseley 1977). Moseley (1977) reported that growth inhibition from a wide variety of diseases remained constant throughout growth. The accuracy of the growth-remaining or straight-line graphic methods, which assume constant growth inhibition, may not therefore be altered by the different patterns of discrepancy. Our method provides a simple means of incorporating the pattern of the discrepancy into the estimation of the mature discrepancy.

The intersection of the mature discrepancy line with the epiphyseodesis reference slopes gives an easy means of determining the most appropriate type and time of epiphysodesis. Few tibial epiphysodeses were undertaken as the pattern of the discrepancy was often unclear until after the most appropriate time for this procedure. Femoral or femoral and tibial epiphysodeses were used more often.

The method is also suitable for planning and recording the results of leg lengthening and changes in length from correction of deformities. Overlengthening is recorded as a negative value. The technique has many of the advantages of the straight-line graphic method but requires fewer radiographs (Moseley 1977).

The clinical graph is also used to record other details and the diagnosis. The reverse may be used to tabulate the clinical and radiological measurements, the chronological

and skeletal ages and surgical procedures. A height chart is also included and the parents' height and the child's estimated mature height may also be recorded.

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