Timing of physiodesis in limb length inequality

The Straight Line Graph applied in 30 patients

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In a prospective study 30 children underwent 33 physiodeses for lower limb length inequality (LLI). Timing of surgery was based on (bi)annual orthoradiographic measurements and skeletal age, and in accordance with Moseley's Straight Line Graph. The mean predicted LLI was 5.2 (3.0–11) cm and the mean LLI at the end of growth was 1.4 (0.0–4.3) cm. In 9 patients final LLI exceeded 1.5 cm, and one of these patients was operated on twice. In total, secondary operations were performed three times.

After analysis of the failures it is concluded that the accuracy of the Straight Line Graph is mainly limited by the pattern of skeletal maturation. Recommendations to prevent failures from other causes are given.

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Equalization of the lower limbs may be performed by "epiphyseodiaphyseal fusion" (Phemister 1933), or physeodesis. The outcome of treatment for lower limb length inequality (LLI) depends mainly on the timing of surgery. Reported problems encountered with this exact timing are growth prediction (Anderson et al. 1963), developmental pattern of LLI (Shapiro 1982), and skeletal age estimation (Cundy et al. 1988).

We report our experiences and results in a consecutive series of children with LLI, in all of whom the timing of physeodesis was based on the Straight Line Graph (Moseley 1977).

Patients and methods

Since 1979, all children who present with LLI exceeding 2 cm at our department are followed in a special Limb Length Clinic. Between 1980 and 1989 33 physiodeses were performed in 15 girls and 15 boys (Table 1). All these children were followed until the end of growth.

Once (sometimes twice) a year LLI was measured by orthoradiography (Taillard 1956), and skeletal age was determined by comparing the radiograph of the hand with the atlas of Greulich and Pyle (1959). These data were plotted in the Straight Line Graph (Moseley 1977). Timing of physiodesis of the distal femur and/or proximal tibia was determined accordingly when predicted LLI at the end of growth exceeded 3 cm.

Statistical analysis was done with stepwise logistic regression analysis and the exact trend test.

Results

The predicted mean LLI without treatment, was 5.2 (3.0–11) cm. The final mean LLI after physiodesis was 1.4 (0–4.3) cm.

The result of treatment in 11 patients was considered a failure: 8 children had a final LLI exceeding 1.5 cm, 2 had to be operated on twice, and 1 patient ended with a final LLI exceeding 1.5 cm despite 2 operations (Table 2).

The influence of skeletal maturation was analyzed further. Delay in maturation caused overcorrection exceeding 1.5 cm in 2 patients (Cases 13 and 17) and necessitated a second operation in one, Case 7. In another 6 cases this phenomenon caused overcorrection of less than 1.5 cm. Acceleration of skeletal maturation occurred before operation in Cases 11 and 18 and could therefore be taken into account in the timing of the operation. The observed changes in skeletal maturation always led to corresponding changes in growth that could be calculated with the tables of Anderson and Green (Anderson et al. 1963).

The period from operation until skeletal maturity was related to the chance of overcorrection (ß 1.0144, *P*-value of likelihood ratio test 0.03). The predicted final LLI without treatment, the number of preoperative measurements, and chronological and skeletal ages at

Table 1. Clinical data for 30 patients with limb length inequality

A	B	C	D	E	F	G	H	I	J	K	L
1	M	Facioacro dysostosis	13/9	13/0	7	TF	4.4	4.5	0.0	2.1	2.1
2	F	Septic hip	11/2	10/6	4	TF	7.4	7.5	0.0	3.2	3.2
3	M	Congenital short femur	13/10	14/6	2	TF	4.1	4.0	0.0	2.7	2.7
4	M	Hemiatrophia	14/8	13/6	7	TF	3.5	4.0	0.0	0.9	–0.9
5	M	M Ollier	12/7	13/6	1	TF+Th	5.5	5.5	0.0	0.3	–0.3
6	M	M Ehlers-Danlos	14/5	13/6	1	TF	3.1	4.0	1.0	0.7	0.3
7	M	Septic hip	11/9	12/0	3	F+Fc	3.3	4.5	2.0	2.0	0.0
8	F	Fractured tibia	12/10	12/6	2	TF	2.7	3.0	0.0	0.5	0.5
9	F	Hemiatrophia	11/1	10/0	7	F	4.3	5.0	0.0	0.5	0.5
10	F	Klippel Trenaunay	12/0	11/6	6	TF	3.1	3.1	0.0	0.1	0.1
11	M	Streeter syndrome	14/9	13/0	5	TF	3.7	5.0	0.0	0.5	0.5
12	F	Osteomyelitis proximal tibia	10/9	11/0	3	TF	3.9	7.0	0.0	0.1	0.1
13	M	*Arthrogryposis*	13/8	14/0	6	TF	3.8	5.0	1.5	4.2	–2.7
14	F	Hemiatrophia	10/9	11/0	5	TF	3.8	5.0	0.0	1.4	–1.4
15	F	Hemihypertrophia	11/5	10/6	1	TF	8.1	8.1	1.0	1.1	–0.1
16	M	Hemihypertrophia	13/7	12/6	9	TF	3.3	4.0	0.0	1.4	–1.4
17	M	Fractured femur and tibia	11/2	12/0	5	F	3.1	3.1	0.0	4.0	–4.0
18	F	Posterior medial bowing tibia	11/10	12/6	4	F	3.1	4.0	0.5	0.1	0.6
19	F	Poliomyelitis	12/4	13/0	1	TF	3.7	4.0	2.0	1.6	3.6
20	F	M Ollier	10/11	11/6	1	F	3.2	8.0	1.0	1.3	–0.3
21	F	Posterior medial bowing tibia	11/6	11/6	7	TF	5.2	6.0	0.0	0.1	0.1
22	M	Klippel Trenaunay	12/7	13/0	6	TF	3.2	3.5	0.0	1.3	–1.3
23	F	Idiopathic	12/7	12/0	6	TF	3.2	3.5	1.0	2.5	–1.5
24	F	Cerebral palsy	13/3	13/0	3	TF	2.8	3.5	1.5	0.4	1.1
25	F	Skeletal dysplasia	11/0	12/0	3	TF	4.6	5.0	0.0	4.3	4.3
26	M	Septic hip	13/5	13/0	2	TF	6.5	6.0	2.0	0.9	2.9
27	M	*Poliomyelitis*	12/11	12/6	5	TF	3.9	5.0	1.0	0.7	0.3
28	M	Fibula aplasia type 3	11/5	12/0	4	TF	7.2	8.0	0.0	0.1	–0.1
29	M	Osteomyelitis distal femur	11/5	12/4	4	F+Th	5.0	6.0	0.0	4.0	4.0
30	F	Hemihypertrophia	10/11	10/6	2	F	4.5	11	0.0	0.5	–0.5

A Patient number
B Sex
C Etiology
D Age at operation; years/months
E Skeletal age at operation; years/months
F Number of preoperative orthoradiographic measurements
G Site of physiodesis
T tibia
F femur
TF tibia and femur
\+ second operation
c contralateral
h homolateral
H LLI at operation (cm)
I Predicted inequality without physiodesis
J Predicted inequality with physiodesis
K Difference between predicted and realized LLI
L Final LLI at maturity, minus sign means overcorrection

Table 2. Failures

Cause	Patient number
Insufficient preoperative measurements	3, 19, 26
Premature fusion of damaged growth plate	2, 25, 29
Delay in skeletal maturation	7, 13, 17
Surgeon's failures	
Operation failure	5
Underestimated growth before physiodesis	1

operation could not be related to overcorrection or final LLI exceeding 1.5 cm.

The mean difference between predicted and final LLI was 1.5 (0.1–4.3) cm for all 30 patients and 0.6 (0.1–1.5) cm after exclusion of the 11 failures.

Discussion

The only other study in which the Straight Line Graph was used in all patients reported a mean final LLI of 1.5 (0.2–4.0) cm, while 17/35 patients ended with a final LLI of 1.5 cm or less and no secondary operations were performed (Timperlake et al. 1991).

Analysis of our failures has led to a number of recommendations. A sufficient number of pre-operative measurements will provide better understanding of the development of LLI and skeletal maturation. For that reason early referral to a Limb Length Clinic and physiodesis of both femur and tibia, instead of only one of them at an earlier stage, is preferable. This can, however, result in the disadvantage of knees at uneven heights. Premature closure of damaged growth plates in the short limb may be foreseen by comparison with the contralateral side. Prevention of surgeon's failures

is inherent to the experience obtained. With the help of these recommendations a better final result could theoretically have been obtained in 6 patients.

The failures due to a delay in skeletal maturation do not seem to be preventable; they all occurred after the operation. In treatment of LLI the problem of changes in skeletal age in relation to a child's chronological age have been noted before (Green and Anderson 1957, Blair et al. 1982). Variation in radiographic determination of skeletal age is also a source of error (Cundy et al. 1988). Furthermore, the observed changes in skeletal maturation can represent differences between the children in our study and the children from whom the original data of the Straight Line Graph and the atlas of Greulich and Pyle were derived. Normal skeletal changes in puberty (Buckler 1984), delayed or premature onset of puberty, illness and operation may also contribute to a change in the skeletal age related to the chronological age. Our study shows that the Straight Line Graph can be accurate in predicting LLI after treatment by physiodesis, but this accuracy is limited by the pattern of skeletal maturation.

The advantage of physiodesis as the least traumatic procedure to correct a LLI is tempered by the disadvantages of repeated radiographic measurements and the risk of substantial residual LLI or overcorrection. Our study suggests that even with our recommendations 1 out of 6 patients would not have obtained a satisfactory result. An alternative treatment for moderate LLI is shortening of the long leg after the end of growth, although these operations have their problems too (Kenwright and Albinana 1991).

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