EPIPHYSIAL STAPLING AND LEG EQUALISATION

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This paper reviews a series of thirty-three children treated for inequality in the length of their lower limbs by epiphysial stapling. Much has been written on the subject since Blount and Clarke (1949) published their description of the operation. The reason for adding this short series to the literature was that in this instance it was the intention to leave the staples in position and to review the results well after skeletal maturity had been reached. All the children had been treated in the leg equalisation clinic of the Royal National Orthopaedic Hospital.

MATERIAL

Thirty patients had stapling of both lower femoral and upper tibial epiphyses; two had stapling of the lower femoral epiphysis, and one of the upper tibial epiphysis. In thirty-one cases of upper tibial stapling the upper fibular epiphysis was fused at the same time. Blount and Clarke's technique of extraperiosteal stapling was used, three staples being placed over the medial and lateral aspects of the epiphysial plate.

It was intended that the staples once inserted should be retained; the timing of the operation was such that equality of limb length would be expected at the time of skeletal maturity. No patient had the staples removed before maturity because equality of leg length had been achieved. Four patients had the staples removed before maturity for other reasons, and two patients had them removed after maturity. The remaining twenty-seven patients seen at review still had the staples in position.

The average time at review after operation was eight years. All patients were well past skeletal maturity, the average age of the women being twenty and of the men twenty-one. Radiographs had shown the average chronological age at skeletal maturity in this series to be 15.1 years in girls and 16.5 years in boys.

UNCERTAINTIES OF PREDICTION

The growth charts of Green and Anderson (1947) were used to predict the correction that might be expected at various skeletal ages. It was realised that in many patients the actual correction would fall short of that predicted, and in patients suffering from poliomyelitis the lowest line of the chart was taken.

Figures 1 and 2 show the chart used. Superimposed on this are the actual corrections gained in poliomyelitis and in other disorders. In the femur only twelve of the twenty-nine recorded corrections fell within the predicted range. Five of a total of ten patients with late results of poliomyelitis were predicted correctly. This suggests that the result in poliomyelitis is not very different from that in other conditions. In the tibia only eight of twenty-seven patients had a correction within the predicted range, half of those being patients with poliomyelitis.

In Figures 3 and 4 the predicted correction in the whole limb is recorded together with the actual correction. In these figures the average line on the prediction chart was used in the prediction for all cases. Figure 3 represents nineteen girls, six with shortening from poliomyelitis and thirteen with leg inequality for other reasons. In children aged from ten to twelve the average predicted correction was 6.2 centimetres, whereas the actual correction
Growth charts, after Green and Anderson (1947), as used for the lower femoral epiphysis.

Growth charts, after Green and Anderson (1947), as used for the upper tibial epiphysis.
The predicted and actual corrections in girls.

The predicted and actual corrections in boys.
was only 3·3 centimetres—an error of 47 per cent. In children aged twelve to thirteen the predicted correction was 3·4 centimetres and the actual correction 3·2 centimetres—an error of only 6 per cent.

Figure 4 represents eighteen boys, eleven with shortening after poliomyelitis and seven others. Those operated upon between the ages of ten and thirteen had an average predicted correction of 5·7 centimetres but an actual correction of only 2·8 centimetres—an error of 51 per cent. Those operated upon between the ages of thirteen and fifteen had a predicted correction of 4·6 centimetres, with an actual correction of 3·3 centimetres—an error of 28 per cent.

It has been said that the chief source of error in predicting correction is the uncertain amount of growth in the short leg. This is particularly true in patients with poliomyelitis or congenitally short limbs. Growth charts are based on the expectation that, at a particular skeletal age, a predictable amount of growth will occur between this time and maturity in the stapled leg. After stapling there is a considerable variation in growth in what is in most instances a normal limb. These disparities may have several causes: growth patterns vary in different patients; estimations of skeletal age may be inaccurate; or the staples may be imperfectly placed. Spreading of the staples was evident in many cases, suggesting that some growth had occurred at the epiphysis.

PRACTICAL EFFECTIVENESS

Table I shows the correlation between the inequality of leg length and the wearing of a raised shoe. Two of the thirty-three patients have been excluded. One had severe structural scoliosis with marked pelvic obliquity, so that even though overcorrection of 4 centimetres had been obtained there was still an apparent shortening of 2 centimetres, and a small raise was worn. The second patient excluded had had suppurrative arthritis of the hip with dislocation. When lying down he had only 1 centimetre of shortening, but on walking there was a further 5 centimetres of telescoping of the affected leg. On this account a raise was worn.

Of the fifteen women examined none wore a raise on the shoe, but all had shortening of less than 3½ centimetres. In the case of the sixteen men, of the twelve with 3½ centimetres of shortening or less only two wore a raise, one of these in fact having legs of equal length.

It seems that 3½ centimetres is the critical amount of shortening in the adult. Most patients with less than this amount of shortening did not wear a raised shoe. Twenty-three children had an inequality of over 3½ centimetres at the time of operation. Nineteen of these had less than 3½ centimetres of shortening at maturity. A further six children who had a

<table>
<thead>
<tr>
<th>Shortening (centimetres)</th>
<th>Number of patients</th>
<th>Number wearing raise</th>
<th>Shortening (centimetres)</th>
<th>Number of patients</th>
<th>Number wearing raise</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>0-2</td>
<td>4</td>
<td>0</td>
<td>0-2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2-3.5</td>
<td>7</td>
<td>0</td>
<td>2-3.5</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Over 3.5</td>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>0</td>
<td>Total</td>
<td>16</td>
<td>5</td>
</tr>
</tbody>
</table>
disparity of less than 3½ centimetres at operation would certainly have had a disparity greater than this amount at maturity had they not been operated upon. Two of these children did not have accurate scanographic measurements immediately before operation, but both had shortening of less than 3½ centimetres at maturity. Only four of the thirty-one children had inequality of more than 3½ centimetres at review.

**COMPLICATIONS**

The complications of the operation are divided into the following groups: 1) deformity; 2) laxity of ligaments; 3) subjective symptoms; 4) necessity for further operations. To these complications may be added the inevitable decrease in expected height.

**Deformity**—There is considerable variation in the angle that the tibia makes with the femur in the normal subject, particularly in the degree of valgus and in the amount of hyperextension. These variations are greater in the female than the male. In the cases under review there was usually no normal limb with which to compare the angles of the stapled knee.

<table>
<thead>
<tr>
<th>TABLE II</th>
<th>VALGUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valgus (degrees)</td>
<td>Number of patients</td>
</tr>
<tr>
<td>0</td>
<td>24</td>
</tr>
<tr>
<td>1–5</td>
<td>3</td>
</tr>
<tr>
<td>6–10</td>
<td>5</td>
</tr>
<tr>
<td>11–15</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>33</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE III</th>
<th>GENU RECURVATUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>Number of patients</td>
</tr>
<tr>
<td>Hyperextension (degrees)</td>
<td></td>
</tr>
<tr>
<td>0–5</td>
<td></td>
</tr>
<tr>
<td>6–10</td>
<td></td>
</tr>
<tr>
<td>11–15</td>
<td></td>
</tr>
<tr>
<td>16–20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
</tr>
</tbody>
</table>

*Valgus* (Table II)—Four of the eighteen men and five of the fifteen women had measurable genu valgum. Of these nine patients only one had valgus of more than 10 degrees, and in this case the angle was only 12 degrees. Lusted and Keats (1959) suggested that valgus of up to 10 degrees might be considered normal.

*Varus*—No patient had genu varum. Twenty-four of the thirty-three patients had straight limbs. In some of these a normal carrying angle of a few degrees may have been lost.
Genu recurvatum (Table III)—The normal range of hyperextension is not known. If one takes the arbitrary figures of 5 degrees for men and 10 degrees for women as the upper limit of the normal range, then nine of the eighteen men and seven of the fifteen women had genu recurvatum. This is roughly one-half of the cases, but in only one instance, a girl with 25 degrees of genu recurvatum, was further surgery indicated. She had the staples removed and a Phemister (1933) epiphysiodesis was done on the tibial and femoral epiphyses to prevent increase in the deformity.

**TABLE IV**

<table>
<thead>
<tr>
<th>Degree</th>
<th>Cruciate ligaments</th>
<th>Collateral ligaments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slight</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Moderate</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Marked</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>10</td>
</tr>
</tbody>
</table>

**TABLE V**

<table>
<thead>
<tr>
<th>Hyperextension</th>
<th>No hyperextension</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>With cruciate laxity</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>Without cruciate laxity</td>
<td>16</td>
<td>2</td>
</tr>
</tbody>
</table>

**TABLE VI**

<table>
<thead>
<tr>
<th>Valgus</th>
<th>No valgus</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>With collateral laxity</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Without collateral laxity</td>
<td>7</td>
<td>16</td>
</tr>
</tbody>
</table>

Laxity of ligaments (Table IV)—A surprising observation was that twelve of the eighteen men and eight of the fifteen women had laxity of the ligaments at the stapled knee. In some cases the laxity affected the collateral ligaments, in others the cruciate ligaments. In five of the twenty cases laxity of both collateral and cruciate ligaments was evident. The cases were divided on clinical impression into slight, moderate and marked degrees of laxity.

In the ten patients with collateral laxity one had a marked, and one a slight degree of medial ligament laxity. The other eight patients had laxity of both collateral ligaments. Pilcher (1962) mentioned the occurrence of ligament instability in six out of thirty-five patients reviewed, two of these having cruciate laxity and four lateral ligament laxity. Other papers on the subject have not referred to this complication.

Tables V and VI show the correlation between the laxity and deformity. It is evident that ligament laxity bore no relation to valgus or recurvatum deformity. Neither did the age at operation have any bearing on the presence of laxity.

**Symptoms**—Eleven of the eighteen men and eight of the fifteen women complained of various symptoms, but in none were the complaints severe. Two patients complained of two symptoms, making a total of twenty-one complaints. The nature of these symptoms is shown in Table VII.
Further operations—Eleven of the thirty-three patients required a further operation as a result of the initial stapling. Two patients required a third operation, making a total of thirteen further operations in all. No patient required an operation to correct deformity. One of the two patients who subsequently had a tibial and femoral Phemister epiphysiodesis had genu recurvatum of 25 degrees. The second operation was carried out to prevent an increase in the deformity: at examination four years after operation the deformity was still 25 degrees, but the knee was symptomless. The other tibial and femoral epiphysiodesis was done as it was thought that the staples were not controlling growth. The patient listed under femoral epiphysiodesis had a femoral stapling initially. It was later decided to do a tibial Phemister epiphysiodesis for further correction, and at the same time to convert the femoral stapling into an epiphysiodesis. The reasons for further operations are shown in Table VIII.

**TABLE VII**

**Symptoms of which the Patients Complained**

<table>
<thead>
<tr>
<th>Complaint</th>
<th>Number of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slight tenderness over prominent staples</td>
<td>4</td>
</tr>
<tr>
<td>Occasional twinge, particularly in cold or damp weather</td>
<td>7</td>
</tr>
<tr>
<td>Ache in cold or damp weather</td>
<td>3</td>
</tr>
<tr>
<td>Knee stiffness in the morning or in the cold</td>
<td>3</td>
</tr>
<tr>
<td>Impairment of sensibility below a medial scar</td>
<td>1</td>
</tr>
<tr>
<td>Aching on rising from a sitting position</td>
<td>1</td>
</tr>
<tr>
<td>A pricking sensation beneath a scar</td>
<td>1</td>
</tr>
<tr>
<td>Occasional cramp in the knee</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>21</strong></td>
</tr>
</tbody>
</table>

**TABLE VIII**

**Further Operations Carried out**

<table>
<thead>
<tr>
<th>Operation</th>
<th>Number of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femoral epiphysiodesis</td>
<td>1</td>
</tr>
<tr>
<td>Tibial and femoral epiphysiodesis</td>
<td>2</td>
</tr>
<tr>
<td>Reinsertion of staples for extrusion</td>
<td>6</td>
</tr>
<tr>
<td>Removal of staples following extrusion</td>
<td>2</td>
</tr>
<tr>
<td>Removal for pain on kneeling</td>
<td>1</td>
</tr>
<tr>
<td>Manipulation under anaesthetic for stiffness</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total of further operations</strong></td>
<td><strong>13</strong></td>
</tr>
</tbody>
</table>

**Height**—Those patients with a corrected “long” leg have been excluded. The height of the seventeen men varied between 5 feet 1½ inches (156 centimetres) and 5 feet 9 inches (175 centimetres), with an average of 5 feet 5½ inches (166 centimetres). This is about 3 inches (7½ centimetres) shorter than the national average. Ten of the males would have liked to be taller, but none if it meant wearing a raise on the shoe, or increasing the raise already worn.
The height of the twelve women ranged between 4 feet 9½ inches (146 centimetres) and 5 feet 7½ inches (171 centimetres), the average being 5 feet 2½ inches (159 centimetres). The national average is about 5 feet 5 inches (165 centimetres). Only three of the women would have liked to be taller, but none at the cost of wearing a raise on the shoe.

DISCUSSION

The advantages of the operation are its simplicity, the short time in hospital and the quick return of function. This is extremely important in children of school age who because of their various disabilities will probably need to earn their living by their brains rather than by brawn.

The complications of this operation were many, but in none did they rob the patient of activity possible before operation.

With the exception of one patient with genu recurvatum there was no gross deformity in this series. A further fifteen patients, however, did have hyperextension of the knee beyond the normal range. Examination of the radiographs in these cases did not suggest that the staples were badly placed, one of the staples always being situated as far behind as possible through a collateral approach. The anatomy of the lower femur is such that unless staples are placed directly posteriorly a slight degree of genu recurvatum will in many instances be inevitable.

The unexpected occurrence of ligament laxity was disturbing. The laxity did not give rise to symptoms at the time of review but might do so in the future. The laxity bore no relationship to the presence of deformity or to the age of the patient at operation. Smillie (1962) discussing lesions of the menisci of the knee in children, stated: “it is evident also that cartilage, bone and soft tissues such as the menisci have not equal rates of growth.” It may well be that growth of ligaments is to some extent independent of the growth of bone and proceeds at a different rate. Decreasing the growth of bone may not in some cases decrease the growth of the ligaments, and so allow laxity of the joint. If this is true, joint laxity cannot be prevented.

Of the thirteen further operations required, eight were for extrusion of the staples. These were all well placed at the time of operation, and it did not appear that faulty technique was the reason for extrusion. The staples were, however, of stainless steel, and it may be that by using flat-sectioned Vitallium staples this complication could be reduced.

Most of the men would have liked to be taller. Those who would normally have been short for hereditary reasons, and those with gross inequality who lost considerable stature by the stapling procedure would have been more suitably treated by leg lengthening.

The main disadvantage of stapling was the error in predicting correction because of the uncertain growth of the short limb. A lesser factor was the growth that occurred in the knee that had been stapled. The prediction was least accurate in the boys operated on under thirteen and the girls under twelve. It would be more logical in these cases to restore equality by a lengthening procedure, thus eliminating the major factors causing error of prediction.

In boys over thirteen and girls over twelve the predicted correction was accurate. Unless the small stature of the patient would have made it preferable to lengthen the short limb, these older children were adequately treated by stapling. The complications discussed are many but not severe, and comparison would need to be made with a comparable series of cases of leg lengthening or shortening by other means to condemn the stapling procedure on this account.

SUMMARY AND CONCLUSIONS

1. Thirty-three patients who had had stapling of the lower femoral and upper tibial epiphysis to correct inequality of the leg lengths were reviewed after maturity. The staples were inserted so that correction of the disparity would coincide with termination of growth.

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2. The predicted corrections were found to be inaccurate. The error was 47 per cent in girls operated on between ten and twelve and 51 per cent in boys between ten and thirteen. In older children the prediction was more accurate.

3. Despite the inaccuracy of prediction only four patients were left with shortening of more than 3·5 centimetres.

4. Complications of the operation were deformity, ligamentous laxity, subjective symptoms and necessity for further operation.

5. Only one girl had a serious deformity—genu recurvatum of 25 degrees. Half the patients had minor degrees of hyperextension.

6. The causes of the complications are discussed and suggestions made how their incidence might be reduced.

7. It is concluded that the operation of stapling the epiphyses around the knee of the long leg has a small but useful part to play in the correction of inequality of leg lengths. It should be confined to tall boys over thirteen and girls over twelve.

I wish to thank Mr C. W. S. Manning for inspiring this paper and Mr H. Jackson Burrows for advice in its preparation. The work of the Medical Records Department of the Royal National Orthopaedic Hospital and of Mr R. J. Whitley of the Photographic Department is also gratefully acknowledged.

REFERENCES


