A FORMULA FOR DIAPHYSEAL LIMB LENGTHENING

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Calculation of the expected limb length discrepancy at maturity plays an important part in the timing of operations designed to equalise length. Present methods assume similar pre-operative and postoperative rates of bone growth in limbs undergoing diaphyseal lengthening procedures. Moseley (1977) conceived a straight line graph to predict the optimal timing of surgery to lengthen the shorter limb, or to slow growth in the longer one.

Recently Shapiro (1987) has calculated more precise growth rates after diaphyseal lengthening; he defined different pre-operative and postoperative longitudinal growth rates in femora and tibiae. Before operation the rate of growth of congenitally short femora was, on average, 82% of that on the normal side; after operation the figure was 90%. An average of 88% pre-operatively and 64% postoperatively was found in congenitally short tibiae and in tibiae which were short secondary to Ollier's disease, poliomyelitis and haemangioma. These rates of growth may vary according to the disease process.

Method. A simple formula for predicting the length of a normal bone at maturity is proposed. It combines the differential growth rates found by Shapiro, with the standard charts produced by Anderson and Green (1948), Anderson, Messner and Green (1964) and by Maresh (1955). This formula should allow the amount of lengthening required for equalisation to be predicted with greater accuracy.

If SAP is the length of the shorter bone at presentation, LAP is the length of the longer bone at presentation, LAM is the length of the longer bone at maturity, and PLN is the predicted lengthening necessary, then the formula is:

\[ \text{PLN} = (1-x) \cdot \text{LAM} + x \cdot \text{LAP} - \text{SAP}. \]

For the femur where \( x = 0.9 \), PLN = 0.1 LAM + 0.9 LAP - SAP.

For the tibia where \( x = 0.64 \), PLN = 0.36 LAM + 0.64 LAP - SAP.

Derivation of the formula. Growth of the affected bone after operation can be expressed as a percentage of the growth of the normal bone from surgery to maturity: this percentage is the factor ‘x’. This concept can be expressed as the difference between the length of the longer bone at maturity and the length of the longer bone at presentation multiplied by ‘x’: thus growth after surgery = \( x \cdot (\text{LAM} - \text{LAP}) \).

The length of the shorter bone at maturity (SAM) is a combination of its length at presentation (SAP), the predicted lengthening necessary (PLN) and the amount of growth after operation. Thus:

\[ \text{SAM} = \text{SAP} + \text{PLN} + x(\text{LAM} - \text{LAP}). \]

At maturity the bone lengths of each limb should be equal (ie, \( \text{SAM} = \text{LAM} \)). Therefore:

\[ \text{LAM} = \text{SAP} + \text{PLN} + x(\text{LAM} - \text{LAP}). \]

Resolving this formula for PLN:

\[ \text{LAM} = \text{SAP} + \text{PLN} + x\text{LAM} - x\text{LAP}; \]

\[ \text{PLN} = \text{LAM} - x\text{LAM} + x\text{LAP} - \text{SAP}; \]

\[ \text{PLN} = (1-x) \cdot \text{LAM} + x\text{LAP} - \text{SAP}. \]

Shapiro’s results for the congenitally short femur, show a 90% postoperative growth. Hence:

\[ \text{PLN} = 0.1 \text{LAM} + 0.9 \text{LAP} - \text{SAP}. \]

Similarly for the tibia, substituting Shapiro’s 64% gives \( x = 0.64 \). Hence:

\[ \text{PLN} = 0.34 \text{LAM} + 0.64 \text{LAP} - \text{SAP}. \]

Discussion. The formula described applies only when the shorter bone is being lengthened and the longer bone is not being interfered with. Its accuracy in predicting the amount of lengthening needed will obviously be enhanced by observing the patient over a period of time; this will increase the accuracy of predicting the mature length of the normal limb from the growth charts. However, in the rare situation where continued observation is impossible, the formula can be applied using only a single recording of the bone lengths.

If in the future further information accumulates with regard to differential growth rates in different disease processes leading to shortening, then the variable factor ‘x’ will need to be changed accordingly.

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REFERENCES


THE JOURNAL OF BONE AND JOINT SURGERY