NERVE TRACTION DURING CORRECTION OF KNEE FLEXION DEFORMITY

A CASE REPORT AND CALCULATION

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We report the case of a child with cerebral palsy and spastic diplegia treated for bilateral fixed flexion of the knee by bilateral hamstring lengthening. An attempt to straighten the legs from 90° to 20° flexion damaged the sciatic nerve.

There are no objective means of estimating how much deformity can be reduced safely. We present a method of calculating the extra strain in the sciatic nerve produced by reducing a flexion deformity. The result, combined with clinical judgement, provides guidelines for safe corrective surgery.

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Children with spastic diplegia and a fixed flexion deformity of the knee are sometimes treated by lengthening the posterior tendons (Ray and Ehrlich 1979), the main benefit being an improvement in knee extension during stance (Thometz, Simon and Rosenthal 1989). There is, however, a danger of damage to the sciatic nerve by overstretching in the postoperative plaster. These children may not always be able to communicate painful symptoms, and it is therefore important to know how much correction is safe. We report a case history and our investigation of the causes of such a complication.

CASE REPORT

An eight-year-old boy with cerebral palsy and spastic diplegia walked with difficulty, and his 90° bilateral fixed flexion of the knees was treated by bilateral hamstring lengthening. After operation his knees were held in 20° of flexion in plaster cylinders. He was seen to be in some pain, but was discharged home the following morning. After three weeks, his parents brought him back for plaster removal, stating that he had been tearful at night, but they had assumed that this was to be expected.

When the plaster was removed, the child was found to have lost the power of foot dorsiflexion, and to have hyperaesthesia of the feet. He spontaneously hyperflexed his knees and was unable to walk for several months.

How far can the sciatic nerve be safely stretched? Hasegawa (1992) showed that in rabbits rapid elongation of the nerve by 5% caused no significant changes in electrophysiology, morphology or nerve blood flow. More elongation than this disturbed both conduction and blood flow, with marked changes occurring after 12% stretching. At this elongation, there was partial degeneration if traction was released after two hours; after five days there was extensive degeneration. Slow elongation during limb lengthening has also been shown to cause neurophysiological abnormalities in peripheral nerves (Galardi et al 1990).

We have devised a mathematical model to calculate the strain which might be expected in the sciatic nerve of a child after the correction of a fixed flexion deformity of the knee and have used this to estimate the safe amount of correction.

METHOD

Figure 1a is a schematic representation of the lower limb. OX represents the femur of length $l_x$, OY represents the tibia of length $l_y$. The analysis is simplest for a starting angle of 90° between femur and tibia, but can also be made for straightening from other positions of fixed flexion.

The sciatic nerve is assumed to pass parallel to the femoral and the tibial shafts at a distance $a$; the curving path it would follow between them is approximated by the straight dashed lines. Figure 1b shows the effect of straightening the limb to an angle $\theta$; this causes stretching by an additional distance of $2d$. The length $d$ may be

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calculated from the similar triangles OCB and O'C'B, where
\[
d = a_1 (\tan(\phi) - 1)/\tan(\phi)
\]
(1)

The strain in the nerve is given by
\[
s = \text{change in length} \times 100\% / \text{original length}
\]
or, from the dimensions given above
\[
s = (2d/(l_1 + l_2 - 2a)) \times 100\%
\]

If the knee starts at a flexion angle of less than 90° then the starting length of the nerve is given by
\[
l_1 = l_1 + l_2 - 2a
\]
where \(d_1\) is defined as in equation 1 with the appropriate value for \(\phi\). The strain in the nerve is now given by
\[
s = (2(d - d_1)/l_1) \times 100\%
\]

In practice the inverse problem is of interest: given the dimensions of the limb and the initial deformity \(\theta_i\), what is the angle which will keep the strain in the sciatic nerve below a chosen value, \(s\)? The equations above may be rearranged to show that
\[
\theta = 2\tan^{-1} \left\{ \tan \left( \frac{\theta_i}{2} \right) - \frac{s(l_1 + l_2 - 2a)}{200a} \right\}
\]

Only an outline of the mathematical analysis is presented here. Further information may be obtained on application to the authors.

RESULTS
As an example of the results for a typical child, we took the length of the femur, \(l_n\), to be 20 cm, the length of the tibia, \(l_2\), to be 17 cm and the distance from the nerve to the axis of the knee to be 2 cm. Figure 2 shows that the strain increases as the knee is extended, and that this reaches 5% when knee flexion has been reduced from 90° to about 61°. Straightening the knee to 20° flexion produces an expected strain of about 10%, which is comparable to that shown to cause permanent damage in the rabbit sciatic nerve. The strain produced depends both on the length of the limb and the distance \(a\) between the nerve and the femur. Figure 3 shows how the nerve strain varies as the distance \(a\) increases from 1 to 4 cm with the leg length unchanged.

When the flexion angle starts at less than 90°, more release can be achieved safely. The effect of different starting angles is shown in Figure 4, using the same limb
dimensions and $a = 2$ cm. The theoretical maximum for nerve strain of 5% allows a flexion angle of 70° to be straightened to about 30°, and almost full straightening from 50°.

The graphs show that the relationship between flexion angle and nerve strain is not linear, but the non-linearity is quite small and, given the other approximations which we used, it is probably safe to assume that nerve strain reduced by any release of a hip flexion deformity can be balanced against the increase produced by extending the knee. Reduction of hip flexion by 20° would probably allow an extra 20° of extension at the knee.

DISCUSSION

Sciatic nerve traction during routine leg lengthening can readily be recognised because of pain and weakness, but children with cerebral palsy often have difficulty in communicating any distress. Neurological examination may also be difficult, and it is best to anticipate such complications. In the case which we report above, the attempt at a 70° correction was excessive: the mean published postoperative improvement in such knee flexion deformity is only 30° (Ray and Ehrlich 1979; Nene, Evans and Patrick 1993). A few days in plaster with overstretching can be disastrous.

The mathematical model which we describe as an aid to careful clinical assessment assumes that the sciatic nerve of a child behaves in the same way as that of a rabbit and that it is fixed at the hip and the ankle. Compensatory movement at the ankle as well as the hip will allow an increase in correction without changing the tension in the sciatic nerve.

Our model also assumes that the nerve follows straight-line paths. The normal curved path would slightly reduce the calculated strains and there is probably some tension even in a fixed flexion position. Our model assesses the extra tension and provides useful guidance.

Surgical correction of flexion deformity at the knee aims to maintain an improved angle and prevent postoperative contracture, but nerve traction must be avoided. Our analysis provides a guideline for safe corrective surgery: we recommend that specific values are calculated from the formulae, using the leg length, the distance of the nerve from the axis of knee flexion and the starting flexion angle.

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REFERENCES


